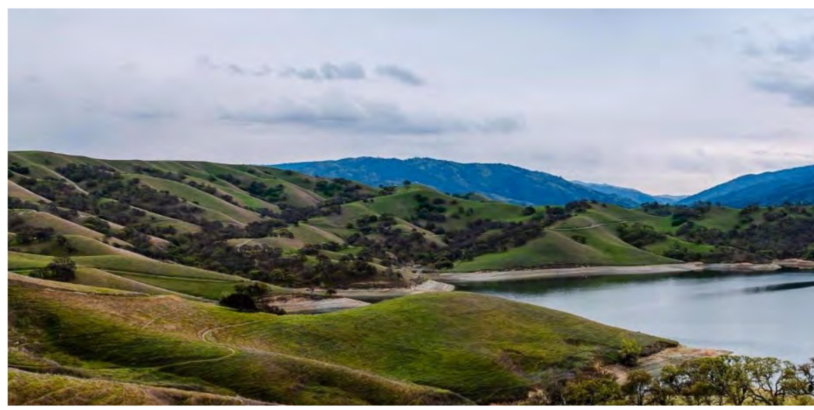
Public Review Draft
November 2021

Alternative Groundwater Sustainability Plan

for the Livermore Valley Groundwater Basin

Appendix



ZONE 7 WATER AGENCY
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APPENDIX A

DWR'S RECOMMENDATIONS ON THE 2016 ALTERNATIVE GSP

CALIFORNIA DEPARTMENT OF WATER RESOURCES
SUSTAINABLE GROUNDWATER MANAGEMENT OFFICE
901 P Street, Room 313-B | Sacramento, CA 95814 | P.O. Box 942836 | Sacramento, CA 94236-0001

July 17, 2019

Mr. Matt Katen
Zone 7 Water Agency
100 N. Canyons Parkway
Livermore, California 94551

Dear Mr. Katen,

The Department of Water Resources (Department) has evaluated the alternative submitted for the Livermore Valley Basin. Based on recommendations from the Staff Report, included as an exhibit to the attached Statement of Findings, the Department has determined that the Livermore Valley Alternative satisfies the objectives of the Sustainable Groundwater Management Act (SGMA) and is approved. The Staff Report also proposes recommended actions for the consideration of the Zone 7 Water Agency that the Department believes will enhance the Alternative and facilitate future evaluation by the Department. The recommended actions do not constitute a qualified approval of the Alternative; however, the Department encourages they be given due consideration and suggest incorporating any resulting changes to the Alternative in future updates.

As required by SGMA, the Department shall review approved alternatives to ensure they remain in compliance with the objectives of the Act. Approved alternatives are required to submit annual reports to the Department on April 1 of each year, and to resubmit the alternative by January 1 every five years. The first five-year update is due by January 1, 2022.

Please contact me at (916) 651-0870 or Craig.Altare@water.ca.gov if you have any questions related to the Department's evaluation or your implementation of the approved alternative.

Thank You,

Craig Altare, P.G.
Supervising Engineering Geologist

Attachments:
1. Statement of Findings Regarding the Approval of the Livermore Valley Basin Alternative

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES

STATEMENT OF FINDINGS REGARDING THE APPROVAL OF THE LIVERMORE VALLEY BASIN ALTERNATIVE

The Department of Water Resources (Department) is required to evaluate and assess whether submitted alternatives to groundwater sustainability plans satisfy the objectives of the Sustainable Groundwater Management Act (SGMA) pursuant to Water Code Section 10733.6. This Statement of Findings explains the Department's decision regarding the alternative (Alternative) submitted by Zone 7 Water Agency for the Livermore Valley Groundwater Basin (Basin No. 2-10). The Alternative was submitted under Water Code Section 10733.6(b)(3), which allows for the submittal of an analysis of basin conditions that demonstrates that the basin has operated within its sustainable yield over a period of at least 10 years.

Department management has reviewed the Department staff report, entitled Sustainable Groundwater Management Program Alternative Assessment Staff Report – Livermore Valley Basin (Staff Report), attached as Exhibit A, recommending approval of the Alternative. Based on its review of the Staff Report, Department management is satisfied that staff have conducted a thorough evaluation and assessment of the Alternative and concurs with staff's recommendation and all the recommended actions, and thus hereby approves the Alternative on the following grounds:

1. The Alternative was submitted within the statutory deadline of January 1, 2017 (Water Code Section 10733.6(c)).

2. The Alternative is within a basin that is in compliance with Part 2.11 (commencing with Water Code Section 10920) as required by Water Code Section 10733.6(d).

3. The Alternative has been submitted by Zone 7 Water Agency pursuant to Water Code Section 10733.6(b)(3) and included a report prepared by a registered professional geologist who is licensed by the state and was submitted to the Department under that geologist's seal. The data submitted in support of the Alternative included continuous data from the end of the 10-year period to current conditions. 23 CCR Section 358(c)(3).

4. The Zone 7 Water Agency explained how the elements of the Alternative are functionally equivalent to the elements of a groundwater sustainability plan required by Articles 5 and 7 of the GSP Regulations, 23 CCR Section 350 et seq., in the Alternative Elements Guide submitted by the Agency.

5. Based on Paragraphs 3 and 4 above, the Alternative is considered complete and includes the information required by SGMA and the GSP Regulations, sufficient to warrant an evaluation by the Department. 23 CCR Section 358.4(a)(3).

6. The Alternative applies to and covers the entire Basin as required by 23 CCR Section 358.2(a) and 358.4(a)(4), respectively, and as discussed in Section IV.D of the Staff Report.

7. The Zone 7 Water Agency has the legal authority and financial resources necessary to implement the Alternative.

8. The Department has received public comments on the Alternative and has considered them in the evaluation of the Alternative as required by 23 CCR Section 358.2(f).

Department management makes the following specific findings based on the evaluation and assessment of the Alternative prepared by Department staff:

9. The Alternative demonstrated that the Zone 7 Water Agency had, prior to SGMA, established goals and implemented projects and management actions to address historical overdraft experienced in the early 1900s until the mid-1960s.

10. The Alternative demonstrates that the Zone 7 Water Agency has a sufficient and reasonable understanding of the groundwater conditions in the Livermore Valley Basin that would cause undesirable results and how to avoid those undesirable results by stabilizing groundwater levels through importing water, implementing groundwater management programs and artificial recharge.

11. The Zone 7 Water Agency developed a natural sustainable yield for the Basin, relying on sufficient and credible information and data, and developed groundwater pumping quotas based on the sustainable yield. The groundwater pumping quotas, in addition to artificial recharge and other management actions, has ensured the Basin has been operated within its sustainable yield for a period of at least 10 years.

12. The Zone 7 Water Agency will continue to implement its projects and management actions to ensure the Livermore Valley Basin will be operated within its sustainable yield.

13. In light of Paragraphs 1-12 above, the Alternative satisfies the objectives of SGMA.

In addition to the grounds listed above, the Department also finds that:

1. The Alternative has demonstrated that the Basin is being operated within it sustainable yield and is consistent with the state policy regarding the human right to water (Water Code Section 106.3) and the public trust doctrine.

2. The evaluation and assessment of whether the Alternative submitted by the Zone 7 Water Agency for the Livermore Valley Basin satisfies the objectives of SGMA is a project under CEQA, but that the project is exempt from CEQA under the common sense exemption for the following reasons.

   No physical change to the environment is associated with the evaluation and assessment of the alternatives undertaken by the Department. The Alternative submitted by the Agency is based on a Groundwater Management Plan and projects and management actions that were previously adopted and the Agency has already begun implementing.

   By finding that the Alternative satisfies the objectives of SGMA, the Agency is authorized to continue to manage the basin subject to that Alternative, without the need to develop a GSP. As a result, the evaluation and assessment of the Alternative undertaken by the Department creates no foreseeable indirect impacts, and any impacts that might occur would be difficult to predict with any accuracy and too speculative to allow the Department to provide for meaningful analysis and review.

Based on the above, the Alternative submitted by the Zone 7 Water Agency for the Livermore Valley Basin is approved. Recommended actions identified in the Staff Report will assist the Department's review of the Alternative's implementation for consistency with SGMA and are thus recommended to be included in the resubmitted Alternative, due on January 1, 2022, as required by Water Code Section 10733.6(c).

Signed:

Karla A Nemeth

Karla Nemeth, Director

Date: July 17, 2019

Exhibit A: Sustainable Groundwater Management Program Alternative Staff Report – Livermore Valley Basin

State of California
Department of Water Resources
Sustainable Groundwater Management Program
Alternative Assessment Staff Report

Groundwater Basin Name:	Livermore Valley (Basin No. 2-010)
Submitting Agency:	Zone 7 Water Agency
Recommendation:	Approve
Date Issued:	July 17, 2019

I. Summary

The Zone 7 Water Agency (Zone 7 or Agency) submitted an alternative (Livermore Valley Alternative *or* Alternative) for the Livermore Valley Groundwater Basin (Livermore Valley Basin or Basin) to the Department of Water Resources (Department) for evaluation and assessment as provided by the Sustainable Groundwater Management Act (SGMA).[1] The Livermore Valley Alternative is based on an analysis of basin conditions that demonstrates the basin has operated within its sustainable yield over a period of at least 10 years.[2] The Livermore Valley Alternative uses information developed previously as part of water resources planning efforts, which are described in other related documents and referenced through the Alternative Report. After a review of the Alternative Report, other related documents, and consideration of public comments submitted to the Department, Department staff find that the Livermore Valley Alternative satisfies the objectives of SGMA and recommends approval of the Alternative.

Zone 7 was established in 1957 to address water supply and flooding in the Livermore Valley and manage the Livermore Valley Basin to reverse the then-existing overdraft condition of the Basin.[3] Zone 7 represents one of ten zones in the Alameda County Flood Control and Water Conservation District area within Alameda County. The Agency has been addressing water resources issues since it was established.[4] The planning documents referenced in the Alternative Report document established goals and implemented projects and management actions by the Agency to address historical overdraft experienced in the early 1900s until the mid-1960s. The Livermore Valley Alternative demonstrates that the Agency has a good understanding of groundwater

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[1] Water Code § 10720 *et seq*.
[2] Water Code § 10733.6(b)(3)
[3] Groundwater Management Plan, Section 2.1, p. 2-3
[4] Groundwater Management Plan, Section 2.1, pp. 2-1 to 2-4

conditions and sustainable management, and has stabilized groundwater levels through importing water, implementation of groundwater management programs, and artificial recharge.

Furthermore, Department staff considers the information that the Agency provided to be sufficient to demonstrate the Basin has been operating within the sustainable yield for at least 10 years. The Agency has accomplished operating within the Basin's sustainable yield by managing to target values for inflows and outflows from the Basin. These target values of inflows were developed in 1992, based on the Agency's approximation of the natural sustainable yield of the Basin, which is the sum of the average amount of natural recharge from percolation of rainfall, natural stream flow, and irrigation waters, and inflow of subsurface water.[5] The natural sustainable yield of the Basin was then used by the Agency as the basis for allocating pumping amounts to municipal pumpers, which each have an established groundwater pumping quota. In general, this management approach, in addition to artificial recharge by the Agency has kept the Basin from repeating historical overdraft conditions.[6] The Agency states that use of an established groundwater pumping quota, artificial recharge, and other management actions have maintained operation of the basin within the sustainable yield. The Alternative includes a description of an extensive monitoring program and data enabling the Department and the public to track conditions over time.

The Alternative sufficiently demonstrates that the Livermore Valley Basin has operated within its sustainable yield for a period of at least 10 years. In addition, staff have identified recommended actions that are designed to facilitate the Department's ongoing evaluation and assessment of the Plan including implementation and a determination of whether the Plan continues to satisfy the objectives of SGMA or adversely affects an adjacent basin.

The remainder of this assessment is organized as follows:

- **Section II. Review Principles** describes the legal and other considerations regarding the Department staff's assessment and evaluation of alternatives.
- **Section III. Alternative Materials** describes materials (i.e., plans, reports, data, and other information) submitted by the Agency that, collectively, the Department considered as the Alternative.
- **Section IV. Required Conditions** describes whether the Alternative satisfies each of the four conditions required for the Department to review an alternative.
- **Section V. Alternative Contents** describes the information contained in the Alternative submittal.

[5] Alternative Report, Section 2.4.4, pp. 2-90 to 2-92
[6] Alternative Report, Section 2.4.4, pp. 2-90 to 2-92

- **Section VI. Assessment** describes Department staff's evaluation of the Alternative, whether it satisfies the objectives of SGMA, and, if applicable, describes recommended actions proposed for the first five-year update.

II. Review Principles

The Department has evaluated the Alternative to determine whether it satisfies the objectives of SGMA for the Livermore Valley Basin. To satisfy the objectives of SGMA, an alternative based on an analysis of basin conditions must demonstrate that the basin has been operated within its sustainable yield for a period of at least 10 years.[7] The SGMA definition of sustainable yield requires the avoidance of undesirable results.[8] As a result, an alternative based on an analysis of basin conditions must demonstrate that the submitting agency has an understanding of groundwater conditions that would cause undesirable results, as well as analysis in the alternative demonstrating the absence of undesirable results over a 10-year period.

An alternative, to be evaluated by the Department, must be submitted by the statutory deadline and be within a basin that complies with Part 2.11 of Division 6 of the Water Code.[9] The submitted alternative must also be complete and must cover the entire basin.[10] The GSP Regulations[11] require the Department to evaluate an Alternative "in accordance with Sections 355.2, 355.4(b), and Section 355.6, *as applicable*, to determine whether the Alternative complies with the objectives of the Act".[12] The elements of the cited sections are not all applicable to alternatives. Some provisions apply to GSPs and alternatives alike, to alternatives only prospectively, or do not apply to alternatives at all.[13] Ultimately, the purpose of the evaluation is to determine whether an alternative satisfies

[7] Water Code § 10733.6(b)(3)
[8] Water Code § 10721(w)
[9] Water Code § 10733.6(c)-(d)
[10] 23 CCR § 358.4(a)
[11] 23 CCR § 350 *et seq.*
[12] 23 CCR § 358.4(b) (emphasis added)
[13] Procedural requirements, including submissions by the agency, posting by the Department, and the public comment period, apply equally to plans and alternatives (23 CCR § 355.2(a)-(c)). The periodic review of Plans (23 CCR § 355.6(a)) applies to alternatives prospectively but does not apply to initial submissions. Other regulatory provisions are inapplicable to alternatives, including the two-year review period (23 CCR § 355.2(e)), which is based on the statutory time-frame that applies to Plans but not alternatives (Water Code § 10733.4(d)); the "incomplete" status that allows the agency to address "one or more deficiencies that preclude approval, but which may be capable of being corrected by the Agency in a timely manner" (23 CCR § 355.2(e)(2)), which applies to plans undergoing development, but not alternatives that purportedly satisfy the objectives of SGMA at the time of their submission (Water Code § 10733.6(a)); and, for the same reason, corrective actions to address deficiencies in plans (23 CCR § 355.4(a)(4)), which applies to plans developed after the adoption of SGMA, but is inapplicable to alternatives that predate SGMA.

the objectives of SGMA.[14] The agency must explain how the elements of an alternative are "functionally equivalent" to the elements of a GSP required by Articles 5 and 7 of the GSP Regulations and are sufficient to demonstrate the ability of an alternative to achieve the objectives of SGMA.[15] The explanation by the agency that elements of an alternative are functionally equivalent to elements of a GSP furthers the objective of demonstrating that an alternative satisfies the objectives of SGMA. Alternatives based on groundwater management plans or historical basin management practices that predate the passage of SGMA or adoption of GSP Regulations, although required to satisfy the objectives of SGMA, are not necessarily expected to conform to the precise format and content of a GSP. The Department's assessment is thus focused on the ability of an alternative to satisfy the objectives of SGMA as demonstrated by information provided by the agency; it is not a determination of the degree to which an alternative matched the specific requirements of the GSP Regulations.

When evaluating whether an alternative satisfies the objectives of SGMA and thus is likely to achieve the sustainability goal for the basin, staff reviews the information provided by and relied upon by the agency for sufficiency, credibility, and consistency with scientific and engineering professional standards of practice.[16] The Department's review considers whether there is a reasonable relationship between the information provided and the assumptions and conclusions made by the agency, whether sustainable management criteria and projects and management actions described in an alternative are commensurate with the level of understanding of the basin setting, and whether those projects and management actions are feasible and likely to prevent undesirable results.[17] Staff will recommend that an alternative be approved if staff believe, in light of these factors, that alternative has achieved or is likely to achieve the sustainability goal for the basin.[18]

An alternative based on a demonstration that the basin has operated within its sustainable yield over a period of at least 10 years may be approved based on information that demonstrates that objective criteria defining operating standards that governed groundwater management for the basin were established and consistently achieved. Even when staff review indicates that an alternative will satisfy the objective of SGMA, the Department may recommend actions to facilitate future evaluation of that alternative and to allow the Department to better evaluate whether an alternative adversely affects

[14] Water Code § 10733.6(a)). The Department considers the regulatory language in 23 CCR § 358.2(d) ("complies with the objectives of [SGMA]") to be equivalent to the statutory threshold upon which it is based.
[15] 23 CCR § 358.2(d)
[16] 23 CCR § 351(h)
[17] 23 CCR § 355.4(b)(1), (3), and (5).
[18] 23 CCR § 355.4(b)

adjacent basins. DWR proposes that recommended actions be addressed by the submission date for the first periodic evaluation.

Staff assessment of an alternative involves the review of information presented by the agency, including models and assumptions, and an evaluation of that information based on scientific reasonableness. The assessment does not require Department staff to recalculate or reevaluate technical information provided in an alternative or to perform its own geologic or engineering analysis of that information. The staff recommendation to approve an alternative does not signify that Department staff, were they to exercise the professional judgment required to develop a plan for the basin, would make the same assumptions and interpretations as those contained in an alternative, but simply that Department staff has determined that the assumptions and interpretations relied upon by the submitting agency are supported by adequate, credible evidence, and are scientifically reasonable.

III. Alternative Materials

The Agency submitted an alternative based on an analysis demonstrating the Basin has operated within its sustainable yield for a period of at least 10 years, pursuant to Water Code Section 10733.6(b)(3). The Livermore Valley Alternative includes the following documents:

- Alternative Groundwater Sustainability Plan for the Livermore Valley Groundwater Basin, December 2016 (Alternative Report *or* Report). The Alternative Report is the primary document relied upon by the Agency to show the Basin operated within its sustainable yield for at least 10 years.
- Groundwater Management Plan for Livermore-Amador Valley Groundwater Basin, 2005 (Groundwater Management Plan).[19] The Groundwater Management Plan was prepared by the Agency to provide the framework for groundwater management planning and has been implemented in coordination with other water management planning efforts since adoption in 2005.
- Annual Report for the Groundwater Management Program, 2015 Water Year (2015 Annual Report). The 2015 Annual Report was completed for the Groundwater Management Program and conveys data for historical and 2015 groundwater elevation monitoring, 2015 surface water flows and quality monitoring, historical and 2015 groundwater quality monitoring, 2015 water level and water quality data from mining area ponds or quarry lakes as part of the Chain of Lakes/Mining Area Monitoring Program, ground surface elevation changes at

[19] The basin name used in the Groundwater Management Plan was the Livermore-Amador Valley Groundwater Basin.

benchmark locations as of 2015 (as part of Land Surface Elevation Monitoring Program), and historical and 2015 climate monitoring.

- Annual Report for the Groundwater Management Program, 2014 Water Year (2014 Annual Report). The 2014 Annual Report was completed for the Groundwater Management Program and conveys data for historical and 2014 groundwater elevation monitoring, 2014 surface water flows and quality monitoring, historical and 2014 groundwater quality monitoring, 2014 water level and water quality data from mining area ponds or quarry lakes as part of the Chain of Lakes/Mining Area Monitoring Program, ground surface elevation changes at benchmark locations as of 2014 (as part of Land Surface Elevation Monitoring Program), and historical and 2014 climate monitoring.
- Salt Management Plan, 2004. The Salt Management Plan was prepared to address the increasing level of total dissolved solids in the main groundwater basin (Main Basin) and provides technical information and analysis that support the Agency's salt management strategy.
- Nutrient Management Plan, Livermore Valley Groundwater Basin, 2015 (Nutrient Management Plan). The Nutrient Management Plan was prepared as an addendum to the Agency's Salt Management Plan and provides an assessment of the existing and future groundwater nutrient concentrations in the Basin and presents planned actions for addressing nutrient loads and high groundwater nitrate concentrations in localized areas of concern.
- 2015 Urban Water Management Plan (UWMP). The UWMP documents the Agency's most recent (as of 2015) water supply planning efforts which address water demand, water supply, and water resource management for the region covered by the urban water suppliers (Dublin San Ramon Services District, Livermore, Pleasanton, and California Water Service Company) in the Livermore-Amador Valley.
- Water Supply Evaluations Update, 2016. The Water Supply Evaluations Update provides an evaluation of Zone 7's long-term water supply and incorporates key assumptions, an approach, an analysis, and results that were vetted with the Livermore-Amador Valley's local water supply retailers.
- Draft Report Well Master Plan, 2003. The Draft Report Well Master Plan presents an understanding of the hydrogeology of the basin through cross sections, compilation of aquifer test data, groundwater modeling, and water quality data. The intent of the document was to identify preferred locations for wells and wellfields, and provide a preliminary guide for well construction, well production rates, total well yield, spacing requirements, design, cost, and potential water quality impacts.
- Historical SqueeSAR Ground Deformation Analysis over Livermore and Pleasanton, (CA) using ERS, ENVISAT and Sentinel Satellites, TRE Altimara, 2016 (Ground Deformation Analysis) (InSAR Report). The InSAR Report

documents an InSAR analysis that was performed using radar data for the 24-year period between 1992 and 2016, from three different satellites, to evaluate ground movement by measuring surface deformation in the areas of Livermore and Pleasanton.

- A Report of the History of Adjusted Values of Bench Marks Located in the Vicinity of the Main Groundwater Basin of the Livermore-Amador Valley, Altamont Land Surveyors, 1994 (Benchmark Report). The Benchmark Report documents a compilation of the available recorded elevations of localized bench marks established and monitored by Federal and Local Government agencies in what is referred to in the report as the main groundwater basin of the Livermore-Amador Valley.

The Agency also submitted an Alternative Elements Guide (Elements Guide) and a notice of exemption from the requirements of the California Environmental Quality Act (CEQA). The Agency has submitted Annual Reports, as required.[20] Other information provided to or relied upon by the Department has been posted on the Department's website and includes material submitted by the Agency, public comments, and correspondence.

IV. Required Conditions

An alternative, to be evaluated by the Department, must be submitted by a statutory deadline and be within a basin that complies with Part 2.11 of Division 6 of the Water Code.[21] The submitted alternative must also be complete and must cover the entire basin.[22]

A. Submission Deadline

SGMA requires that an alternative for a basin categorized as high- or medium-priority as of January 31, 2015, be submitted no later than January 1, 2017.[23]

The Agency submitted the Livermore Valley Alternative on December 29, 2016, before the statutory deadline.

B. Part 2.11 (CASGEM) Compliance

SGMA requires that the Department assess whether an alternative is within a basin that is in compliance with Part 2.11 of Division 6 of the Water Code,[24] which requires that

[20] The Annual Report is not part of the Alternative and was not reviewed by the Department for the purpose of approving the Alternative.
[21] Water Code § 10733.6
[22] 23 CCR § 358.6
[23] Water Code § 10733.6(c). Pursuant to Water Code § 10722.4(d), a different deadline applies to a basin that has been elevated from low- or very low-priority to high- or medium-priority after January 31, 2015.
[24] Water Code § 10733.6(d)

groundwater elevations in all groundwater basins be regularly and systematically monitored and that groundwater elevation reports be submitted to the Department.[25] To manage its obligations under this law, the Department established the California Statewide Groundwater Elevation Monitoring (CASGEM) Program. The acronym CASGEM is used in this document to denote both the program and the groundwater monitoring law.[26]

SGMA specifies that an alternative does not satisfy the objectives of SGMA if the basin is not in compliance with the requirements of CASGEM.[27] The Department confirmed that the Livermore Valley Basin was in compliance with the requirements of CASGEM prior to evaluating this Alternative and confirmed that the Basin remained in compliance with CASGEM through the last reporting deadline, prior to issuing this assessment.

C. Completeness

GSP Regulations specify that the Department shall evaluate an alternative if that alternative is complete and includes the information required by SGMA and the GSP Regulations.[28] An alternative submitted pursuant to Water Code Section 10733.6(b)(3) must include an analysis demonstrating the basin has operated within its sustainable yield over a period of at least 10 years. That analysis must include a report prepared by a registered professional engineer or geologist who is licensed by the state, and that report must be submitted under that engineer's or geologist's seal. The alternative must include an explanation of how the elements of the alternative are functionally equivalent to the elements of a GSP required by Articles 5 and 7 of the GSP Regulations and are sufficient to demonstrate the ability of the alternative to achieve the objectives of SGMA.[29]

The Agency submitted an analysis under the seal of a licensed Professional Geologist along with an Alternative Elements Guide, which includes the Agency's explanation of how the elements of the Alternative are functionally equivalent to the elements of a GSP. The Department staff found the Alternative to be complete and containing the required information, sufficient to warrant an evaluation by the Department.

D. Basin Coverage

An alternative is required to cover the entire basin.[30] An alternative that is intended to cover an entire basin may be presumed to do so if the basin is fully contained within the jurisdictional boundaries of the submitting agency. However, an alternative submitted by

[25] Water Code § 10920 *et seq*.
[26] Stats.2009-2010, 7th Ex.Sess., c. 1 (S.B.6), § 1
[27] Water Code § 10733.6(d)
[28] 23 CCR § 358.4(a)(3)
[29] 23 CCR § 358.4(c)-(d)
[30] 23 CCR § 358.4(a)(4)

an agency whose jurisdictional boundaries do not include all areas of the basin may nevertheless be found to effectively cover the entire basin. Because the intent of SGMA is to provide for sustainable management of groundwater that does not cause undesirable results, an alternative effectively covers the entire basin if it results in groundwater management that avoids undesirable results.[31] An alternative that cannot avoid undesirable results is not sustainably managing the basin even if the entire basin is within the jurisdiction of the managing agency, but an alternative that avoids undesirable results throughout the basin is sustainably managing that basin even if some part of the basin lies outside the jurisdiction of that agency.

The Alternative addresses the entire area of the Basin as currently defined by the Department. The Agency has jurisdiction over the portion of the basin within Alameda County, which covers most of the basin (Figure 1). For the remaining portion of the basin outside the Agency's jurisdiction that extends into Contra Costa County, the Agency has developed a memorandum of understanding with those agencies with jurisdiction including Contra Costa County, Contra Costa Water Agency, the City of San Ramon, the East Bay Municipal Utility District, and the Dublin San Ramon Services District. The MOU gives the Agency the delegated authority to be the GSA for the portion of the Basin outside of the jurisdiction of the Agency, which is located within the jurisdictions of those agencies listed above.[32]

Based on the facts provided, Department staff determined that the Alternative covers the entire Basin.

[31] Water Code § 10721(v)
[32] Alternative Report, Appendix A, PDF p. 229

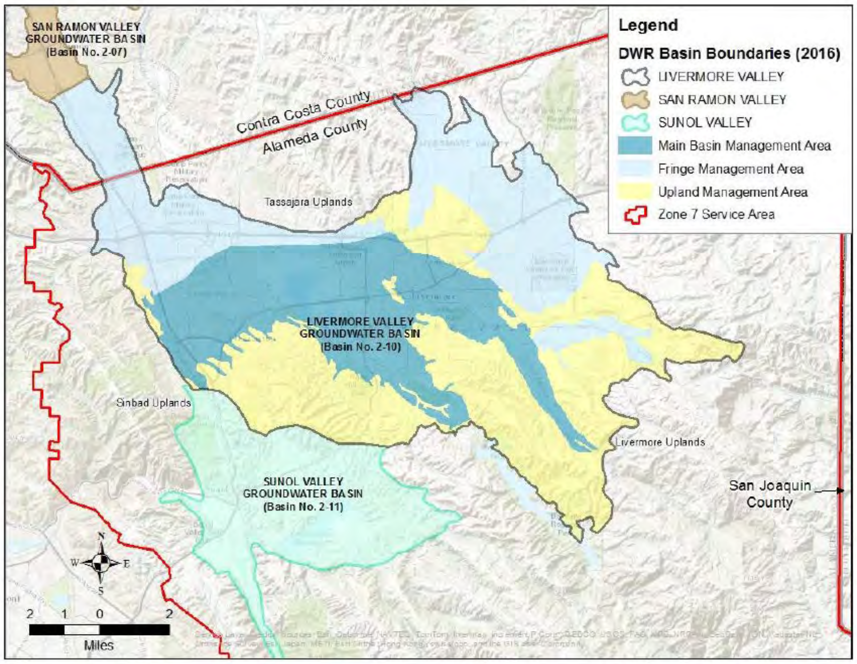

Figure 1. Map of Plan Area, Livermore Valley Groundwater Basin[33]

V. Alternative Contents

GSP Regulations require the submitting agency to explain how the elements of an alternative are functionally equivalent to the elements of a GSP as required by Article 5 of the GSP regulations[34] and are sufficient to demonstrate the ability of an alternative to achieve the objectives of SGMA.[35]

As stated previously, alternatives based on historical basin management practices that predate the passage of SGMA or adoption of GSP Regulations, although required to satisfy the objectives of SGMA, are not necessarily expected to conform to the precise format and content of a GSP, and the criteria for adequacy of an alternative is whether the Department is able to determine that an alternative satisfies the objectives of SGMA. Department staff rely on the submitting agency's determination of functional equivalence of alternative elements to facilitate its evaluation and assessment of an alternative (*see* Assessment, below). Although the exact components of a GSP are not required for an alternative, for organizational purposes the discussion of information contained in the Alternative Report and related documents provided by the Agency generally follows the elements of a GSP provided in Article 5 of the GSP Regulations. The reference to

[33] Alternative Report, Figure 1-4, p. 1-8
[34] 23 CCR § 354-354.44
[35] 23 CCR § 358.2(d). The requirements pertaining to Article 7 of the GSP Regulations (23 CCR § 356-356.4) relate to annual reports and periodic evaluation and are not applicable to review of the initial alternative.

requirements of the GSP Regulations at the beginning of each section is to provide context regarding the nature of the element discussed but is not meant to define a strict standard applicable to alternatives.

A. Administrative Information

GSP Regulations require information identifying the submitting agency, describing the plan area, and demonstrating the legal authority and ability of the submitting agency to develop and implement a plan for that area.[36]

The Alternative Report contains information describing the Agency, which represents one of ten active zones in the Alameda County Flood Control and Water Conservation District (District), and the legal authority of the Agency to implement projects and management actions. SGMA designated the Agency as the exclusive Groundwater Sustainability Agency within its statutory boundaries.[37] The Agency's key water resource responsibilities include the following:[38]

- Serve as the contractor with DWR for the State Water Project
- Manage the local water right on Arroyo Valle
- Procure other water supplies as necessary to meet demands
- Provide wholesale treated water supply
- Provide untreated water for agriculture
- Operate and maintain water treatment and transmission systems
- Manage regional stormwater for public safety and protection of property
- Sustainably manage the Livermore Valley Basin

Under the Agency's Groundwater Management Program, the Agency administers management of the Basin and prevents groundwater overdraft.

The Alternative Report provides a description of the plan area, existing water resource monitoring and management programs, conjunctive use programs, and applicable general plans.[39] The Alternative Report states that the Agency involves the public, stakeholders and local agencies in its planning and programs through meetings, data sharing and online media and has memorialized this approach as an operational policy in the Agency's 1987 Statement on Groundwater Management.[40] The Agency describes

[36] 23 CCR § 354.2 et seq.
[37] Water Code § 10723 (c)(1)(A)
[38] Alternative Report, Section 1.2.2, pp. 1-3 to 1-4
[39] Alternative Report, Section 1.3, pp. 1-8 to 1-29
[40] Alternative Report, Section 1.3.5, pp. 1-27 to 1-28

how they routinely consider other agencies and interested parties in the Basin during management activities.[41]

B. Basin Setting

GSP Regulations require information about the physical setting and characteristics of the basin and current conditions of the basin, including a hydrogeologic conceptual model, a description of historical and current groundwater conditions, and an assessment of the water budget.[42]

1. Hydrogeologic Conceptual Model

The GSP Regulations require a descriptive hydrogeologic conceptual model of the basin that includes a written description supported by cross sections and maps.[43]

The Alternative Report describes the hydrogeologic conceptual model of the Basin, including the geologic and structural setting, basin boundary definitions, and the basin hydrostratigraphy, and identifies principal aquifers and aquitards.[44] The Alternative Report describes the Livermore Valley Basin as a structural basin bound on the east and west by northwest-southeast trending faults, a thrust fault on the north, and bedrock hills to the south.[45] The Alternative Report divides the Basin into three areas based on geologic, hydrogeologic, and groundwater conditions.[46] These three areas include the Main Basin Management Area, the Fringe Management Area, and the Uplands Management Area (*see* Figure 1, above).[47] The hydrogeologic conceptual model discusses the conditions of the entire Basin, but the focus is on the Main Basin Management Area. The Main Basin Management Area refers to the central portion of the Basin that produces approximately 93 percent of groundwater in the Basin from a thick alluvial sequence that contains the highest yielding aquifers, the best quality groundwater, and the major municipal wells.[48] The Agency referred to this portion of the Basin as the central basin between 1980 and 1988 and began using the term Main Basin in 1988.[49]

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[41] Outreach effort are listed on the Agency website: https://www.zone7water.com/; and Alternative Report, Section 1.3.5, pp. 1-27 to 1-28
[42] 23 CCR § 354.12 et seq.
[43] 23 CCR § 354.14(a)
[44] Alternative Report, Section 2.2, pp. 2-10 to 2-25
[45] Alternative Report, Section E-2.2, p. E-4
[46] Alternative Report, Section E-1.2, p. E-3
[47] 23 CCR § 351(r) "Management area" refers to an area within a basin for which the Plan may identify different minimum thresholds, measurable objectives, monitoring, or projects and management actions based on differences in water use sector, water source type, geology, aquifer characteristics, or other factors.
[48] Alternative Report, Table 2-21 and Table 2-22, p. 2-88; and Table 2-24, p. 2-91. Average demands in the Main Basin, Fringe, and Upland Management Areas are 13,400 acre-feet per acre (93.4 percent), 728 acre-feet per acre (5.1 percent), and 217 acre-feet per acre (1.5 percent), respectively. Groundwater Management Plan, Section 3.1.4, p. 3-4
[49] Groundwater Management Plan, Section 3.1.4, p. 3-4

The Main Basin is bounded by several subsurface barriers to lateral groundwater movement, including numerous faults, which have been observed and investigated by Zone 7 and others.[50] The Fringe Management Area is characterized as having thinner alluvium with low groundwater storage, low well yields, and poorer groundwater quality. The Uplands Management Area is underlain by a low-yielding aquifer and, as a result, there are few wells in the area.[51]

The Alternative Report incorporates detailed information pertaining to the basin hydrology, geology, aquifers and aquitards, and climatic conditions into the hydrogeologic conceptual model of the Basin. The Agency also maintains a numerical groundwater flow model of the basin for predicting the consequences of proposed groundwater basin management actions.[52] The active part of the numerical model covers subareas in both the Main Basin Management Area and the northwestern Fringe Management Area and generally uses the understanding of the hydrostratigraphy of the Basin as the basis for groundwater model layers and aquifer parameters.[53]

2. Groundwater Conditions

The GSP Regulations require a description of historical and current groundwater conditions in the basin that includes information related to groundwater elevations, groundwater storage, seawater intrusion, groundwater quality, subsidence, and interconnected surface water, as applicable. The GSP Regulations also require an identification of groundwater dependent ecosystems.[54]

The Alternative Report and supporting documentation describe groundwater conditions for the Basin, with emphasis on the Main Basin Management Area (*see* Figure 1, above).[55] The Agency relies on data from numerous monitoring locations[56] primarily located in the Main Basin Management Area and Fringe Management Area to characterize groundwater use, current and historic conditions of groundwater elevation, groundwater in storage, water quality, land subsidence, and surface water-groundwater interaction.[57] The Agency presents groundwater elevation hydrographs from key wells throughout the Main Basin Management Area and the Fringe Management Area in the Alternative Report.[58] These hydrographs illustrate that groundwater elevations have

[50] Groundwater Management Plan, Section 3.1.4, p. 3-4
[51] Alternative Report, Section E-1.2, p. E-3
[52] Alternative Report, Section 2.6, p. 2-96; and 2015 Annual Report, Section 11.5, p. 11-14
[53] Alternative Report, Figure 2-14, p. 2-23; and Section 2.2.3.4, p 2-23 and pp. 2-25 to 2-27
[54] 23 CCR § 354.16
[55] Alternative Report, Section 2.3, p. 2-2; 2015 Annual Report, Section 5, p. 5-1; and Section 11, p. 11-1
[56] Alternative Report, Section 4, p. 4-1; Groundwater Management Plan, Appendix C, PDF p. 137; 2015 Annual Report, Section 2.2, p.2-1; Section 3.2, p. 3-1; Section 4.2, p.4-2; Section 5.2, p. 5-7; Section 6.2, p. 6-5; Section 7.2, p. 7-2; and Section 8.2, p. 8.2
[57] Alternative Report, Figure 2-17, p. 2-28
[58] Alternative Report, Figure 2-21, pg. 2-35

generally been stable for the periods of records dating back to the 1970s in most cases, except for drought periods (in the early 1990s and 2012-2015), where groundwater levels in some wells experienced temporary declines. Groundwater elevations recovered in those wells that experienced groundwater elevation declines.[59] The Agency created groundwater level maps using detailed information from a series of wells distributed through the Main Basin Management Area and Fringe Management Area.[60] The resulting contour maps are presented in the Alternative Report and present groundwater flow directions and gradients consistent with the hydrogeologic conceptual model.[61]

The Agency operates the basin to remain above historic low groundwater levels throughout the Main Basin Management Area.[62] To quantify these levels, a contour map of historic lows has been prepared by the Agency for management purposes.[63] The map of historic low groundwater levels was first generated during the Agency's efforts to produce the Draft Report Well Master Plan.[64] The historic lows map was generated using a compilation of recorded low groundwater elevations in various wells in the basin typically from the 1960s, 1977, or 1987-1992 drought periods. Outside of the Main Basin Management Area, historic lows have not yet been determined; however, groundwater level hydrographs from various representative wells in the Fringe Management Area indicate that groundwater levels have not fluctuated significantly over time.[65]

The Agency presents the estimated groundwater storage in the Main Basin Management Area from 1974 to 2015 in the Alternative Report and describes how groundwater storage was calculated.[66] The Agency calculated the Main Basin as having a storage capacity of more than 250,000 acre-feet. The Agency states that when groundwater elevations were at their historic lows, the estimated remaining groundwater in storage was 128,000 acre-feet. The Agency describes groundwater storage of 128,000 acre-feet (when groundwater elevations are at historic lows) or less as "reserve storage" and the additional 126,000 acre-feet above this amount to be "operational storage". The Agency maintains "reserve storage" by operating the basin to keep groundwater levels above historic lows and actively manages the remaining 126,000 acre-feet for supply reliability.[67] The Alternative Report illustrates that the groundwater storage in the Main Basin Management Area has been within the "operational storage" range for the period reported, from 1974 to 2015.[68] The Agency estimates the groundwater in storage in the upper alluvial aquifer of the

[59] Alternative Report, Figure 2-21, p. 2-35
[60] Alternative Report, Figure 2-17, p. 2-28
[61] Alternative Report, Figure 2-24, p. 2-41; and Figure 2-25, p. 2-26
[62] Alternative Report, Figure 2-29, p. 2-48; and Section 2.3.6, p. 2-45
[63] Alternative Report, Figure 2-23, p. 2-28; Section 2.3.4.2, p. 2-36; and Section 2.3.4.3, p. 2-37
[64] Draft Report Well Master Plan, Section ES.2, pp. ES-2 to ES-3
[65] Alternative Report, Figure 2-21, p. 2-35
[66] Alternative Report, Figure 2-30, p. 2-50
[67] Alternative Report, Section 2.3.7.1, pp. 2-49 to 2-50
[68] Alternative Report, Figure 2-30, p. 2-50

Fringe Management Area is about 200,000 acre-feet, but that groundwater is not used for municipal supply or managed groundwater storage in this area, primarily due to poor groundwater production.[69] The groundwater in storage in the Uplands Management Area was not estimated because the Agency states that it consists of semi-consolidated bedrock of highly-variable specific yields and is of unknown thickness.

The Alternative Report describes the primary groundwater quality issues in the three management areas of the Basin, monitoring networks used for analysis of groundwater quality, and statistical analyses used to evaluate constituents of concern. Primary constituents of concern in the Main Basin Management Area are locally high TDS, hardness, nitrate, organic compounds and naturally occurring boron and chromium. The Alternative Report acknowledges locally elevated levels of these constituents in the Basin and describes the management actions taken to address water quality issues in the Basin. [70] The Agency conducts routine water quality sampling which is typically analyzed in the Agency's water quality laboratory, monitoring to comply with the Del Valle water rights permits and Title 22 domestic Water Quality and Monitoring Regulations. Monitoring also includes sampling and analysis in accordance with the Salt/Nutrient Management Plan and the Toxic Site Surveillance Program. The Salt Management Plan, which was incorporated into the Agency's Groundwater Management Plan and was designed to identify strategies to stop or offset degradation of salt and mineral buildup from water recycling and wastewater disposal. The Toxic Site Surveillance Program tracks sites where groundwater has been impacted from anthropogenic sources and identifies those that pose a potential threat to drinking water. Management actions taken when water quality conditions at a well exceed or approach the identified threshold, includes blending groundwater with demineralized water from Zone 7's Mocho Groundwater Demineralization Plant to meet water quality thresholds.[71] Other management actions taken by the Agency to offset degradation of salt and mineral buildup include artificial recharge with low TDS imported water (when available), pumping and delivering groundwater to customers (salts are exported as wastewater), and operating groundwater demineralization facilities that export salts as a waste by-product (concentrate/brine).[72]

The Alternative Report describes that land surface elevations have been monitored for over 60 years in parts of the Basin and that the Agency has found no evidence of inelastic subsidence.[73] Data collection over the period captures a range of elastic surface

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[69] Alternative Report, Section 2.3.7.2, pp. 2-50 to 2-51

[70] Alternative Report, Section 4.6, p. 4-18; Groundwater Management Plan, Section 5.3, p. 5-9; 2015 Annual Report, Section 12, p. 12-1; Nutrient Management Plan, Section 6, p. 63; and Salt Management Plan, Section 7 through Section 12

[71] Alternative Report, Section 5.3.3.3, p. 5-11

[72] Alternative Report, Section 5.3.3.2, p. 5-10

[73] Alternative Report, Section 2.3.9, p. 2-74

elevations that are associated with cycles of elevation gains and losses that mimic dry/wet hydrologic cycles and correlate with groundwater elevation trends. The Agency has observed elastic surface elevation fluctuations in the range of 0.3 feet per cycle.[74] The Agency has an ongoing monitoring program to collect land surface elevation data semi-annually at more than 60 elevation benchmarks to evaluate subsidence in the Main Basin Management Area.

The Alternative Report describes surface water - groundwater interaction in the Basin and states that groundwater generally does not contribute to baseflow along surface water reaches in the basin. However, the Agency does recognize a surface water-groundwater connection for seasonal springflow in the Springtown Alkali Sink (or Alkali Sink) area and recognizes interaction of groundwater and surface water in gravel mining areas.[75]

The Springtown Alkali Sink is in the Fringe Management Area of the Basin along Altamont Creek, near stream gages on the creek monitored by Zone 7. The Agency describes a hydrologic analysis prepared for the City of Livermore in 1998 to characterize the localized aquifers and groundwater conditions near Springtown Alkali Sink.[76] Historical springs were present in the Alkali Sink area, caused by high groundwater levels in the underlying shallow aquifer zone. Development in the late 1960s deepened Altamont Creek, which was believed to have created a local drain for shallow groundwater, and a reduction in the presence of significant springs. The Agency reports that as a result, groundwater elevations are lower, which caused the alkali-saline wetland habitat, supported by the springs, to be seasonal.[77] The relationship of groundwater and surface water in the Alkali Sink area has been investigated with the development of a three-dimensional numerical groundwater flow MODFLOW model and the development of a modeled water budget for the sink. Groundwater in the Alkali Sink is monitored and managed to maintain groundwater levels to avoid surface water depletion.[78] The Alternative Report acknowledges the presence of groundwater dependent ecosystems in the Springtown Alkali Sink and states that the Sink is habitat to over a dozen federally-listed, state-listed or state-listed-as-sensitive plant and animal taxa and is critical habitat for other species.[79] As a result, the Springtown Alkali Sink and adjacent creeks are protected either as Preserves of the City of Livermore or conservation easements or are owned and managed by the Agency or the Federal Communications Commission.[80] In

[74] Alternative Report, Section 2.3.9, p. 2-74
[75] Alternative Report, Section 2.3.10, p. 2-76
[76] Alternative Report, Section 2.1.4, p. 2-7
[77] Alternative Report, Section 2.1.4, p. 2-8
[78] Alternative Report, Section 3.3.5.1, p. 3-23
[79] Alternative Report, Section 2.3.10.2, p. 2-77
[80] Alternative Report, Section 2.3.10.2, p. 2-77

addition, restoration of the sink is identified as a designated project of the Bay Area Integrated Water Resources Management Plan.[81]

The Agency identifies a second possible exception of surface water and groundwater interaction where the water table is exposed in gravel quarries in gravel mining areas. The Agency, in coordination with the two active mining companies in the basin, CEMEX and Vulcan Materials, monitor water levels and water quality in select mining area ponds or quarry lakes to track and document evaporation, circulation, and conveyance of water between pits. The data collected from these monitoring stations factor into the Agency's groundwater elevation maps for the Basin, water budget calculations, groundwater quality assumptions, and groundwater model efforts.[82] The Agency states that no groundwater-dependent ecosystems exist in the mining area and the quarry pits are not are not identified for specific beneficial uses in the Basin Plan developed by the Regional Water Quality Control Board.[83] The Agency is working closely with the mining companies to develop a quarry reclamation plan in the future to provide groundwater recharge and conveyance through the mining area.[84]

3. Water Budget

GSP Regulations require a water budget for the basin that provides an accounting and assessment of the total annual volume of groundwater and surface water entering and leaving the basin, including historical, current and projected water budget conditions, and the change in the volume of water stored, as applicable.[85]

The Alternative Report includes discussion of the current water budget that includes inflows, outflows, change in storage, sustainable yield, operational groundwater storage, surface water supplies, and other factors affecting the Agency's ability to operate the basin within its sustainable yield.[86] The Agency also discussed their projected water budget and plans for future management.[87] The information provided in the Alternative Report describes the current methods used by the Agency to calculate water budgets for the Main Basin Management Area, the Fringe Management Area, and the Uplands Management Area.

The Agency has evaluated the water budget in the Main Basin Management Area since 1974 and has documented the water budget in Annual Water Year Reports, published to the Agency's website.[88] The Agency provides an overview of its methodologies used to

[81] Alternative Report, Section 2.3.10.2, p. 2-77
[82] Alternative Report, Section 4.4, p. 4-8
[83] Alternative Report, Section 2.3.10.3, p. 2-78
[84] Alternative Report, Section 2.3.10.3, p. 2-77
[85] 23 CCR § 354.18
[86] Alternative Report, Section 2.4.2, p. 2-81
[87] Alternative Report, Section 2.5, p. 2-95
[88] Alternative Report, Section 2.4.3, p. 2-89

calculate the water budget in the Main Basin Management Area, which includes using two independent methods to estimate the current water budget, one that estimates the inflows and outflows and calculates the change in total groundwater storage (referred to by the Agency as the Hydrologic Inventory), and a second method that uses the groundwater elevation and storage coefficients to estimate the total change in groundwater storage (referred to by the Agency as the Groundwater Elevation method).[89] The Agency states that these two methodologies have been used for comparison and has allowed periodic re-examination and refinement of water budget computations, which the Agency later describes in the Alternative Report.[90] Inflows into the Main Basin Management Area using the Hydrologic Inventory method include rainfall recharge, stream recharge, applied water recharge, subsurface groundwater inflow, and pipe leakage. Outflows from the Main Basin Management Area using the Hydrologic Inventory method include municipal pumping, agricultural pumping, mining use, and groundwater basin overflow. The components of the water budget are derived independently, either directly from monitoring program results or calculated using the results of the monitoring program.[91] The Alternative Report presents the results from the calculations of inflows, outflows, and total change in storage for Water Year 1974 through Water Year 2015.[92] Furthermore, Figure 10-7 of the 2015 Annual Report provides a detailed table that presents the data used to generate Figure 2-40 provided in the Alternative Report.[93]

The Agency states that the Hydrologic Inventory method was used to estimate the water budget for the Fringe Management Area, using the same inflow and outflow components as described for the Main Basin Management Area, with the addition of a few outflow components specific to the management area (e.g., golf courses, domestic wells, subsurface to streams, subsurface to Main Basin).[94] The Agency presents a simplified groundwater budget for the Uplands Management Area, identifying rainfall/stream recharge as the inflow component and outflow identified as agricultural pumping and domestic wells.[95]

The Agency acknowledges that approximately 80 percent of the water supply is imported. Therefore, maintaining imported water supplies allows the Agency to operate the Basin within the sustainable yield.[96] The Agency describes sources of imports and surface water supplies that include supplies from the State Water Project, Lake Del Valle, groundwater banking (including Semitropic and Cawelo), and other water transfers.[97] The Agency

[89] Alternative Report, Section 2.4, pp. 2-79 to 2-90
[90] Alternative Report, Section 2.4.1, pp. 2-79 to 2-81
[91] Alternative Report, Section 2.4.1, p. 2-80
[92] Alternative Report, Figure 2-40, p. 2-89 and Section 2.4.3, pp. 2-89 to 2-90
[93] 2015 Annual Report, Figure 10-7, PDF pp. 182-183
[94] Alternative Report, Section 2.4.2.5 and Table 2-21, pp. 2-87 to 2-88
[95] Alternative Report, Section 2.4.2.6, p. 2-88
[96] Alternative Report, Section 2.4.4.2, p. 2-93
[97] Alternative Report, Section 2.4.4.2, pp. 2-93 to 2-94

states that imported water is either delivered to Zone 7's retailers and agricultural customers or it is used for artificial recharge in the Main Basin Management Area when surplus surface water is available.[98]

4. Management Areas

GSP Regulations authorizes, but does not require, an agency to define one or more management areas within a basin if the agency has determined that creation of management areas will facilitate implementation of the GSP.[99]

The Agency has identified three management areas: the Main Basin Management Area, the Fringe Management Area, and the Uplands Management Area that are within the Livermore Valley Basin. The Agency defines these management areas based on geologic, hydrogeologic, and groundwater conditions in the Basin. The Main Basin Management Area is described as having the highest yielding aquifers, best quality groundwater, and is where municipal wells are located. Whereas the Fringe Management Area is described as having low yielding aquifers with few wells for domestic, agricultural, and golf course irrigation purposes. The Upland Management Area is described as having low yielding aquifer and few wells used for domestic supply and agricultural purposes.[100]

C. Sustainable Management Criteria

GSP Regulations require a sustainability goal that defines conditions that constitute sustainable groundwater management for the basin, the characterization of undesirable results, and establishment of minimum thresholds and measurable objectives for each applicable sustainability indicator, as appropriate.[101]

1. Sustainability Goal

GSP Regulations require that sustainable management criteria include a sustainability goal that culminates in the absence of undesirable results within the appropriate timeframe, and includes a description of the sustainability goal, describes information used to establish the goal for the basin, describes measures that will be implemented to ensure the basin operates within its sustainable yield, and contains an explanation of how the sustainability goal will be met. [102] The sustainability goal for an alternative based on an analysis of basin conditions represents the criteria that allowed the basin to be

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[98] Alternative Report, Section 2.4.4.2, p. 2-93
[99] 23 CCR § 354.20
[100] Alternative Report, Section E-1.2, p. E-3; and Section 2.3.2, p. 2-32
[101] 23 CCR § 354.22
[102] 23 CCR § 354.24. For an alternative based on a demonstration of 10 years of sustainable management, the sustainability goal, or its functional equivalent, would have been developed at some previous time during basin management, and its goals met by the time the Alternative was submitted to the Department.

operated within its sustainable yield for a period of at least 10 years, which includes the avoidance of undesirable results.[103]

The Agency's goal is to continue to operate the Basin within its sustainable yield and to manage groundwater resources to prevent undesirable results.[104] The Agency also has a stated goal of managing the local groundwater resources to provide a reliable supply and to protect the groundwater resources for all beneficial uses.[105]

2. Sustainability Indicators

The GSP Regulations specify that an agency define conditions that constitute sustainable groundwater management for a basin, including the characterization of undesirable results and the establishment of minimum thresholds and measurable objectives for each applicable sustainability indicator.[106]

Sustainability indicators are defined as any of the effects caused by groundwater conditions occurring throughout the basin that, *when significant and unreasonable*, cause undesirable results.[107] Sustainability indicators thus correspond with the six undesirable results – chronic lowering of groundwater levels indicating a depletion of supply if continued over the planning and implementation horizon, reduction of groundwater storage, seawater intrusion, degraded water quality, including the migration of contaminant plumes that impair water supplies, land subsidence that substantially interferes with surface land uses, and depletions of interconnected surface water that have adverse impacts on beneficial uses of the surface water[108] – but refer to groundwater conditions that are not, in and of themselves, significant and unreasonable. Rather, sustainability indicators refer to the effects caused by changing groundwater conditions that are monitored, and for which criteria in the form of minimum thresholds are established by the agency to define when the effect becomes significant and unreasonable, producing an undesirable result.

The sustainability indicators section thus conflates three requirements of the sustainable management criteria set out in the GSP Regulations: undesirable results, minimum thresholds, and measurable objectives. Information pertaining to the processes and criteria relied upon to define undesirable results applicable to the basin as quantified through the establishment of minimum thresholds are discussed for each sustainability indicator. However, a submitting agency is not required to establish criteria for an

[103] Water Code § 10721(w)
[104] Alternative Report, Section 3.1, p.3-1
[105] Alternative Report, Section 3.1, p. 3-1; and Groundwater Management Plan, Section 4.1, p. 4-1
[106] 23 CCR § 354.22
[107] 23 CCR § 351(ah)
[108] Water Code § 10721(x)

undesirable result when the agency can demonstrate that an undesirable result for that sustainability indicator is not present and is not likely to occur in the basin.[109]

a. Chronic Lowering of Groundwater Levels

GSP Regulations specify that the minimum threshold for chronic lowering of groundwater levels be based on groundwater elevations indicating a depletion of supply that may lead to undesirable results.[110]

The minimum thresholds for groundwater levels only apply to the Main Basin Management Area and a small portion of the Fringe Management Area. The Agency uses the historical low groundwater level map (*see* Groundwater Conditions, above), to define the minimum thresholds for the Main Basin Management Area and a small portion of the Fringe Management Area. The Alternative Report uses the historical low groundwater level map, rather than identifying groundwater levels from individual wells in a tabular format, to define the minimum thresholds.

The Agency states that groundwater levels are routinely measured in the Fringe Management Area, and occasionally in the Uplands Management Area.[111] Groundwater level hydrographs from seven wells in the Fringe Management Area are presented in the Alternative Report, with six presenting data collected extending back to the 1980s and one presenting data collected back to the early 2000s.[112] The Agency does not provide information regarding the frequency or timing of when groundwater level data has been collected historically in the Uplands Management Area. The Agency states that if it is determined that wells in areas outside the Main Basin Management Area are experiencing loss of beneficial uses, then the conditions would be reviewed, and a recovery plan would be created.[113]

The Agency states that the area with the highest density of wells outside of the Main Basin Management Area, occurs in the Uplands Management Area and is referred to as the Happy Valley Area. This area is unincorporated, unsewered, and relies on domestic wells for water supply. However, due to high nitrate detections in some domestic wells, Alameda County has placed a moratorium on new onsite wastewater treatment system construction in Happy Valley, reducing the potential for additional development. In addition, the Agency states that discussions are underway between City of Pleasanton and Alameda County Local Agency Formation Commission (LAFCO) for the incorporation

[109] 23 CCR § 354.26(d)
[110] 23 CCR § 354.28(c)(1)
[111] Alternative Report, Section 4.5, p. 4-12
[112] Alternative Report, Figure 2-21, p. 2-35
[113] Alternative Report, Section 3.3.1.2, p. 3-7

of Happy Valley into the City limits and/or expansion of city water and sewer services to Happy Valley parcels.

The Agency identifies an alternative minimum threshold to account for areas outside the Main Basin Management Area, which requires any new well construction (other than replacement wells) in higher density well areas be evaluated by the Agency. The objective of the Agency's evaluation would be to complete an early assessment of any proposed wells to ensure the construction of proposed wells does not result in over-pumping for any localized area of well clusters.[114] Through the Agency's authority permitting new wells within its jurisdiction, the Agency can require that new well permit applications are accompanied by a certified CEQA analysis supporting that the new well would not significantly impact local water levels.[115]

The Agency describes an undesirable result as the lowering of regional water levels resulting in wells no longer capable of supporting their beneficial uses.[116] This undesirable result may be experienced as water levels falling below pump intakes, falling below the top of screens, and/or reduction in well yields. The Agency further explains that for municipal wells, the loss of one well in a wellfield or multiple for a short time might be compensated through a short-term redistribution of pumping or purchase of supplemental supplies.[117] The Agency has an ongoing policy in place to re-distribute pumping in areas that experience short-term declines to mitigate local impacts.[118] The Agency also focuses artificial recharge efforts near wellfields and plans to establish new wellfields in areas where levels routinely remain above historic lows. The Agency further states that a systemic failure of wellfields or long-term loss of wells would be an undesirable result.[119] For rural, domestic wells, the loss of even one well could cause an undesirable result if it leads to the well no longer being able to support its beneficial use.[120]

The Agency describes an undesirable result in areas outside the Main Basin Management Area as over-pumping that could locally impact beneficial uses of private wells, especially in groundwater dependent areas.[121]

[114] Alternative Report, Section 3.3.1.2, p. 3-9
[115] Alternative Report, Section 3.3.1.2, p. 3-9
[116] Alternative Report, Section 3.3.1.1, p. 3-5
[117] Alternative Report, Section 3.3.1.1, p. 3-5
[118] Alternative Report, Section 3.3.1.1, p. 3-5
[119] Alternative Report, Section 3.3.1.1, p. 3-5
[120] Alternative Report, Section 3.3.1.1, p. 3-5
[121] Alternative Report, Section 3.3.1.1, p. 3-5

b. Reduction of Groundwater Storage

GSP Regulations specify that the minimum threshold for reduction of groundwater storage shall be a total volume of groundwater that can be withdrawn from the basin without causing conditions that may lead to undesirable results.[122]

The minimum threshold for reduction of groundwater storage is based on the basin storage when groundwater levels throughout the Main Basin Management Area are at historic lows. The Agency uses historical low groundwater levels throughout the Main Basin Management Area to calculate the minimum threshold for basin storage, which is estimated as 128,000 acre-feet.[123] Over the last 40 years the Agency has operated the basin within the operational storage range above the minimum threshold (*see* Groundwater Conditions, above). If an emergency condition were to require the reserve storage to be accessed, the Agency states that they would develop a recovery plan with specific, and time-relevant, recovery actions. The Agency states that loss of storage in the Fringe and Upland Management Areas would not have the same detrimental effect on operational storage as in the Main Basin Management Area.[124] Minimum thresholds in the Fringe and Uplands management areas are not provided in the Alternative Report.

The Agency defines undesirable results in the Main Basin Management Area as being represented by groundwater levels falling significantly below historic lows across most of the area as well as storage volumes in the area being reduced into the reserve storage in a non-emergency situation.[125]

c. Seawater Intrusion

GSP Regulations specify that the minimum threshold for seawater intrusion be defined by a chloride concentration isocontour for each principal aquifer where seawater intrusion may lead to undesirable results.[126]

The Agency states that seawater intrusion is not a relevant issue for this inland basin, and do not identify an objective or sustainability indicator.[127] The Agency presents information to demonstrate that the Basin is an inland basin that is structurally-bound basin by northwest-southeast trending faults on the east and west, upland bedrock hills on the south, and the Mt. Diablo thrust fault to the north.[128]

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[122] 23 CCR § 354.28(c)(2)
[123] Alternative Report, Section 3.3.2.2 and Figure 3-3, pp. 3-10 to 3-11
[124] Alternative Report, Section 3.3.2.1, p. 3-10; Figure 2-21, PDF p. 96; and Tables 2-21 and 2-22, p. 2-88
[125] Alternative Report, Section 3.3.2, p. 3-9
[126] 23 CCR § 354.28(c)(3)
[127] Alternative Report, Section 3.1 footnote 3, p. 3-1
[128] Alternative Report, Section E-2.2, p. E-4

d. Degraded Water Quality

GSP Regulations specify that the minimum threshold for degraded water quality shall be the degradation of water quality, including the migration of contaminant plumes that impair water supplies or other indicator of water quality as determined by the agency that may lead to undesirable results.[129]

The Agency sets minimum thresholds established at levels required to meet federal and state standards.[130] The Agency states that trends toward the minimum thresholds triggers management responses in coordination with the Agency's retailers, which could include short-term actions or long-term actions further described in the Alternative Report.[131] The Agency has implemented management actions to address water quality issues like TDS, nitrate, toxic sites, and salt loading (*see* Groundwater Conditions, above).

The Agency states an undesirable result in the Main Basin Management Area is the loss of beneficial uses as measured at each of the municipal wells in the area caused by degradation of the Lower Aquifer with TDS, key inorganic constituents, and/or toxic substances such that levels in municipal wellfields cannot be blended, treated, or managed to provide drinking water supply.[132] The Agency states an undesirable result in the Fringe and Upland Management Areas is the loss of beneficial uses due to contamination when treatment is not possible or practicable.[133]

The Agency has actively responded to numerous groundwater quality issues in the Basin over time. The Agency has been able to address each issue and prevent or reduce significant and unreasonable degradation of groundwater quality in the Basin through management actions. The Agency works adaptively with regulatory agencies to ensure protection of the Basin to meet beneficial uses. Groundwater quality is managed on a regional basis as measured at municipal wells while protecting and improving groundwater quality within the Main Basin Management Area.[134]

e. Land Subsidence

GSP Regulations specify that the minimum threshold for land subsidence shall be the rate and extent of subsidence that substantially interferes with surface land uses and may lead to undesirable results.[135]

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[129] 23 CCR § 354.28(c)(4)
[130] Alternative Report, Section 3.3.3, p. 3-11
[131] Alternative Report, Section 3.3.3.2, p. 3-18
[132] Alternative Report, Section 3.3.3.1, p. 3-12
[133] Alternative Report, Section 3.3.3.1, p. 3-12
[134] Alternative Report, Section 3.3.3, p. 3-11
[135] 23 CCR § 354.28(c)(5)

The Agency uses historical low groundwater levels as minimum thresholds for land subsidence since no inelastic land subsidence occurred when groundwater levels were previously at historic lows.[136]

The Agency states that inelastic subsidence would represent a potential undesirable result in the Basin, with several potential effects on beneficial uses and users of groundwater and on land uses and property interests in this urban area. The Agency further defines what potential effects in detail in the Alternative Report.[137]

The processes defining land subsidence potential throughout the basin were investigated in detail in the Draft Well Master Plan, which included numerical groundwater modeling to evaluate different operational scenarios in the Basin.[138] The Draft Well Master Plan identified areas in the Basin that would be most prone to groundwater drawdown below historical low groundwater levels and recommended subsidence monitoring in those areas.[139] The outcome of studies completed for the Well Master Plan resulted in the development of the Agency's detailed land surface elevation monitoring program.[140] The Agency states and provides data from two research efforts, to support the conclusion that no inelastic land subsidence has occurred in the Basin within the 13-year monitoring period between 2002 and 2015.[141] The InSAR Report and Benchmark Report, provided as Appendices to the Alternative Report, document the monitoring network, results from the two research efforts, and demonstrate that no undesirable results associated with land subsidence would substantially interfere with surface land uses in the Basin.

f. Depletion of Interconnected Surface Water

GSP Regulations specify that the minimum threshold for depletions of interconnected surface water shall be the rate or volume of surface water depletions caused by groundwater use that has adverse impacts on beneficial uses of the surface water and may lead to undesirable results.[142]

According to the Agency, interconnected surface water and groundwater dependent ecosystems are limited in the Basin, with interconnected surface water existing primarily in the Springtown Alkali Sink area, seasonally (*see* Groundwater Conditions, above).[143] The Agency sets minimum thresholds to avoid surface water depletion in the Springtown Alkali Sink as the historic low groundwater elevations recorded at two wells located in the

[136] Alternative Report, Section 3.3.4, p. 3-20
[137] Alternative Report, Section 3.3.4.1, pp. 3-20 to 3-21
[138] Alternative Report, Section 2.3.9, p. 2-74; and Draft Report Well Master Plan, Section 2.4, p. 2-7
[139] Draft Report Well Master Plan, Section 2.4, pp. 2-7 to 2-9
[140] Alternative Report, Section 2.3.9, p. 2-74
[141] Alternative Report, Section 2.3.9, p. 2-74; and Section 3.3.4, p. 3-20
[142] 23 CCR § 354.28(c)(6)
[143] Alternative Report, Section 2.3.10, p. 2-76; and Section 3.3.5, p. 3-22

Springtown Alkali Sink Wetlands.[144] The Agency states that using the lowest recorded groundwater elevation as a proxy provides for a margin of uncertainty and is consistent with the management strategy of using historic low groundwater elevations throughout the Basin.[145]

The Agency defines an undesirable result as depletion of surface water in the Springtown Alkali Sink, potentially resulting in adverse effects on the Springtown Alkali Sink ecosystem and protected species.[146]

The Agency monitors five wells near the Springtown Alkali Sink. Groundwater level trends in these monitoring wells generally have been steady. The Agency states that maintenance of groundwater levels and flow patterns are criteria for avoiding undesirable results. The Agency states that their role in permitting wells allows the Agency an early assessment of any proposed wells to ensure that they are constructed to account for operating groundwater levels in the basin and do not result in over-pumping for any localized area of well clusters.[147]

D. Monitoring Networks

GSP Regulations require that each basin be monitored, and that a monitoring network include monitoring objectives, monitoring protocols, and data reporting requirements be developed that shall promote the collection of data of sufficient quality, frequency, and distribution to characterize groundwater and related surface water conditions in the basin and evaluate changing conditions.[148]

The Alternative Report relies on a network of monitoring wells and other monitoring sites to gather data on groundwater levels, surface water flow conditions, groundwater and surface water quality, climate, and land surface elevation.[149] The Alternative Report includes the Agency's standard operating procedures as Appendix B, which outlines the protocols followed by the Agency to ensure the quality of data collected for the monitoring program.[150] Data collected from the monitoring networks was used to support the development of a numerical model for the Basin.

The Agency's groundwater elevation monitoring program includes measurement of groundwater levels in about 240 wells across the Main Basin Management Area and a

[144] Alternative Report, Section 3.3.5.2, pp. 3-24 to 3-25
[145] Alternative Report, Section 3.3.5.2, p. 3-25
[146] Alternative Report, Section 3.3.5.1, p. 3-23
[147] Alternative Report, Section 3.3.1.2, p. 3-9; and Section 3.3.5, p. 3-22
[148] 23 CCR § 354.32
[149] Alternative Report, Section 4, p. 4-1; Appendix C, PDF p. 247; 2015 Annual Report, Section 2.2, p. 2-1; Section 3.2, p. 3-1; Section 4.2, p. 4-2; Section 5.2, p. 5-7; Section 6.2, p. 6-5; Section 7.2, p. 7-2; and Section 8.2, p. 8-2
[150] Alternative Report, Appendix B, PDF p. 237

portion of the Fringe Management Area. This network includes nested wells, which are used to determine local vertical groundwater gradients.[151] The monitoring and sampling frequency for wells associated with these objectives ranges from continuous to semi-annually.[152] The Agency does not identify wells in the Upland Management Area as part of the monitoring network.

The Agency monitors groundwater quality in more than 230 wells across the Basin as part of the Agency's groundwater quality monitoring program. The Agency's Groundwater Quality Monitoring Program is primarily focused on the Main Basin Management Area, but routinely monitors wells in the Fringe Management Area, and occasionally in the Uplands Management Area. The Groundwater Quality Program has several objectives for Routine Water Elevation Monitoring, Del Valle Water Rights, Municipal Water Supply, Salt Management Plan, Nutrient Management Plan, Dublin San Ramon Services District, and Toxic Site Surveillance. Wells monitored and sampled for the respective objectives are widespread across the Main Basin Management Area and different sampling and frequency associated with those objectives. The monitoring and sampling frequency for wells associated with these objectives ranges from quarterly to annually.

As part of the Agency's surface water monitoring program, the Agency monitors and collects semi-continuous streamflow measurements and periodic water level measurements to track surface water storage. The Agency collects surface water quality at least once per year at 10 recorder sites and quarry ponds.[153] The Agency's climate monitoring network tracks rainfall and evaporation daily, or every 15 minutes, in the Livermore Valley with climatological stations spread across the basin.[154]

The Agency's Land Surface Elevation Monitoring Program includes a network of more than 60 elevation benchmarks locations spanning the Agency's production wellfields in the Main Basin Management Area and includes the collection of semi-annual measurements.

Monitoring sites for groundwater levels and land surface elevation are not reported for the Uplands Management Area. The Agency acknowledges the limited monitoring programs for the Upland Management Area and states that monitoring is done on an issue- or as-needed basis. The Agency states that this management strategy is justified because there is a low number of active wells in the Upland Management Area, with low well yields, and historically low groundwater use in the area.[155]

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[151] Alternative Report, Section 4.5, p. 4-12
[152] Alternative Report, Section 4.5, p. 4-12
[153] Alternative Report, Section 4.3, p. 4-4
[154] Alternative Report, Section 4.2, p. 4-1; 2015 Annual Report, Figure 2-5, PDF pp. 41-42; and Figure 2-7, PDF p. 44
[155] Alternative Report, Section 4.10, p. 4-27

E. Projects and Management Actions

GSP Regulations require a description of the projects and management actions the submitting agency has determined will achieve the sustainability goal for the basin, including projects and management actions to respond to changing conditions in the Basin.[156]

The Agency has over 40 years of experience managing the Basin and implementing plans and programs and identifies numerous on-going and proposed projects whose implementation have helped the Agency operate the Basin for at least 10 years within the Basin's sustainable yield.[157] The ongoing projects and management actions are implemented to ensure the sustainability of the Basin's groundwater supply and groundwater quality out to the planning horizon.

The Agency acknowledges that approximately 80 percent of the Basin's water supply is from imported surface water that is delivered to the Agency's retailers and agricultural customers and is used for artificial recharge in the Main Basin Management Area. The Agency acknowledges the uncertainty of future imported water supplies and describes other projects and management actions that are ongoing or planned to provide water supply reliability, should supplemental supplies be required for supply or recharging the Basin.[158]

In addition to the import of surface water, those projects and management actions include allocation of groundwater pumping quotas to municipal pumpers, conjunctive use projects, Draft Well Master Plan, Chain of Lakes Recharge Projects, existing and future recycled water projects, and water conservation.[159] The Agency identifies artificial recharge program as a key component of the Agency's conjunctive use program, which consists of recharging the groundwater basin through release of surface water to dry arroyos. The artificial recharge program is used as a mechanism for improving groundwater storage and as a water quality management tool, managing releases to arroyos when TDS of source water is low.[160] The Well Master Plan was developed in 2003 and has resulted in the construction of several municipal supply wells.[161] Projects associated with the Chain of Lakes Recharge Projects have been ongoing, with full implementation not expected before 2050.[162] The Agency's existing recycled water projects include use for landscape irrigation and other minor amounts for dust

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[156] 23 CCR § 354.44
[157] Alternative Report, Section 5, p. 5-1; Water Supply Evaluations Update, Section 6 through Section 11; and 2015 Urban Water Management Plan, Section 6 through Section 8
[158] Alternative Report, Section 5.2.1, p. 5-1
[159] Alternative Report, Section 5.2, p. 5-1
[160] Alternative Report, Section 5.2.2, p. 5-3
[161] Alternative Report, Section 5.2.3, p. 5-4
[162] Alternative Report, Section 5.2.4, p 5-4

suppression, grading projects, and crop irrigation. Future recycled water projects could include use for groundwater recharge/injection, surface water augmentation, and connection upstream to water treatment plants. The Agency recognizes use of recycled water as a valuable component of water supply portfolio when it is managed under the Salt Management Plan and Nutrient Management Plan.[163]

The Agency identifies several ongoing programs that support maintaining groundwater quality and indirectly support maintaining groundwater supply, which include the Well Ordinance Program, Toxic Site Surveillance Program, Salt Management, Nutrient Management, and Offsite Wastewater Treatment Systems.[164] The Agency identifies the ongoing Well Ordinance Program as providing multiple benefits, with the most notable being protection of the Basin from negative impacts associated with poorly-constructed wells.[165] The Toxic Site Surveillance Program is an ongoing program that informs the Agency by documenting, tracking, and giving priority to sites based on the potential threat to groundwater posed by the site.[166] The 2004 Salt Management Plan is an active, ongoing program and includes strategies to reduce salt loading to groundwater basin and mitigate future salt impacts from planned increased recycled water use in the Main Basin (see Groundwater Conditions, above).[167] One of the strategies identified by the Salt Management Plan, lead to the construction of Zone 7's Mocho Groundwater Demineralization Plant, which is operated to remove salts from the groundwater basin while improving delivered drinking water quality through blending demineralized water with extremely low TDS with groundwater (see Groundwater Conditions, above). The Nutrient Management Plan was developed in 2015 to assess existing and future nutrient contributions from current and planned expansion of recycled water projects and future development in the Livermore Valley. The Nutrient Management Plan identifies best management practices to minimize nitrogen loading in the Basin and identifies ongoing monitoring and future opportunities to add new monitoring wells and/or soil borings.[168] The Alternative Report also describes Offsite Wastewater Treatment System Management, which includes multiple policies established by the Agency and implemented in cooperation with the Alameda County Environmental Health.[169] Further, the Nutrient Management Plan recommends future actions to prevent nutrient loading from increasing in areas of concern.

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163 Alternative Report, Section 5.2.5, p. 5-6
164 Alternative Report, Section 5.3, p. 5-8
165 Alternative Report, Section 5.3.1, p. 5-8
166 Alternative Report, Section 5.3.2, p. 5-9
167 Alternative Report, Section 5.3.3, p. 5-9
168 Alternative Report, Section 5.3.4, p. 5-11
169 Alternative Report, Section 5.3.5, p. 5-13

V. Assessment

The following describes the evaluation and assessment of the Alternative for the Livermore Valley Basin as determined by Department staff. In undertaking this assessment, Department staff did not conduct geologic or engineering studies, although Department staff may have relied on publicly available geologic or engineering or other technical information to verify claims or assumptions presented in the Alternative.[170] As discussed above, Department staff has determined that the Livermore Valley Alternative satisfied the conditions for submission of an alternative.[171] The Alternative was submitted within the statutory period, the Basin was found to be in compliance with the reporting requirements of CASGEM, and staff finds the Alternative to be complete and to cover the entire Basin (*see* Required Conditions, above). Based on its evaluation and assessment of the Livermore Valley Alternative, as discussed below, Department staff finds that the Agency sufficiently demonstrated that the Basin has operated within its sustainable yield over a period of at least 10 years. Staff recommends that the Livermore Valley Alternative be approved.

A. Evaluation of Alternative Contents

The Alternative Report's description of the Agency's responsibilities and authority under the 2003 Assembly Bill 1125 and provided additional information were adequate to demonstrate the Agency's authority to manage groundwater in the Livermore Valley Basin. The information and descriptions regarding the hydrogeologic conceptual model in the Alternative Report demonstrate a thorough understanding of the Basin and were sufficient for evaluating the Alternative to determine whether the basin has operated within its sustainable yield.

The Agency has sufficiently characterized groundwater use, current and historic conditions of groundwater elevation, groundwater in storage, water quality, land subsidence, and surface water-groundwater interaction. The primary focus of the Alternative Report and existing monitoring networks is the Main Basin Management Area and a part of the Fringe Management Area. The Alternative Report presented groundwater level data from wells in the Fringe Management Area and in the Main Basin Management Area. The Department staff found it reasonable that the primary focus of the Alternative Report is on the Main Basin area because all municipal groundwater pumping and approximately 93 percent of Basin-wide pumping occurs in the Main Basin Management Area, and only minor pumping occurs in the Fringe and Upland management areas. The lack of data and information presented in the Fringe and

[170] Instances where the Department review relied upon publicly available data that was not part of the Alternative are specifically noted in the assessment.
[171] 23 CCR § 358.4(a)

Uplands management areas does not preclude the Department staff from making an evaluation of the sustainability of the Basin.

The Department staff finds that the methods used to calculate water budgets are based on sufficient and credible data and use standard practices and methodology for calculations. The Alternative Report describes the current methods used by the Agency to calculate water budgets for the Main Basin Management Area, the Fringe Management Area, and the Uplands Management Area. The calculation method and input datasets are well-documented and appear reasonable for the intended use. Any data gaps identified in the future by the Agency or by Department staff for the Basin or any of the three management areas should be addressed in the annual reports or updates to the Alternative Report.

Department staff find the use of historical low groundwater levels to be a reasonable approach, supported by sufficient and credible information, for defining minimum thresholds for chronic lowering of groundwater levels. The Agency demonstrates that they have established this minimum threshold for groundwater levels and have operated above the historical lows for more than 10 years and that staying above historical groundwater levels has avoided undesirable results in the Basin. However, the Alternative Report relies on a water level surface rather than the water level data for the minimum thresholds. Department staff believe it would facilitate future review and assessment of the Alternative if the water level data for historical lows was provided (see Recommended Action 1).

In addition, the minimum thresholds only cover Main Basin Management Area and a small portion of the Fringe Management Area. The Agency states groundwater levels are routinely measured in the Fringe Management Area, and occasionally in the Uplands Management Area.[172] The Department staff find it reasonable that the Alternative Report lacks minimum thresholds defined for the majority of the Fringe Management Area and the Uplands Management Area because of the lack of groundwater use and looking forward it is unlikely that further development will lead to groundwater declines in these portions of the Basin (*see* Chronic Lowering of Groundwater Levels, above). However, to facilitate ongoing review and assessment of the Alternative, Department staff recommend developing quantitative thresholds for the Fringe and Uplands Management areas (See Recommended Action 2).

The Department staff find that the Agency provided adequate information to demonstrate that the Basin is not experiencing depletion of groundwater storage and has been operated sustainably for at least 10 years. The Department staff finds that the Alternative Report demonstrates that the Main Basin Management Area will likely continue to be

[172] Alternative Report, Section 4.5, p. 4-12

operated sustainably based on the description of the Agency's basin management. The Agency manages the groundwater within the limits of operational storage to maintain adequate supplies and prevent overdraft, operating within the sustainable yield of the basin. The Agency states that the groundwater in storage in the Main Basin Management Area has remained above 200,000 acre-feet for over 40 years, except for a period during the drought in the 1990s. The groundwater in storage has never reached the minimum threshold of 128,000 AF during the period of historical groundwater management, between 1974 and 2015.

The Agency states that seawater intrusion is not a relevant issue for this inland Basin and is not likely to occur in the Basin. Department staff agree with the Agency's conclusion and consider it to be reasonable that the Agency has not developed criteria for this sustainability indicator, given the physical setting of the basin, as described in the Hydrogeologic Conceptual Model.

The Agency sets minimum thresholds for groundwater quality based on federal and state standards. The Agency states that undesirable results would be experienced if municipal wellfields experience a loss in beneficial uses and groundwater cannot be blended, treated, or managed to provide drinking water supply. The Department staff find this to be a reasonable approach to managing groundwater quality and that the Agency demonstrated that through management actions, water quality sampling pursuant to Title 22 requirements, and implementation of regulatory programs, the Basin has been adaptively managed and has not experienced undesirable results with respect to water quality (*see* Groundwater Conditions and Projects and Management Actions, above).

The Department staff find that the Agency provides adequate data to demonstrate that the Basin has not experienced undesirable results with respect to inelastic land subsidence in the Basin over the 10 years and provides a reasonable approach for monitoring and documenting changes in land surface elevation in the Basin. Staff also find it reasonable to use historical low groundwater levels as minimum thresholds for land subsidence.

The Agency identifies the Springtown Alkali Sink as a possible location of interconnected surface water in the Basin and establishes the minimum thresholds as the historic low groundwater elevation at two wells in the Alkali Sink Wetlands, consistent with the management strategy used for several other sustainability indicators in the Basin. Department staff find that the Agency's monitoring and management of the Basin has demonstrated that groundwater levels maintained above historic low groundwater elevations in the Basin has avoided undesirable results associated with depletion of surface water near the Springtown Alkali Sink and is reasonably protective of the Springtown Alkali Sink ecosystem and protected species.

The monitoring network provides a comprehensive network of wells and other measuring methods to evaluate the sustainability indicators. The Agency maintains decades of monitoring results and demonstrates detailed knowledge and understanding of the Basin. The Agency actively monitors for changes in groundwater conditions and uses the monitoring data to manage the Basin sustainably. It is noted that the monitoring network identified in the Alternative Report does not designate specific monitoring wells to collect groundwater elevation data or designate benchmark locations for measuring land surface elevation in the Uplands Management Area. Department staff find that the Agency's justification for not including a detailed monitoring network for the Uplands Management Area is reasonable, because of the limited use of groundwater in this portion of the basin, the low production potential, the limited potential for further development due to a moratorium on onsite wastewater treatment systems in the county in high density well areas, and the Agency's oversight in reviewing and issuing well permits (see Recommended Action 4).

Although the description of future Projects and Management actions are not required for this type of analysis, the Alternative Report demonstrated that through the historical implementation of projects and management actions, the Basin has reached a locally-defined level of sustainability and is operating to a sustainable yield.

B. Recommended Actions

The following recommended actions include information that the District may wish to include in the first five-year update of the Alternative to facilitate the Department's ongoing evaluation and assessment of the Alternative as well as recommendations for improvements to the Alternative.

Recommended Action 1.

Staff recommends that in the first update to the Alternative Report, the Agency identify those groundwater levels taken at representative monitoring sites, that are used to define the minimum threshold for the Basin, to facilitate the Department's ongoing responsibility to evaluate the Alternative Report.

Recommended Action 2.

Staff recommends that the Agency should develop quantitative minimum thresholds for the chronic lowering of groundwater levels for the Fringe and Upland management areas to better align with the requirements for management areas and definition of minimum thresholds, as defined in 23 CCR Sections 354.20(b)(2) and 354.28(b)(6).

Recommended Action 3.

Staff recommends that the Agency develop quantitative minimum thresholds for reduction of groundwater storage for the Fringe and Upland management areas to better align with the requirements for management areas and definition of minimum thresholds, as defined in 23 CCR Sections 354.20(b)(2) and 354.28(b)(6).

Recommended Action 4.

Staff recommends that the Agency include monitoring groundwater levels at additional locations in the Uplands Management Area to monitor changes in groundwater conditions and manage the groundwater resources to prevent undesirable results in future updates to the Alternative Report. The Agency should identify the frequency and timing when groundwater levels would be collected at new monitoring stations, and other relevant monitoring well construction information in accordance with the GSP Regulations.

Sustainable Groundwater Management Program

Alternative Assessment Summary

Livermore Valley Basin

Determination: APPROVED

Submitting Agency:

Zone 7 Water Agency (Zone 7)

Alternative Type:

Analysis of basin conditions demonstrating operation within the sustainable yield for at least 10 years

Assessment Summary:*

- The alternative prepared by Zone 7 satisfied the objectives of the Sustainable Groundwater Management Act (SGMA) by successfully demonstrating that the Livermore Valley Groundwater Basin operated within its sustainable yield for a period of at least 10 years. Operation within the sustainable yield means groundwater use in the basin did not cause any of the six undesirable results identified in SGMA during that 10-year period.
- The alternative demonstrated an acceptable understanding of groundwater conditions in the basin. The alternative identified some previously undesirable results which appear to have been alleviated due to State Water Project imports and local groundwater management projects.
- Zone 7 is identified as an exclusive local agency under SGMA and is the Groundwater Sustainability Agency (GSA) for portions of the basin within its jurisdictional area. Additionally, Zone 7 has a memorandum of understanding with other local agencies that give it the delegated authority to be the GSA for areas of the basin outside its jurisdiction.
- The Department of Water Resources provided recommendations related to groundwater levels taken at representative monitoring sites, quantitative thresholds for groundwater storage, and timing of groundwater level measurements for Zone 7 to address in its first five-year update to the alternative, which is due in January 2022.

*For more details, refer to the staff report at https://www.water.ca.gov/Programs/Groundwater-Management/SGMA-Groundwater-Management/Alternatives.

The Nature Conservancy
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Sacramento Field Office
555 Capitol Mall, Suite 1290
Sacramento, California 95814

tel [916] 449-2850
fax [916] 442-2377

nature.org
nature.org/california

June 1, 2018

Trevor Joseph
California Department of Water Resources
901 P Street, Room 313B
Sacramento, California 94236

Submitted to "New Comment" in the SGMA Portal/Alternative

RE: Public Comments on the Annual Report for Basin 2-010 LIVERMORE VALLEY

The Nature Conservancy (the Conservancy) appreciates the opportunity to comment on the Water Year 2017 Annual Report submitted by Zone 7 Water Agency in accordance with the Sustainable Groundwater Management Act (SGMA). This letter supplements a number of prior Nature Conservancy comment letters to the Department related to SGMA materials. We greatly appreciate the open process that the Department has used in carrying out the complex and demanding tasks that SGMA has required, and we look forward to continued participation in SGMA implementation.

The Conservancy is an international non-profit organization dedicated to conserving the lands and waters on which all life depends. We have been deeply involved in the legislative creation and regulatory development of the SGMA. The Conservancy has focused its groundwater work extensively on protection for groundwater dependent ecosystems (GDEs) through the implementation of Groundwater Sustainability Plans (GSPs). That protection depends heavily on how the Department directs the identification and consideration of GDEs in GSPs, Alternatives and Annual Reports.

Below we offer general comments related to this first group of Annual Reports that are related to the Alternatives submitted in March of 2017. Following these general comments, we provide specific comment on the Livermore Valley Annual Report.

1. **The adequacy of the Annual Report may be a function of the adequacy of the Alternative**

   In our previous comments to the Alternatives we noted that most of the submittals did not meet requirement to be," functionally equivalent to the elements of a Plan as required by Articles 5 and 7" as specified in Section 385.2(d) of the GSP Regulations. The submitting agencies failed to include adequate identification and consideration of GDEs as beneficial use of groundwater and interconnected surface water. In addition, native vegetation was frequently excluded as a water use sector, as required for the water budget. In reviewing these initial Annual Reports, we observe that if the required material related to GDEs was missing in the Alternative submitted last year, the required information is also commonly missing in the Annual Report, resulting in an inadequate Annual Report.

2. **Annual Reports Are Required to Address All Water Use Sectors**

   Section 356.2 of the GSP Regulations specifies that data related to groundwater extraction for the preceding water year (§356.2(b)(2)) and total water use (§356.2(b)(4)) must be provided "by water use sector". This requirement to address the full range of human and natural use of water is consistent with the direction of the State policy established in SGMA:

   > §113. STATE POLICY OF SUSTAINABLE, LOCAL GROUNDWATER MANAGEMENT It is the policy of the state that groundwater resources be managed sustainably for long-term reliability and multiple economic, social, and **environmental benefits for current and future beneficial uses**. Sustainable groundwater management is best achieved locally through the development, implementation, and updating of plans and programs based on the best available science. *(emphasis added)*

   Unfortunately, we find that these initial Annual Reports only considered the human side of water use and fail to address the full range of water use sectors as defined in the GSP Regulations.

   > §351 (al) "Water use sector" refers to categories of water demand based on the general land uses to which the water is applied, including urban, industrial, agricultural, **managed wetlands**, managed recharge, and **native vegetation**. *(emphasis added)*

   We believe that it is essential that all SGMA documents (GSPs, Alternatives and Annual Reports, etc.) consistently meet the requirements related to the beneficial use of water by nature. Because the subject Annual Reports are the first of their kind, it is critical that the Department require full compliance with SGMA and the GSP Regulations.

Related specifically to the Annual Report submitted for the Livermore Valley Basin, we find it to be comprehensive and well organized; however, it does not include the required information regarding groundwater extractions/use and total water use for the managed wetlands and native vegetation water use sectors as specified in the GSP Regulations. As noted previously, SGMA requires that sustainable groundwater management consider all beneficial uses of groundwater and interconnected surface water, both those for human use and those for nature. We strongly recommend that this required information be included in the Annual Report before it is deemed adequate.

We further note that through the development of a GSP, the information systems and data to meet these requirements would be available. In a GSP, GDEs in the basin would be identified and considered, a water budget including all water use sectors would be established and other SGMA requirements related to the full range of beneficial uses would be addressed. The Alternative submitted for the Livermore Valley Subbasin and this Annual Report do not meet all the requirements of SGMA.

The Nature Conservancy appreciates the opportunity to comment on this Annual Report and pledges to work to assist the Department and GSAs as the process of implementing California's groundwater sustainability law moves forward.

Sincerely,

Sandi Matsumoto
Associate Director, California Water Program
The Nature Conservancy

CC Matt Katen

The Nature Conservancy
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555 Capitol Mall, Suite 1290
Sacramento, California 95814
[916] 449-2850
nature.org
nature.org/california
groundwatercalifornia.org

1 April 2017

Acting Director William Croyle
California Department of Water Resources
P.O. Box 942836
Sacramento, California 94236

Submitted online via DWR's SGMA portal:
http://sgma.water.ca.gov/portal/alternative/all

Re: Alternative Submittal from Zone 7 Water Agency

Dear Director Croyle:

The Nature Conservancy (TNC) appreciates the opportunity to comment on the alternative submittal from Zone 7 Water Agency (Zone 7) under the Sustainable Groundwater Management Act (SGMA).

Background on Our Interest

TNC is a global, nonprofit organization dedicated to conserving the lands and waters on which all life depends. We have over 100,000 California members and seek to achieve our mission through science-based planning and implementation of conservation strategies. TNC was part of a stakeholder group formed by the Water Foundation in early 2014 to develop recommendations for groundwater reform and actively worked to shape and pass SGMA.

Our reason for engaging is simple: California's freshwater biodiversity is highly imperiled. We have lost more than 90 percent of our native wetland and river habitats, leading to precipitous declines in native plants and the populations of animals that call these places home. These natural resources are intricately connected to California's economy providing direct benefits through industries such as fisheries, timber and hunting, as well as indirect benefits such as clean water supplies. Given the inextricable connection between groundwater and surface water, SGMA must be successful for a sustainable future in California.

California continues to use more water than nature provides. While surface water rights and access to surface water may be curtailed, the balance of water consumed is coming from groundwater – an estimated 60% California's water during the drought was supplied by groundwater. SGMA provides a path for California to sustainably manage groundwater so that the critical groundwater reserves are available when surface water is not.

SGMA is now law, but implementation is just beginning. The success of SGMA depends on bringing the best available science to the table, engaging all stakeholders in robust dialog, providing strong incentives for beneficial outcomes and rigorous enforcement by the State of California.

The recently submitted alternatives mark the first opportunity for the Department of Water Resources (Department) to hold local agencies accountable for sustainability. We ask the Department to fully exercise its authorities granted under SGMA to ensure the adequacy of plans. Given our mission to preserve the plants and animals on which all life depends, we are particularly concerned about the inclusion of nature, as required, in groundwater sustainability plans (GSPs).

"Functionally Equivalent" Requires Fully Addressing Nature's Water Needs

Zone 7 submitted an alternative submittal based on basin conditions. To meet the requirements provided under SGMA, the alternative submittal must:

1. Provide "(a)n analysis of basin conditions that demonstrates that the basin has operated within its sustainable yield over a period of at least 10 years" (23 CCR §358.2(b)(3)); and
2. "(E)xplain how the elements of the Alternative are functionally equivalent to the elements of a Plan required by Articles 5 and 7 of this Subchapter and are sufficient to demonstrate the ability of the Alternative to achieve the objectives of the Act." (23 CCR §358.2(d)

To be "functionally equivalent," the alternative submittal must fully incorporate the numerous requirements to address nature's water needs under SGMA. While there are certainly additional provisions regarding nature's water needs, for the purposes of our review, we focused on the following elements:

1. Are groundwater dependent ecosystems (GDEs) identified? (23 CCR §354.16(g)) Are GDEs and surface water dependent species included as beneficial uses? (23 CCR §354.10(a))

2. Are interconnected surface waters identified and are estimates of the quantity and timing of any depletions specified? (23 CCR 354.16(f), §354.28(c)(6)(A))

3. Do water budgets include water needs for managed wetlands and native vegetation, as defined water use sectors, as well as total surface water inflows and outflows? (23 CCR §354.18(b))

4. Do undesirable results and minimum thresholds describe potential effects on beneficial uses (especially GDEs), land uses (including recreational uses) and property interests (including open space and conservation lands), particularly for the chronic lowering of groundwater, degraded water quality and depletions of interconnected surface waters? (23 CCR §354.26, §354.28,

§355.4(b)(4)) Are these undesirable results being avoided? (Water Code §10733.6(b)(3)) Has the basin operated sustainably for at least the past 10 years? (23 CCR §358.2(c)(3))

5. Does the sustainability goal include the environment, and if so, does the plan include measurable objectives and interim milestones to achieve the environmental portion of the sustainability goal within 20 years? (23 CCR §354.30)

6. Does the monitoring network monitor impacts to beneficial uses? (23 CCR §354.34(b)(2))

Our comments related to the above questions are provided in Attachment A: TNC Evaluation of Zone 7 Water Agency's Alternative Submittal. Based on our review, Zone 7's alternative submittal could be improved by including measurable objectives and interim milestones for achieving the environmental element of the sustainability goal within 20 years.

Thank you for fully considering our comments as you evaluate the adequacy of this alternative submittal.

Best Regards,

Sandi Matsumoto
Associate Director, Water Program
The Nature Conservancy of California

Attachment A: TNC Evaluation of Zone 7 Water Agency's Alternative Submittal

1. Are groundwater dependent ecosystems (GDEs) identified? Yes. Are GDEs and surface water dependent species included as beneficial uses? Indirectly by way of the Regional Water Quality Control Board (RWQCB), San Francisco Region, Basin Plan.

   GDEs: §354.16g: See Zone 7's *Alternative Groundwater Sustainability Plan for the Livermore Valley Groundwater Basin*, December 2016, (AGSP) pages E-12, 2-7 through 2-8, 2-76 through 2-77, and pages 3-22 to 3-25. Below is a brief quote from page 2-8:

   The Alkali Sink may be considered a groundwater dependent ecosystem for the purposes of SGMA, although effects are clearly seasonal. The sink supports an alkali-saline wetland habitat with seasonal surface ponding and shallow, seasonal high-salinity groundwater.

   Beneficial Uses: §354.10a: Zone 7 cooperates with the RWQCB to meet the water quality objectives in the RWQCB Basin Plan. Among the beneficial uses specified in the Basin Plan are commercial and sport fishing, cold freshwater habitat, fish migration, preservation of rare and endangered species, fish spawning, warm freshwater habitat, and wildlife habitat. See AGSP pages 1-28 to 1-29.

2. Are interconnected surface waters identified and are estimates of the quantity and timing of any depletions specified? Yes.

   §354.16f: See AGSP pages 2-76 to 2-79.

   Undesirable Results §354.28c6: See AGSP pages 3-22 to 3-25, which include a description of the potential UR due to depletion of surface water in the Springtown Alkali Sink. Page 3-24 illustrates a minimum threshold to avoid surface water depletion in the Alkali Sink area.

3. Do water budgets include water needs for managed wetlands and native vegetation, as defined water use sectors? No, not as water use sectors.

   §354.18b: The water budget information provided on pages 2-79 through 2-95 seems to meet the intent of Section 354.18b.

4. Do undesirable results (UR) and minimum thresholds describe potential effects on beneficial uses, land uses and property interests, particularly for the chronic lowering of groundwater, degraded water quality and depletions of interconnected surface waters? Yes. Are these UR being avoided? Yes. Has the basin operated sustainably for at least the past 10 years? Yes.

§354.26: See AGSP pages 3-4 through 3-25 for descriptions and discussion of potential UR, minimum thresholds, and sustainability indicators.

§354.28: Minimum thresholds are discussed for potential UR on pages 3-4 through 3-25 of the AGSP.

Presence of UR: The AGSP reports no UR have been observed for several decades (pages 1-30, 2-90, 3-4 through 3-24).

Sustainable operations for more than 10 years, §358.2c3: Yes.

5. Does the sustainability goal include the environment, and if so, does the plan include measurable objectives and interim milestones to achieve the environmental portion of the sustainability goal within 20 years? The environment is included in Zone 7's sustainable management goal indirectly by preventing depletion of surface water supplies (AGSP page 3-1):

   > *The sustainable management goal for this Alternative Plan is to continue to operate the Livermore Valley Groundwater Basin within its sustainable yield and to manage the groundwater resources for the prevention of significant and unreasonable (1) lowering of groundwater levels, (2) reduction in basin storage, (3) degradation of groundwater quality, (4) inelastic land subsidence, or (5) depletion of surface water supplies such that beneficial uses are adversely impacted.* [We assume Zone 7 meant "such that beneficial uses are not adversely impacted".]

   §354.30: AGSP pages 2-37 to 2-48 describe historic and current groundwater levels, and Section 3, *Sustainable Management* Criteria, describes basin management objectives, sustainable management objectives and equivalents of sustainability indicators for the following potential UR: chronic lowering of groundwater levels and reduction of groundwater storage, degraded water quality, land subsidence, and depletion of interconnected surface water.

   A potential UR of ISW depletion would be depletion of surface water in the Alkali Sink and potential adverse effects on the Sink's ecosystem and its species. Pages 3-24 to 3-25 explain the minimum threshold for this potential UR and the monitoring conducted to protect the Alkali Sink. MODFLOW was used to develop a water budget for the sink (page 3-23).

6. Does the monitoring network monitor impacts to beneficial uses? Yes.

   §354.34b2: AGSP Section 4 describes the monitoring objectives and programs intended to track factors affecting the sustainability indicators described in Section 3.

APPENDIX B

DWR CHECKLIST

Table 1. Preparation Checklist for GSP Submittal

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
Article 3. Technical and Reporting Standards				
352.2		Monitoring Protocols	• Monitoring protocols adopted by the GSA for data collection and management • Monitoring protocols that are designed to detect changes in groundwater levels, groundwater quality, inelastic surface subsidence for basins for which subsidence has been identified as a potential problem, and flow and quality of surface water that directly affect groundwater levels or quality or are caused by groundwater extraction in the basin	Appendix G (Monitoring Protocol Appendix)
Article 5. Plan Contents, Subarticle 1. Administrative Information				
354.4		General Information	• Executive Summary • List of references and technical studies	Sections ES and 16
354.6		Agency Information	• GSA mailing address • Organization and management structure • Contact information of Plan Manager • Legal authority of GSA • Estimate of implementation costs	Sections 3.1 to 3.5
354.8(a)	10727.2(a)(4)	Map(s)	• Area covered by GSP • Adjudicated areas, other agencies within the basin, and areas covered by an Alternative • Jurisdictional boundaries of federal or State land • Existing land use designations • Density of wells per square mile	Figure 5-1 to 5-5
354.8(b)		Description of the Plan Area	• Summary of jurisdictional areas and other features	Section 5.1

Table 1. Preparation Checklist for GSP Submittal

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
Article 5. Plan Contents, Subarticle 1. Administrative Information (Continued)				
354.8(c) 354.8(d) 354.8(e)	10727.2(g)	Water Resource Monitoring and Management Programs	• Description of water resources monitoring and management programs • Description of how the monitoring networks of those plans will be incorporated into the GSP • Description of how those plans may limit operational flexibility in the basin • Description of conjunctive use programs	Section 5.2
354.8(f)	10727.2(g)	Land Use Elements or Topic Categories of Applicable General Plans	• Summary of general plans and other land use plans • Description of how implementation of the GSP may change water demands or affect achievement of sustainability and how the GSP addresses those effects • Description of how implementation of the GSP may affect the water supply assumptions of relevant land use plans • Summary of the process for permitting new or replacement wells in the basin • Information regarding the implementation of land use plans outside the basin that could affect the ability of the Agency to achieve sustainable groundwater management	Section 5.3

Table 1. Preparation Checklist for GSP Submittal

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
Article 5. Plan Contents, Subarticle 1. Administrative Information (Continued)				
354.8(g)	10727.4	Additional GSP Contents	**Description of Actions related to:** • Control of saline water intrusion • Wellhead protection • Migration of contaminated groundwater • Well abandonment and well destruction program • Replenishment of groundwater extractions • Conjunctive use and underground storage • Well construction policies • Addressing groundwater contamination cleanup, recharge, diversions to storage, conservation, water recycling, conveyance, and extraction projects • Efficient water management practices • Relationships with State and federal regulatory agencies • Review of land use plans and efforts to coordinate with land use planning agencies to assess activities that potentially create risks to groundwater quality or quantity • Impacts on groundwater dependent ecosystems	Section 5.4
354.10		Notice and Communication	• Description of beneficial uses and users • List of public meetings • GSP comments and responses • Decision-making process • Public engagement • Encouraging active involvement • Informing the public on GSP implementation progress	Section 5.5
Article 5. Plan Contents, Subarticle 2. Basin Setting				
354.14		Hydrogeologic Conceptual Model	• Description of the Hydrogeologic Conceptual Model • Two scaled cross-sections • Map(s) of physical characteristics: topographic information, surficial geology, soil characteristics, surface water bodies, source and point of delivery for imported water supplies	Sections 7.1 to 7.7, Figures 7-1 to 7-3, 7-8 to 7-10, 7-13 to 7-15

Table 1. Preparation Checklist for GSP Submittal

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
Article 5. Plan Contents, Subarticle 2. Basin Setting (Continued)				
354.14(c)(4)	10727.2(a)(5)	Map of Recharge Areas	• Map delineating existing recharge areas that substantially contribute to the replenishment of the basin, potential recharge areas, and discharge areas	Figure 7-16
	10727.2(d)(4)	Recharge Areas	• Description of how recharge areas identified in the plan substantially contribute to the replenishment of the basin	Section 7.7.4.1
354.16	10727.2(a)(1) 10727.2(a)(2)	Current and Historical Groundwater Conditions	• Groundwater elevation data • Estimate of groundwater storage • Seawater intrusion conditions • Groundwater quality issues • Land subsidence conditions • Identification of interconnected surface water systems • Identification of groundwater-dependent ecosystems	Sections 8.3 to 8.9
354.18	10727.2(a)(3)	Water Budget Information	• Description of inflows, outflows, and change in storage • Quantification of overdraft • Estimate of sustainable yield • Quantification of current, historical, and projected water budgets	Sections 9.1 to 9.4
	10727.2(d)(5)	Surface Water Supply	• Description of surface water supply used or available for use for groundwater recharge or in-lieu use	Section 7.7.6, 9.2.1
354.20		Management Areas	• Reason for creation of each management area • Minimum thresholds and measurable objectives for each management area • Level of monitoring and analysis • Explanation of how management of management areas will not cause undesirable results outside the management area • Description of management areas	Sections 10, 13, 14.2

Table 1. Preparation Checklist for GSP Submittal

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
Article 5. Plan Contents, Subarticle 3. Sustainable Management Criteria				
354.24		Sustainability Goal	• Description of the sustainability goal	Section 12
354.26		Undesirable Results	• Description of undesirable results • Cause of groundwater conditions that would lead to undesirable results • Criteria used to define undesirable results for each sustainability indicator • Potential effects of undesirable results on beneficial uses and users of groundwater	Sections 13.1.1, 13.2.1, 13.3.1, 13.4.1, 13.5.1, 13.6.1
354.28	10727.2(d)(1) 10727.2(d)(2)	Minimum Thresholds	• Description of each minimum threshold and how they were established for each sustainability indicator • Relationship for each sustainability indicator • Description of how selection of the minimum threshold may affect beneficial uses and users of groundwater • Standards related to sustainability indicators • How each minimum threshold will be quantitatively measured	Sections 13.1.2, 13.2.2, 13.3.2, 13.4.2, 13.5.2, 13.6.2
354.30	10727.2(b)(1) 10727.2(b)(2) 10727.2(d)(1) 10727.2(d)(2)	Measureable Objectives	• Description of establishment of the measureable objectives for each sustainability indicator • Description of how a reasonable margin of safety was established for each measureable objective • Description of a reasonable path to achieve and maintain the sustainability goal, including a description of interim milestones	Sections 13.1.3, 13.2.3, 13.3.3, 13.4.3, 13.5.3, 13.6.3

Table 1. Preparation Checklist for GSP Submittal

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
Article 5. Plan Contents, Subarticle 4. Monitoring Networks				
354.34	10727.2(d)(1) 10727.2(d)(2) 10727.2(e) 10727.2(f)	Monitoring Networks	• Description of monitoring network • Description of monitoring network objectives • Description of how the monitoring network is designed to: demonstrate groundwater occurrence, flow directions, and hydraulic gradients between principal aquifers and surface water features; estimate the change in annual groundwater in storage; monitor seawater intrusion; determine groundwater quality trends; identify the rate and extent of land subsidence; and calculate depletions of surface water caused by groundwater extractions • Description of how the monitoring network provides adequate coverage of Sustainability Indicators • Density of monitoring sites and frequency of measurements required to demonstrate short-term, seasonal, and long-term trends • Scientific rational (or reason) for site selection • Consistency with data and reporting standards • Corresponding sustainability indicator, minimum threshold, measureable objective, and interim milestone	Section 14
			(Monitoring Networks Continued) • Location and type of each monitoring site within the basin displayed on a map, and reported in tabular format, including information regarding the monitoring site type, frequency of measurement, and the purposes for which the monitoring site is being used • Description of technical standards, data collection methods, and other procedures or protocols to ensure comparable data and methodologies	Figures 14-1 to 14-4, tables 14-A, 14-1, 14-3, 14-4, 14-6 Appendix G (Monitoring Protocol Appendix)

Table 1. Preparation Checklist for GSP Submittal

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
Article 5. Plan Contents, Subarticle 4. Monitoring Networks (Continued)				
354.36		Representative Monitoring	• Description of representative sites • Demonstration of adequacy of using groundwater elevations as proxy for other sustainability indicators • Adequate evidence demonstrating site reflects general conditions in the area	Section 14.4
354.38		Assessment and Improvement of Monitoring Network	• Review and evaluation of the monitoring network • Identification and description of data gaps • Description of steps to fill data gaps • Description of monitoring frequency and density of sites	Section 14.5
Article 5. Plan Contents, Subarticle 5. Projects and Management Actions				
354.44		Projects and Management Actions	• Description of projects and management actions that will help achieve the basin's sustainability goal • Measureable objective that is expected to benefit from each project and management action • Circumstances for implementation • Public noticing • Permitting and regulatory process • Time-table for initiation and completion, and the accrual of expected benefits • Expected benefits and how they will be evaluated • How the project or management action will be accomplished. If the projects or management actions rely on water from outside the jurisdiction of the Agency, an explanation of the source and reliability of that water shall be included. • Legal authority required • Estimated costs and plans to meet those costs • Management of groundwater extractions and recharge	Sections 15.2 to 15.12
354.44(b)(2)	10727.2(d)(3)		• Overdraft mitigation projects and management actions	Section 15.5

Table 1. Preparation Checklist for GSP Submittal

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
Article 8. Interagency Agreements				
357.4	10727.6	Coordination Agreements - Shall be submitted to the Department together with the GSPs for the basin and, if approved, shall become part of the GSP for each participating Agency.	**Coordination Agreements shall describe the following:** • A point of contact • Responsibilities of each Agency • Procedures for the timely exchange of information between Agencies • Procedures for resolving conflicts between Agencies • How the Agencies have used the same data and methodologies to coordinate GSPs • How the GSPs implemented together satisfy the requirements of SGMA • Process for submitting all Plans, Plan amendments, supporting information, all monitoring data and other pertinent information, along with annual reports and periodic evaluations • A coordinated data management system for the basin • Coordination agreements shall identify adjudicated areas within the basin, and any local agencies that have adopted an Alternative that has been accepted by the Department	Sections 3.1 to 3.4, 5.1, 5.5.5, 5.5.6, 14.6
Article 7. Annual Reports and Periodic Evaluations by the Agency				
356.4	10727.2, 10728, 10728.2, 10733.2, and 10733.8	Periodic Evaluations by the Agency	Each Agency shall evaluate its Plan at least every five years and whenever the Plan is amended, and provide a written assessment to the Department. The assessment shall describe whether the Plan implementation, including implementation of projects and management actions, are meeting the sustainability goal in the basin, and shall include the following: (a) A description of current groundwater conditions for each applicable sustainability indicator relative to measurable objectives, interim milestones and minimum thresholds.	Sections 8.3 to 8.9
356.4	10727.2, 10728, 10728.2, 10733.2, and 10733.8	Periodic Evaluations by the Agency	(b) A description of the implementation of any projects or management actions, and the effect on groundwater conditions resulting from those projects or management actions.	Section 15.2

Table 1. Preparation Checklist for GSP Submittal

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
Article 7. Annual Reports and Periodic Evaluations by the Agency (Continued)				
356.4	10727.2, 10728, 10728.2, 10733.2, and 10733.8	Periodic Evaluations by the Agency	(c) Elements of the Plan, including the basin setting, management areas, or the identification of undesirable results and the setting of minimum thresholds and measurable objectives, shall be reconsidered and revisions proposed, if necessary.	Section 11
356.4	10727.2, 10728, 10728.2, 10733.2, and 10733.8	Periodic Evaluations by the Agency	(d) An evaluation of the basin setting in light of significant new information or changes in water use, and an explanation of any significant changes. If the Agency's evaluation shows that the basin is experiencing overdraft conditions, the Agency shall include an assessment of measures to mitigate that overdraft.	Sections 8.1 to 8.9
356.4	10727.2, 10728, 10728.2, 10733.2, and 10733.8	Periodic Evaluations by the Agency	(e) A description of the monitoring network within the basin, including whether data gaps exist, or any areas within the basin are represented by data that does not satisfy the requirements of Sections 352.4 and 354.34(c). The description shall include the following: (1) An assessment of monitoring network function with an analysis of data collected to date, identification of data gaps, and the actions necessary to improve the monitoring network, consistent with the requirements of Section 354.38. (2) If the Agency identifies data gaps, the Plan shall describe a program for the acquisition of additional data sources, including an estimate of the timing of that acquisition, and for incorporation of newly obtained information into the Plan. (3) The Plan shall prioritize the installation of new data collection facilities and analysis of new data based on the needs of the basin.	Section 14.2

Table 1. Preparation Checklist for GSP Submittal

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
Article 7. Annual Reports and Periodic Evaluations by the Agency (Continued)				
356.4	10727.2, 10728, 10728.2, 10733.2, and 10733.8	Periodic Evaluations by the Agency	(f) A description of significant new information that has been made available since Plan adoption or amendment, or the last five-year assessment. The description shall also include whether new information warrants changes to any aspect of the Plan, including theevaluation of the basin setting, measurable objectives, minimum thresholds, or the criteria defining undesirable results.	Section 1.2
356.4	10727.2, 10728, 10728.2, 10733.2, and 10733.8	Periodic Evaluations by the Agency	(g) A description of relevant actions taken by the Agency, including a summary of regulations or ordinances related to the Plan.	Section 15, 15.2
356.4	10727.2, 10728, 10728.2, 10733.2, and 10733.8	Periodic Evaluations by the Agency	(h) Information describing any enforcement or legal actions taken by the Agency in furtherance of the sustainability goal for the basin.	Section 15, 15.2
356.4	10727.2, 10728, 10728.2, 10733.2, and 10733.8	Periodic Evaluations by the Agency	(i) A description of completed or proposed Plan amendments.	Section 1.2
356.4	10727.2, 10728, 10728.2, 10733.2, and 10733.8	Periodic Evaluations by the Agency	(j) Where appropriate, a summary of coordination that occurred between multiple Agencies in a single basin, Agencies in hydrologically connected basins, and land use agencies.	Sections 3.2, 5.5.5, 5.5.6, 13.4.4.1
356.4	10727.2, 10728, 10728.2, 10733.2, and 10733.8	Periodic Evaluations by the Agency	(k) Other information the Agency deems appropriate, along with any information required by the Department to conduct a periodic review as required by Water Code Section 10733.	N/A

APPENDIX C

GEOLOGIC CROSS-SECTIONS
TECHNICAL MEMORANDUM

14 October 2021

TECHNICAL MEMORANDUM

To: Tom Rooze (Zone 7 Water Agency [Zone 7])
Colleen Winey (Zone 7)
Carol Mahoney (Zone 7)

From: Anona Dutton, PG, CHg (EKI Environment & Water, Inc. [EKI])
Aaron Lewis (EKI)
Susan Xie, EIT (EKI)

Subject: **Draft Geologic Cross-Sections for 2022 Alternative Groundwater Sustainability Plan** (EKI C00065.00)

EKI Environment & Water, Inc. (EKI) is pleased to provide to Zone 7 Water Agency (Zone 7) a revised draft technical memorandum presenting three geologic cross-sections of the Livermore Valley Groundwater Basin (Basin) and accompanying written descriptions. Pursuant to our approved scope of work, EKI's work efforts include application of 3D geologic modeling software to develop three cross-sections for the Basin. A final version of these cross-sections and accompanying descriptions is anticipated to be included in the Basin Setting section of the 2022 Alternative Groundwater Sustainability Plan (Alt GSP).

BACKGROUND

Pursuant to Title 23, Section 358.2(a) of the California Code of Regulations (23-CCR §358.2(a)), Groundwater Sustainability Agencies (GSAs) with an approved Alternative Groundwater Sustainability Plan (Alt GSP or Plan) must resubmit an updated Plan to the California Department of Water Resources (DWR) every five years. As part of the five-year update process to the 2016 Alt GSP, Zone 7 contracted EKI to extend the existing Hydrogeologic Conceptual Model (HCM) framework to encompass the entirety of the Basin and to subsequently develop three geologic cross-sections of the Basin for subsequent inclusion in the 2022 Alt GSP. The cross-section locations are shown on Figure 1. A map of the surficial geology, major fault structures, and streams that were incorporated into the cross-sections are shown on Figure 2.

As described in EKI's *Progress Update on Extending Existing Hydrogeologic Framework* (dated 02 April 2021), the RockWorks[1] three-dimensional (3D) geologic modeling software platform was selected by Zone 7 to support data integration, HCM representation, and cross-section development. EKI has further refined the 3D geologic model in Rockworks and imported draft cross-section outputs into the AutoCAD[2] software program to assist in developing cross-section figures for inclusion in the 2022 Alt GSP. Two

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[1] RockWorks 2020 Standard Level License from RockWare is downloaded and installed on 15 October 2020: https://www.rockware.com/product/rockworks/

[2] https://www.autodesk.com/products/autocad/overview?term=1-YEAR&support=null

versions of the geologic cross-sections are included in this technical memorandum. The first version includes all nearby borehole lithology and geophysical data used to inform cross-section development (see Figures 3a, 4a and 5a). The second version presents the total depth and screen intervals of Zone 7's nearby municipal and SGMA monitoring wells and labels the principal surface water features encountered along each trace (see Figures 3b, 4b, and 5b). Accompanying each cross-section is a written description documenting the principal geologic features, as well as the assumptions and references used to inform cross-section development. Also provided is a simplified schematic of the conceptual hydrostratigraphic model of the Basin which maps major stratigraphic facies to corresponding Principal Aquifer units defined for each Management Area in the Alternative GSP (see Figure 6).

GEOLOGIC CROSS-SECTION A-A'

Cross-Section A-A' depicts a generally west-to-east trace through the Basin (see Figures 3a and 3b). The trace begins just west of the southwestern Basin boundary near the Calaveras Fault deformation zone and progresses eastward through the Main Basin (including the Castle, Bernal, Amador, and Mocho II subareas), where a majority of groundwater production occurs in the Basin. The trace cuts directly through a narrow corridor of alluvium connecting the Mocho II and Mocho I subareas (an area commonly referred to as "The Gap") and continues through the southern portion of the Eastern Fringe Area (including the Mocho I and Spring subareas) before terminating in the Upland Area just west of the Greenville Fault deformation zone.

After crossing the main deformation zone of the Calaveras Fault and entering the Basin, Cross-Section A-A' cuts through the Castle subarea, which consists of "uplands underlain by the Livermore Formation and… adjacent valley fill material" (*DWR, 1974*). Here, the Upper Aquifer is comprised of Holocene alluvial deposits ranging from approximately 50 to 75 ft thick. Most of the wells in the Castle Subarea draw from the upper 100 to 200 ft of Plio-Pleistocene Livermore Formation, which is present "as a sequence of gravel, sand, and silt interlayered by clay" (*DWR, 1974*). This productive upper zone of the Livermore Formation (herein referred to as the "Upper Livermore Formation") comprises the Lower Aquifer in the area. "All of these materials apparently slope toward the valley at dips ranging up to ten degrees" (*DWR, 1974*).

Cross-Section A-A' subsequently passes over another presumed splay of the Calaveras Fault and enters the Bernal subarea, which acts as the point of convergence for all major streams and subsurface flows that eventually drain the Basin via the Arroyo de La Laguna. Here, a confining surficial clay unit exists reaching up to 70 ft thickness (herein referred to as the "Overburden"). Beneath the Overburden is the Upper Aquifer, which is comprised of a 50 to >100-ft sequence of unconsolidated, Holocene sandy gravel and silty/clayey gravel deposits. Beneath the Upper Aquifer is a laterally extensive lacustrine clay and silt unit of up to 50 ft thick (herein referred to as the "Aquitard"). Below the Aquitard is a thicker sequence of braided fluvial and deltaic "clean gravel" and sand deposits interbedded with fluvial overbank and floodplain clays and silts (*Norfleet Consultants, 2004*). These Quaternary (Pleistocene-Holocene) deposits are believed to represent a "structurally influenced, incised channel complex" deposited by the ancestral Arroyo Mocho stream (*Norfleet Consultants, 2004*) and are encountered up to >400 ft bgs in the area (*DWR, 1974*). Underlying the Quaternary fluvial and alluvial deposits is the Upper Livermore Formation, for which up to 200 ft is considered productive due to sufficient weathering and permeability relative to the more consolidated zones of the Lower Livermore Formation. The combined sequence of Quaternary alluvial/fluvial deposits and the Upper Livermore Formation are known collectively as the Lower Aquifer in the Main Basin. Well production (primarily by Zone 7 and the City of Pleasanton) in this subarea ranges up to 3,500 gpm and specific capacities range from 3 to 260 gpm per foot of drawdown.

The trace subsequently crosses into the Amador subarea, whereby a majority of groundwater production occurs in the Basin. The Overburden is present in the western half of the Amador subarea, extending east approximately to the Chain of Lakes (COL) mining area, creating semi-confined conditions in the Upper Aquifer where it is present. Beneath the Overburden are Holocene alluvial deposits of the Upper Aquifer, which reach depths of up to 190 ft bgs in the subarea (and approximately 150 ft underlying Cross-Section A-A'). Here, the Upper Aquifer is consistent with the "Cyan" stratigraphic sequence defined in the Norfleet (2004) and Zone 7 (2011) hydrostratigraphy studies. The Aquitard is present below the Upper Aquifer at a thickness of up to 50 ft under the COL area, before gradually thinning to the east. This unit is consistent with the "Grey Clay" sequence defined in the Norfleet (2004) and Zone 7 (2011) studies and serves to create semi-confined to confined conditions in the underlying Lower Aquifer. As in the Bernal Subarea, Lower Aquifer units in the western portion of the Amador subarea are comprised of up to 400 ft of interbedded, Quaternary alluvial/fluvial deposits (consistent with the "Grey" and "Purple" sequences from Norfleet (2004) and Zone 7 (2011)), underlain by 200-300 ft of productive Upper Livermore deposits (consistent with the "Red" sequence in Norfleet (2004) and Zone 7 (2011)). The Basin reaches a maximum depth of >800 ft in the central Amador subarea near the COL mining pits. Well production (primarily by Zone 7 and the City of Pleasanton) in this subarea ranges from 42 to 2,820 gpm and specific capacities range from 1.1 to 217 gpm per foot of drawdown.

Moving further east through the Amador Subarea, Cross-Section A-A' eventually reaches the Livermore Thrust fault zone, which presents a significant unconformity that serves to restrict groundwater flow from the Mocho II subarea to the Amador subarea. According to Norfleet (2004):

> *"The Livermore Thrust ha[s] a westward motion and dip[s] at a high angle to the east. [It] dies out rapidly to the north and do[es] not extend all the way across the current Livermore Valley. Evidence for the Livermore fault was discussed in Thomas et al. (1959) and DWR (1963, 1966, and 1974). The fault has historically been considered to be a strike-slip fault, but the data are more consistent with an east dipping, west-moving thrust fault. The Livermore thrust cut and uplifted Livermore Gravels, suggesting that the fault developed after deposition of the classical Livermore Gravels." (Norfleet, 2004)*

Several varying interpretations exist in the literature regarding the nature and extent of this fault and the degree to which it impedes groundwater flow. In their Bulletin-118 description of the Basin, DWR notes:

> *"The Livermore [Thrust] is an effective barrier to ground water inflow from the Mocho subbasin except in the vicinity of the ancestral channel of Arroyo Mocho north of Oak Knoll, where ground water moves across this fault essentially unimpeded" (DWR, 1974).*

Cross-Section A-A' traces north of Oak Knoll, within the ancestral Arroyo Mocho paleochannel. However, based on nearby water level observations collected in Fall 2019, an apparent 80-foot drop in groundwater elevation is observed in the Lower Aquifer moving westward across the fault, indicating that some degree of hydraulic restriction occurs across the fault zone in this area. Notably, this groundwater flow barrier across the fault is not observed in the Upper Aquifer.

The total depths of wells in the Mocho II subarea east of the Livermore Thrust suggest that the base of the Lower Aquifer (i.e., the bottom of the productive Upper Livermore Formation) is encountered 200-300 ft higher in this subarea than in the Amador subarea west of the fault, indicating a significant discontinuity likely exists in the Lower Aquifer formations even within the incised ancestral Arroyo Mocho channel complex resulting from uplift on the eastern side of the fault. A relatively lower proportion of “clean gravels” is also observed east of the Livermore Thrust, resulting in lower productivity of the Lower Aquifer in the Mocho II subarea (*Norfleet Consultants, 2004*). Upper Aquifer deposits progressively thin to around 50 ft thickness moving east through Mocho II subarea. The Aquitard and underlying Quaternary deposits gradually diminish as the trace moves further east outside the ancestral Arroyo Mocho paleochannel, and eventually disappear before reaching the Mocho II – Mocho I boundary such that Pleistocene-Holocene alluvial deposits are directly underlain by deposits of the Upper Livermore Formation.

Another apparent steepening of the hydraulic gradient in the Lower Aquifer is observed west of the Mocho II/Mocho I boundary as deposits of the Upper Livermore Formation continue to reduce to a total depth of approximately 330 ft bgs at well 3S2E10Q002. A short distance to the east, a narrow, roughly 50-ft thick sequence of young alluvial deposits of the Arroyo Seco channel underlain by older, interbedded sand and gravel deposits of the Upper Livermore Formation connects the Main Basin to the Eastern Fringe Area in an alluvial channel known colloquially as “The Gap”. The Gap is surrounded by outcrops of the relatively impermeable Lower Livermore Formation to the north and south, also known as Livermore Uplands. These outcrops are connected by way of a buried ridge of Lower Livermore Formation within the Gap that serves to restrict the vertical cross-sectional area of connection between Upper and Lower Aquifer deposits in the Eastern Fringe Area and the Main Basin to the west (*DWR 1974, LLNL 1984*). There is considerable uncertainty to the degree which flow is restricted across The Gap, though Fall 2019 water level trends suggests this area acts as an apparent groundwater divide in both the Upper and Lower Aquifers.

As the trace of Cross-Section A-A’ moves across The Gap and into the Mocho I subarea of the Fringe Area, Upper Livermore deposits again deepen to a total depth around 350 ft bgs at well 3S2E11R046 near the southwestern corner of the Lawrence Livermore National Laboratory (LLNL). A local depression in Fall 2019 groundwater elevations was observed in the Fringe Aquifer in this area, likely due to groundwater pumping. These deposits then begin to dip upward to the northeast as the trace moves into the Spring subarea, reducing to a total depth of 175 ft bgs at well 3S2E12J025 on the southeastern side of LLNL (*LLNL, 1984*). Here, the Upper Livermore deposits are described as a series of “beds of cemented gravel, sandy gravel, and sandy clay separated by beds of less-permeable clay and silty clay” (*DWR, 1974*). Overlying Pleistocene-Holocene valley-fill materials in this area “are of similar composition to the sediments of the Livermore Formation, as they are composed principally of reworked Livermore Formation detritus” (*DWR, 1974*). Both the valley fill and underlying Livermore deposits continue to dip upward to the northeast before reaching the Las Positas Fault, which likely serves to truncate the Fringe Aquifer completely. The trace then briefly crosses into the Upland Area, where the Lower Livermore Formation is the dominant outcropping unit and no significant groundwater production occurs, before ending at the southeastern Basin Boundary near the Greenville Fault zone.

GEOLOGIC CROSS-SECTION B-B'

Cross-Section B-B' depicts a generally northwest-to-southeast trace through the western portion of the Basin (see Figures 4a and 4b). The trace begins at the northwestern Basin boundary with the neighboring San Ramon Valley Groundwater Basin to the north. It runs southeast through the Northern Fringe Area (including the Bishop, Dublin, and Camp subareas) before entering the Main Basin. Cross-Section B-B' then passes through a large section of the west-central Main Basin (Amador subarea) and continues southeast up the Arroyo del Valle stream corridor before terminating at the contact between the Amador subarea and the Southern Upland Area near the southern Basin boundary.

The trace begins in the Bishop subarea of the Northern Fringe Area, which contains "one of the deepest developed prisms of water-bearing materials in the Basin…[with] sediments up to 800 feet in depth" (*DWR, 1974*). Surficial deposits are consistent with Holocene alluvial and fluvial sands and gravels, underlain by a thick sequence of relatively fine-grained deposits of the Pleistocene to Plio-Pleistocene Tassajara Formation. These contain "eight to ten separate zones of sand and gravel separated by zones of silt and clay" (*DWR, 1974*). It is assumed that "the greater portion of the sediments below a depth of 100 feet are part of the Tassajara Formation" (*DWR, 1974*). The Fringe Aquifer is defined as the collective sequence of surficial Holocene alluvial deposits and the thicker underlying sequence of permeable Tassajara Formation deposits (herein referred to as the "Upper Tassajara Formation"). Groundwater production is relatively minimal in this subarea and thus few borehole lithologic and e-log data are available to more accurately delineate individual aquifer zones within the Upper Tassajara Formation.

Moving further to the southeast, Cross-Section B-B' enters the Dublin subarea of the Northern Fringe Area. Here, deposits are very similar to those encountered in the Bishop subarea, containing an "essentially flat-lying" sequence of sediments with a "maximum depth of…about 800 feet" (*DWR, 1974*). "Valley-fill materials lap northward onto older sediments of the Tassajara Formation", though the depth at which the Tassajara Formation meets younger Holocene alluvial deposits is not well understood in the area (*DWR, 1974*). Based on available borehole lithology and e-log data, it appears the surficial clay layer (i.e., Overburden) encountered in the Main Basin as well as a laterally extensive clay layer (i.e., Aquitard) underlying the Holocene alluvium are encountered in the southern portion of the Dublin subarea.

After passing through the Dublin subarea, the trace makes a brief east-southeasterly turn and cuts through a small portion of the Camp subarea of the Northern Fringe Area before moving southeast and entering the Main Basin (Amador subarea). The Camp subarea is similar in composition to the Dublin and Bishop subareas to the northwest, containing "beds of sandy clay and sandy gravel which overly the Tassajara Formation" (*DWR 1974*).

The Camp subarea is delineated from the Amador subarea of the Main Basin by an observed groundwater flow barrier described as the "Parks Boundary" (*Norfleet Consultants, 2004*). The Parks Boundary was originally inferred as a fault in DWR's Bulletin-118 hydrostratigraphy summary based on significant variations in groundwater elevations between the Dublin/Camp subareas of the Northern Fringe Area and the Bernal/Amador subareas of the Main Basin (*DWR, 1974*). However, updated interpretations provided in the Norfleet (2004) hydrostratigraphy study suggest that the Parks Boundary represents a buried valley wall delineating the northern extent of the "structurally influenced, incised-channel complex" deposited by the ancestral Arroyo Mocho stream (*Norfleet Consultants, 2004*). While the Holocene alluvial deposits of the Upper Aquifer and the underlying Aquitard appear to be generally consistent across the Parks

Boundary, deposits in the Lower Aquifer south of the boundary consist of a thicker sequence of braided fluvial and deltaic "clean gravel" and sand deposits interbedded with fluvial overbank and floodplain clays and silts (*Norfleet Consultants, 2004*). These are underlain by the Upper Livermore Formation, as opposed to the Tassajara Formation north of the boundary. Based on nearby water level observations collected in Fall 2019, an apparent 30 to 40-foot drop in groundwater elevation is observed in the Lower Aquifer moving south across the Parks Boundary. Lower Aquifer deposits south of the Parks Boundary are known to be more productive than those north of the boundary, thus marking the southern edge of the Northern Fringe Area and the northern edge of the Main Basin.

As Cross-Section B-B' moves southwards across the Parks Boundary and into the Main Basin, the Quaternary alluvial/fluvial deposits of the ancestral Arroyo Mocho paleochannel are encountered at depths up to 500 ft bgs. As mentioned above, these are underlain by deposits of the Upper Livermore Formation, which reach >200 ft thickness in the west-central portion of the Amador Subarea. Holocene alluvial deposits comprising the Upper Aquifer reach a maximum thickness of approximately 150 ft underlying the southern COL mining area within the subarea. Here, the Upper Aquifer is generally consistent with the "Cyan" stratigraphic sequence defined in the Norfleet (2004) and Zone 7 (2011) hydrostratigraphy studies, while the Aquitard comprises the "Grey Clay" sequence and the interbedded sequence of Quaternary alluvial/fluvial deposits comprise the "Grey" and "Purple" sequences. Deposits of the Upper Livermore Formation are generally consistent with the "Red" sequence mapped in the Norfleet (2004) and Zone 7 (2011) studies.

Moving southeast through the Amador Subarea, deposits from the incised channel-complex are found roughly up to Concannon Road, where another water level lineation has historically been observed. Norfleet (2004) interpreted this area as the southern extent of the ancestral Arroyo Mocho paleochannel, and delineated this feature as the "Concannon Boundary". South of the Concannon Boundary, deposits of the ancestral Arroyo Mocho paleochannel are not readily apparent and permeable deposits of the Upper Livermore Formation appear to directly underly the Upper Aquifer and Aquitard. Groundwater conditions range from "unconfined to confined" in this area, with unconfined groundwater occur[ing] principally near the channel of Arroyo del Valle and in the uppermost aquifer" (*DWR, 1974*).

Moving further southeast up the Arroyo del Valle stream corridor, the Upper Livermore Formation continues to dip upward to the south at an angle of one to three degrees (*DWR, 1974*). "Many of the aquifers merge near the course of Arroyo del Valle, where the combined aquifers are present as a deposit of sandy gravel up to 300 feet in thickness" (*DWR, 1974*). The Las Positas Fault, described as a "high-angle tear fault" that "cut and uplifted Livermore Gravels" south of the fault line (*Norfleet Consultants, 2004*), may act as a disconformity in the Upper Livermore Formation as maximum well depths are roughly 200 ft bgs southeast of the fault line. This may also explain the apparent confinement observed in Fall 2019 Lower Aquifer water levels in the vicinity of the fault. However, the degree to which the Las Positas Fault acts as a hydraulic barrier to groundwater flow is uncertain given the current lack of lithologic and geophysical data proximate to the fault line. Recent alluvial deposits of the Arroyo del Valle stream corridor (i.e., Upper Aquifer) continue to thin with the Upper Livermore Formation (i.e., Lower Aquifer) before pinching out at the contact between the Amador subarea and the Southern Uplands, where the relatively impermeable Lower Livermore Formation begins to outcrop. This terminus in permeable deposits marks the effective southern edge of the Basin within the Arroyo del Valle stream corridor.

GEOLOGIC CROSS-SECTION C-C'

Cross-Section C-C' depicts a generally northwest-to-southeast trace through the eastern portion of the Basin (see Figures 5a and 5b). The trace begins at the northeastern Basin boundary and progresses southeastward through a portion of the Northeastern Fringe Area (May and Spring subareas). The trace then makes a turn to the south and continues through the Northeastern Fringe Area (Spring and Mocho I subareas) before cutting directly through a narrow corridor of alluvium connecting the Mocho I and Mocho II subareas (an area commonly referred to as "The Gap"). The trace then progresses further south through the Main Basin (Mocho II subarea), taking another southeasterly turn and continuing up the Arroyo Mocho stream corridor. It then briefly enters the Southern Upland Area before terminating at the southern Basin boundary.

Cross-Section C-C' begins in the May subarea of the Northeastern Fringe Area, where outcrops of the relatively impermeable Lower Tassajara Formation define the northern edge of the Basin. South of the Basin boundary, "ground water occurs only in limited amounts in a relatively thin veneer of valley-fill materials which overlie a thick section of sediments belonging to the Tassajara Formation" (*DWR, 1974*). Here the Fringe Aquifer is defined as the thin veneer of recent (Holocene) alluvium deposited from smaller streams, which "does not exceed 40 ft" thickness in the May subarea (*DWR, 1974*), directly underlain by the permeable upper deposits of the Plio-Pleistocene Tassajara Formation (herein referred to as the "Upper Tassajara Formation") where a majority of groundwater production occurs in the area. The Upper Tassajara Formation is comprised of "beds of sand and gravel, clay and gravel, clay, and silty clay… which range up to 50 ft in thickness [and] dip southward at an average gradient of ten degrees." (*DWR 1974*). Based on nearby water level observations collected in Fall 2019, it appears water level conditions are semi-confined to confined in within the Upper Tassjara Formation this area.

Cross-Section C-C' further progresses southeastward into the Spring subarea of the Northeastern Fringe Area. Here, surficial deposits are very similar to those encountered in the May subarea, containing a thin veneer of recent alluvium not exceeding 50 ft thickness. Deposits underlying the recent alluvium change in composition to reflect those of the Upper Livermore Formation, though the geometry of the contact between the Tassajara and Livermore Formations is not well understood in this area. Upper Livermore deposits in the Spring subarea are described as a "wedge-shaped sequence" of permeable deposits that increase in depth moving southward (*DWR, 1974*). Upper Livermore deposits continue to deepen as the trace turns south and moves into the Mocho I subarea (LLNL, 1984). The "valley-fill portion of the Mocho I province…consists of a heterogeneous mixture of gravelly fan detritus overlying truncated beds of the Livermore Formation" (*DWR, 1974*).

The base of the Upper Livermore Formation deepens in a southerly direction along the Cross-Section C-C' trace through the Mocho I subarea to approximately 300 ft bgs while the upper surface of the formation stays within approximately 30 ft bgs (*LLNL, 1984*). Northeast of well 3S2E10Q002 the trace crosses through a narrow alluvial channel connecting the Mocho I and Mocho II subareas, known colloquially as "The Gap". The Gap is surrounded by outcrops of the relatively impermeable Lower Livermore Formation to the north and south (i.e., out of the plane of the cross-section), also known as Livermore Uplands. These outcrops are connected by way of a buried ridge of Lower Livermore Formation within The Gap that serves to restrict the vertical cross-sectional area of connection between the recent alluvium and underlying Livermore Formation deposits in the Northeastern Fringe Area and the Main Basin to the southwest (*DWR, 1974; LLNL, 1984*). There is considerable uncertainty in the degree to which flow is restricted across The

Gap, though recent water level trends suggest this area acts as an apparent groundwater divide between the Fringe Aquifer and the Upper and Lower Aquifers of the Main Basin.

After moving across The Gap, Cross-Section C-C' progresses south through the Mocho II subarea of the Main Basin. Here, "the valley-fill materials become separated into identifiable strata consisting of beds of sandy gravel and cemented gravel separated by beds of silt and clay" (*DWR, 1974*). In this area, Cross-Section C-C' encounters a thicker sequence of braided fluvial and deltaic "clean gravel" and sand deposits interbedded with fluvial overbank and floodplain clays and silts known to be deposited by the ancestral Arroyo Mocho paleochannel throughout much of the Main Basin (*Norfleet Consultants, 2004*), consistuting the upper portions of the Lower Aquifer. Based on nearby water level observations collected in Fall 2019, it appears this thicker sequence of Quaternary alluvial/fluvial deposits creates some degree of confinement in the Lower Aquifer in the area.

As the trace turns to the southeast and begins traveling up the Arroyo Mocho stream corridor, Cross-Section C-C' travels over the Las Positas Fault. The Las Positas Fault may present an unconformity in the Upper Livermore Formation, though the degree to which it acts as a hydraulic flow barrier in the Lower Aquifer is not well understood.

As Cross-Section C-C' moves further southeast up the Arroyo Mocho stream corridor, the Quaternary alluvial/fluvial deposits of the ancestral Arroyo Mocho paleochannel pinch out and disappear. Here, the recent alluvial deposits of the Arroyo Mocho are underlain directly by semi-consolidated deposits of the Upper Livermore Formation. These deposits progressively thin moving up the stream corridor until they pinch out at the contact between the Mocho II subarea and the Southern Upland Area. At this point, the relatively impermeable Lower Livermore Formation begins to outcrop, marking the effective southern edge of the Basin in the Arroyo Mocho stream corridor. Cross-Section C-C' further extends a short distance through the Southern Upland Area before reaching the southern Basin boundary.

LIST OF FIGURES

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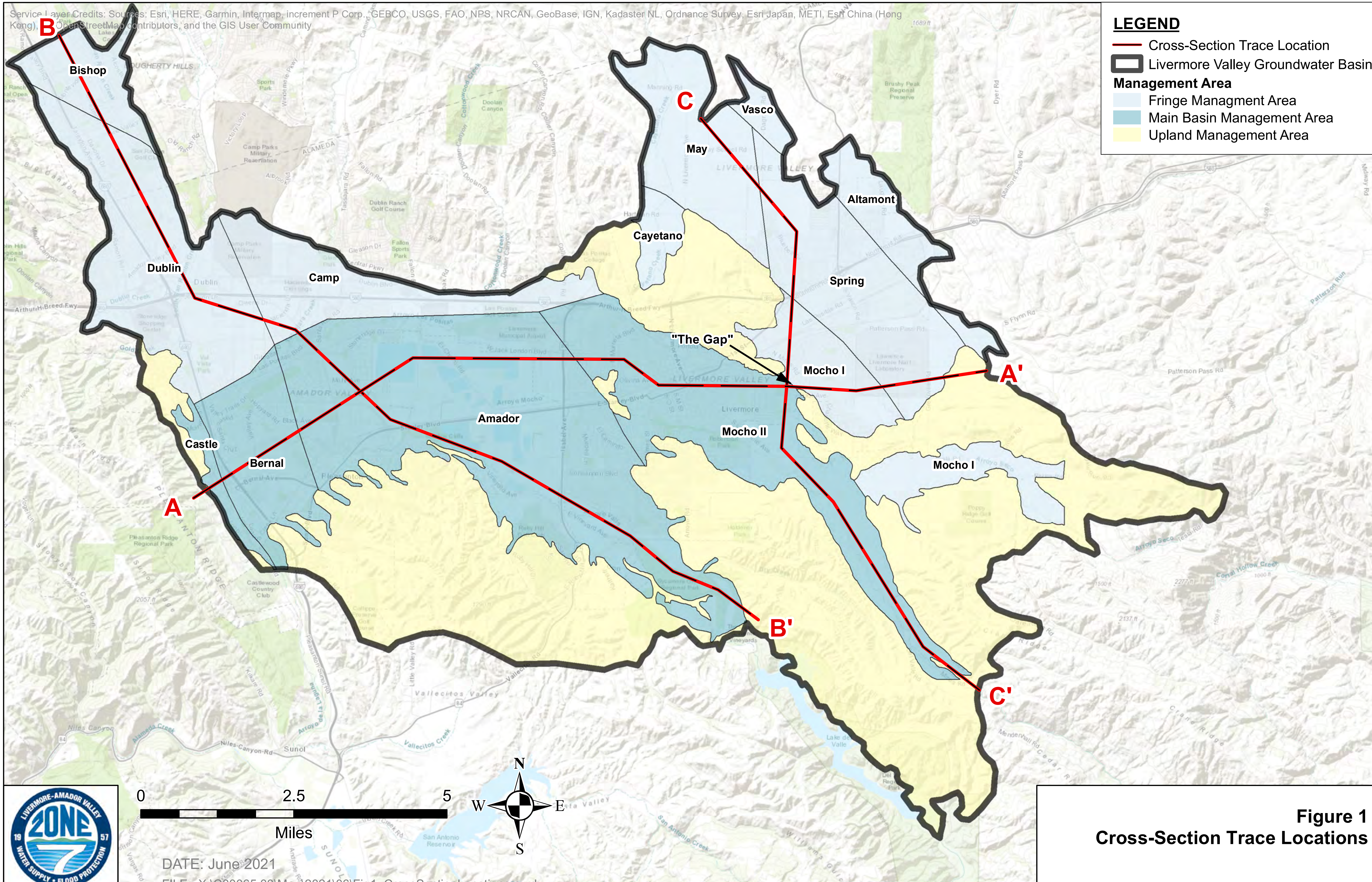


Figure 1
Cross-Section Trace Locations

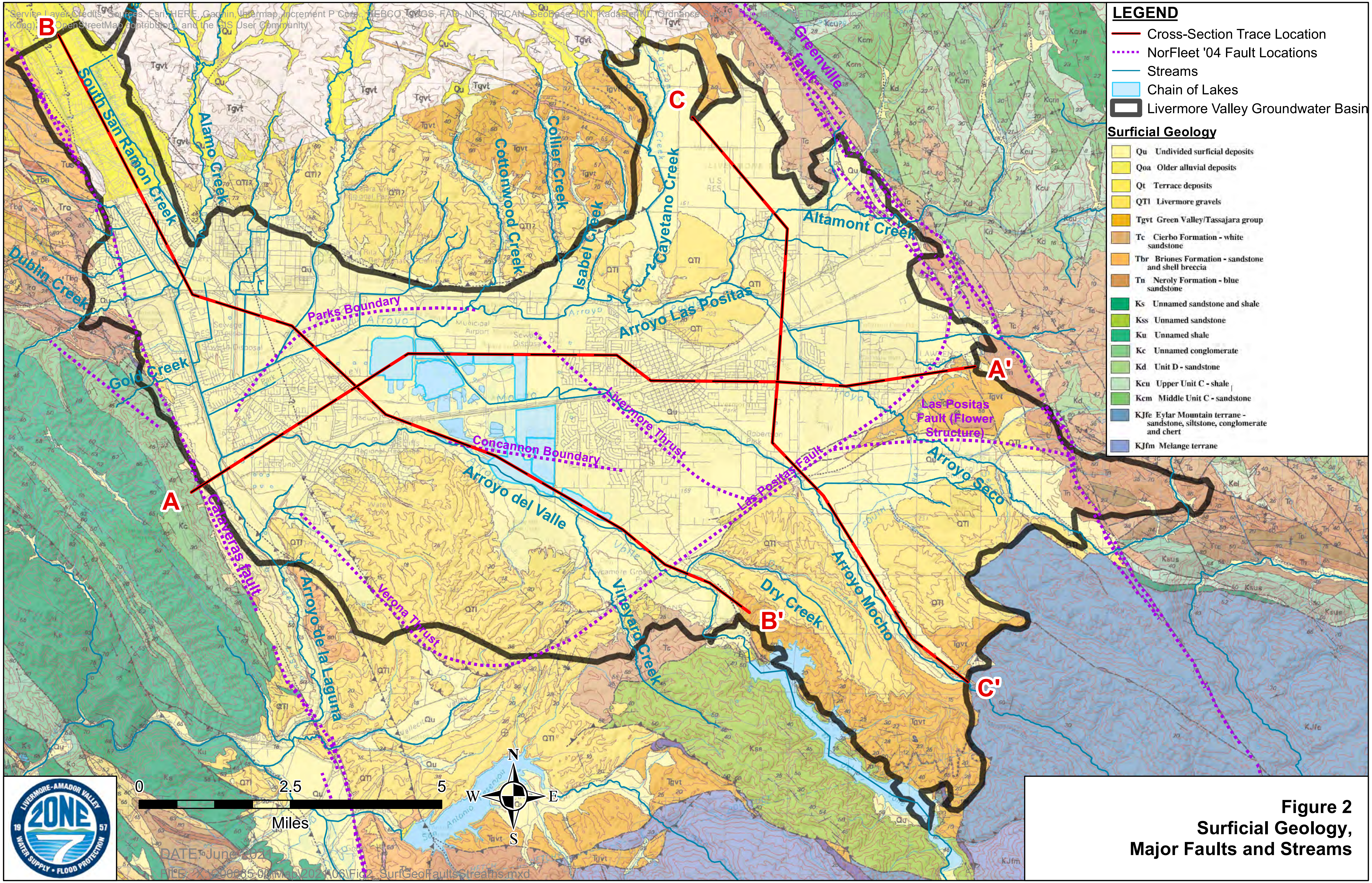
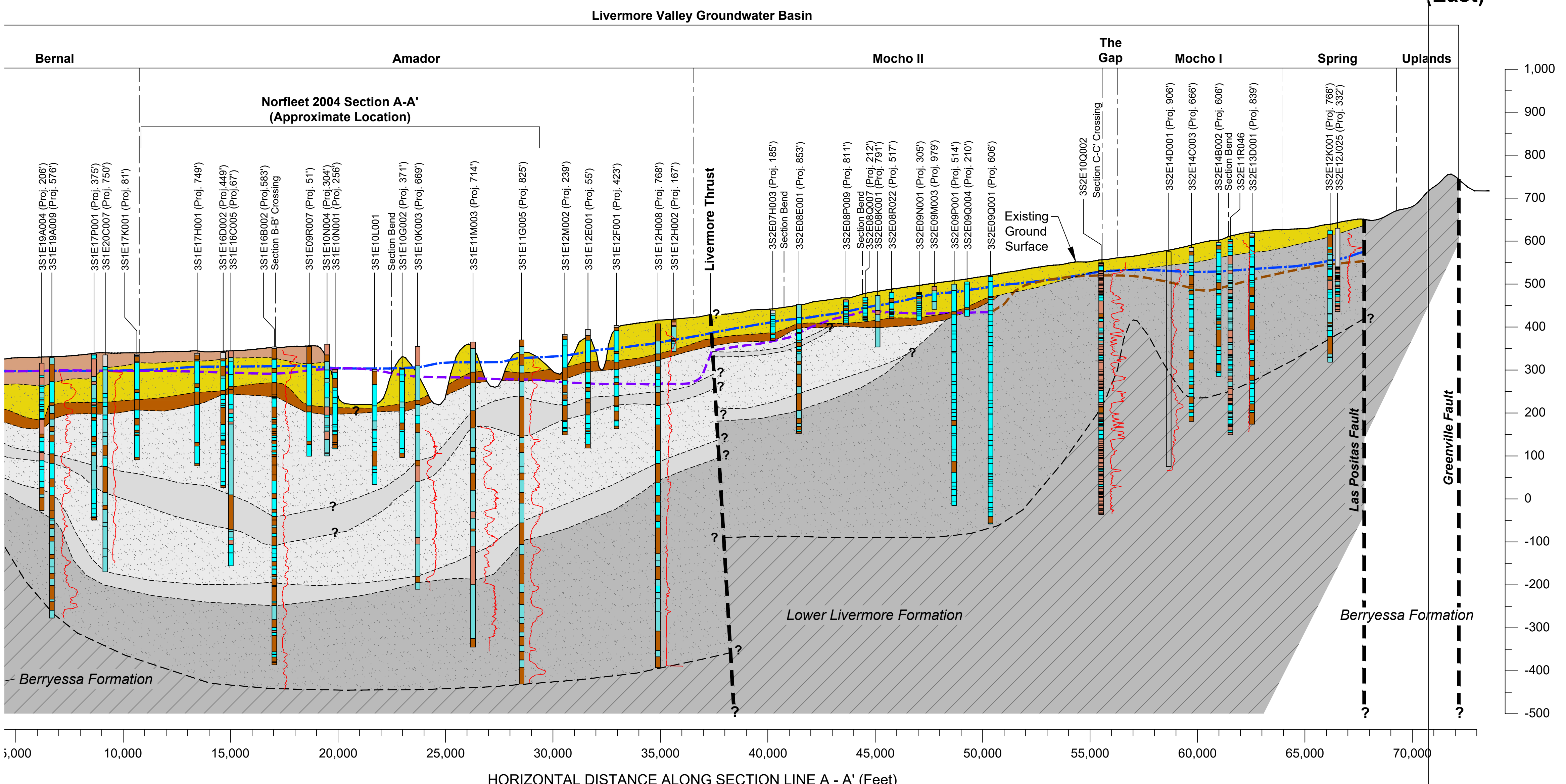
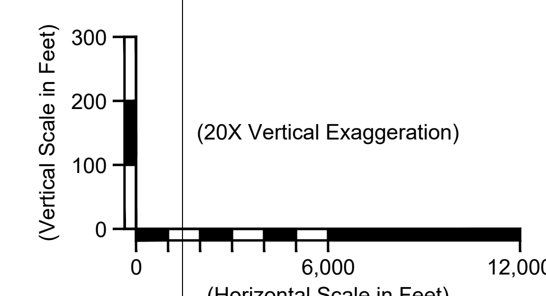


Figure 2
Surficial Geology, Major Faults and Streams

A'
(East)



Cross-Section A - A'



sands)

s)

uifer (Fall 2019)

uifer (Fall 2019)

ermore (Fall 2019)

Lithology

- Topsoil/Fill
- Gravel
- Sand
- Silt
- Clay

Geophysical

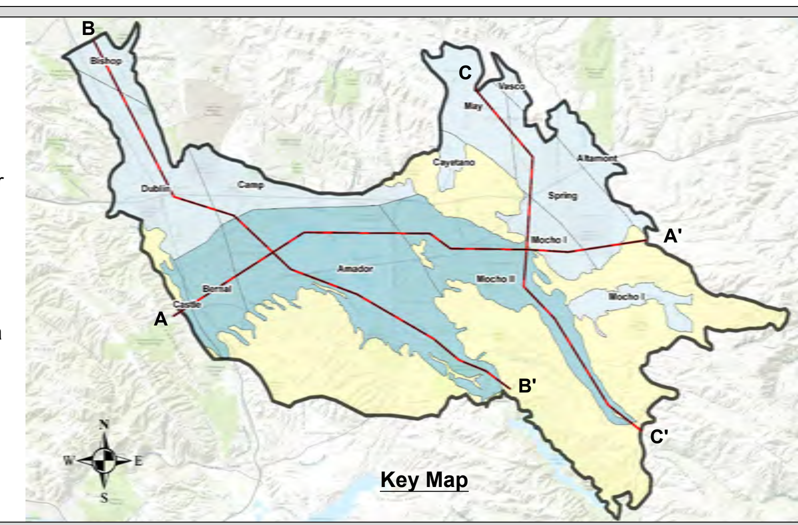
- Long-Normal Resistivity

Map Elements

- A — A' Cross-Section Trace Location
- Livermore Valley Groundwater Basin

Management Area

- Fringe Management Area
- Main Basin Management Area
- Upland Management Area



Key Map

Geologic Cross-Section A - A'

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Livermore, CA
October 2021
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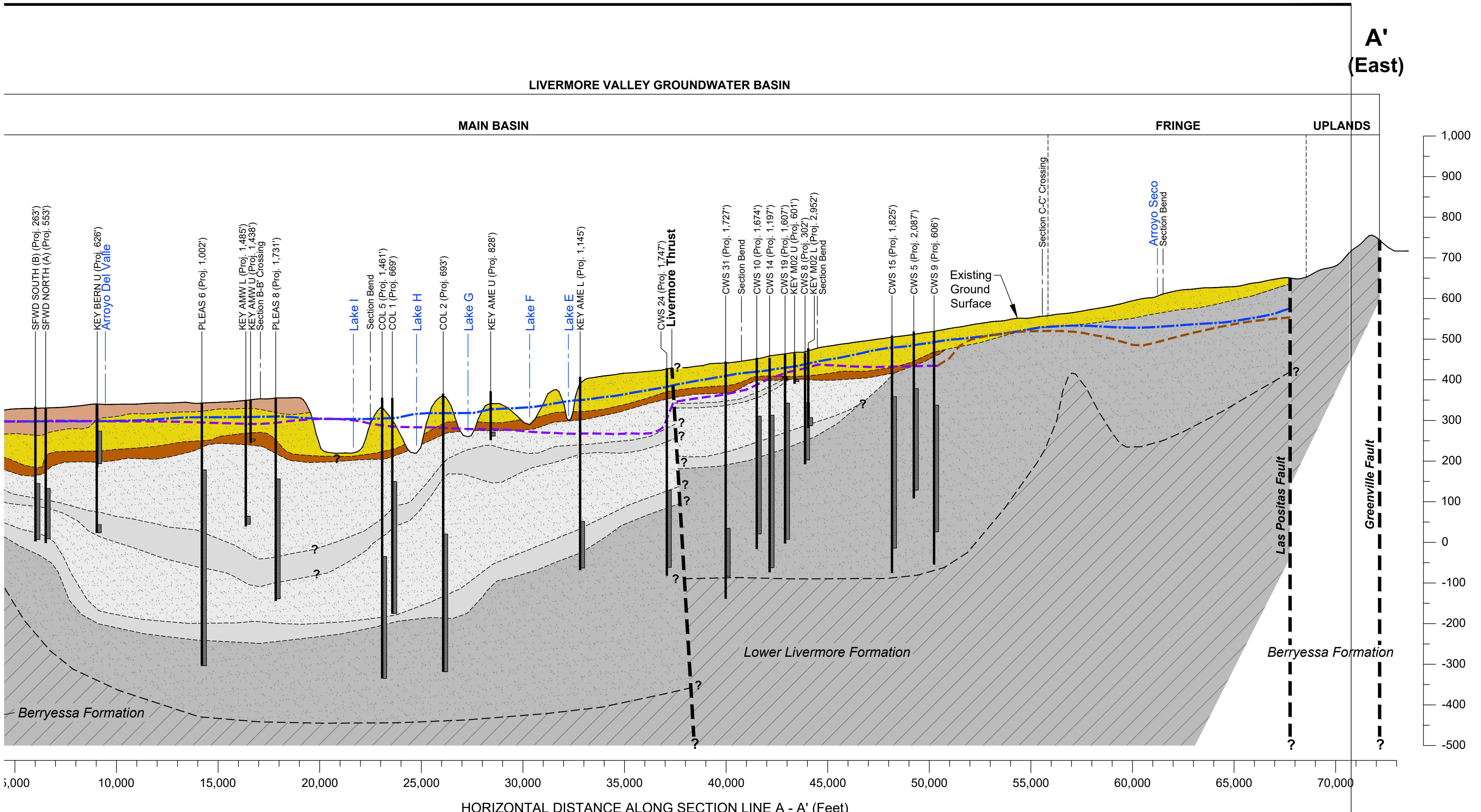
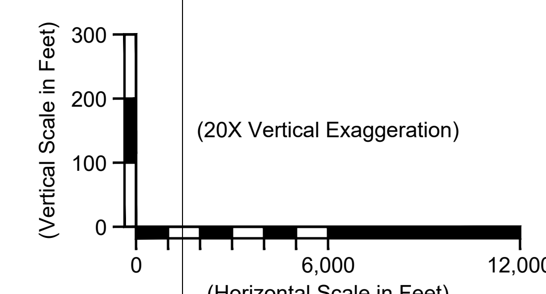
Figure 3a



Cross-Section A - A'



Well Log

Screen Interval

ands)

s)

uifer (Fall 2019)

uifer (Fall 2019)

ermore (Fall 2019)

Map Elements

A —— A' Cross-Section Trace Location

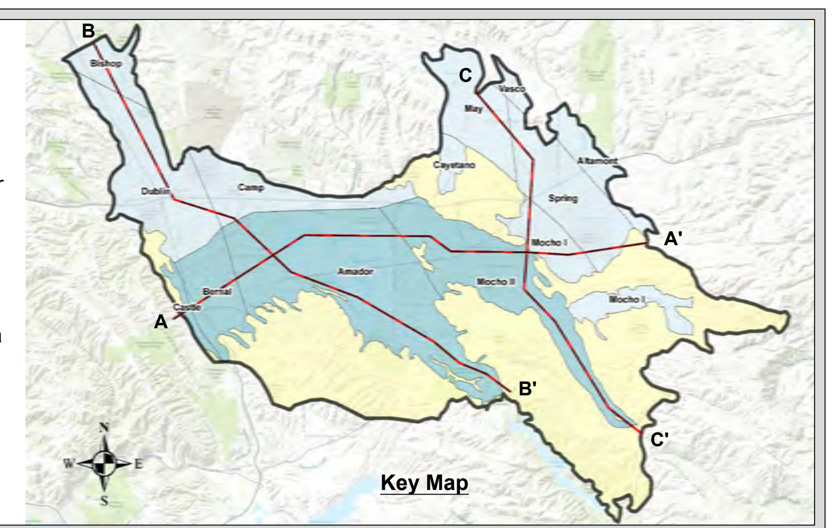
Livermore Valley Groundwater Basin

Management Area

Fringe Management Area

Main Basin Management Area

Upland Management Area



Geologic Cross-Section A - A'

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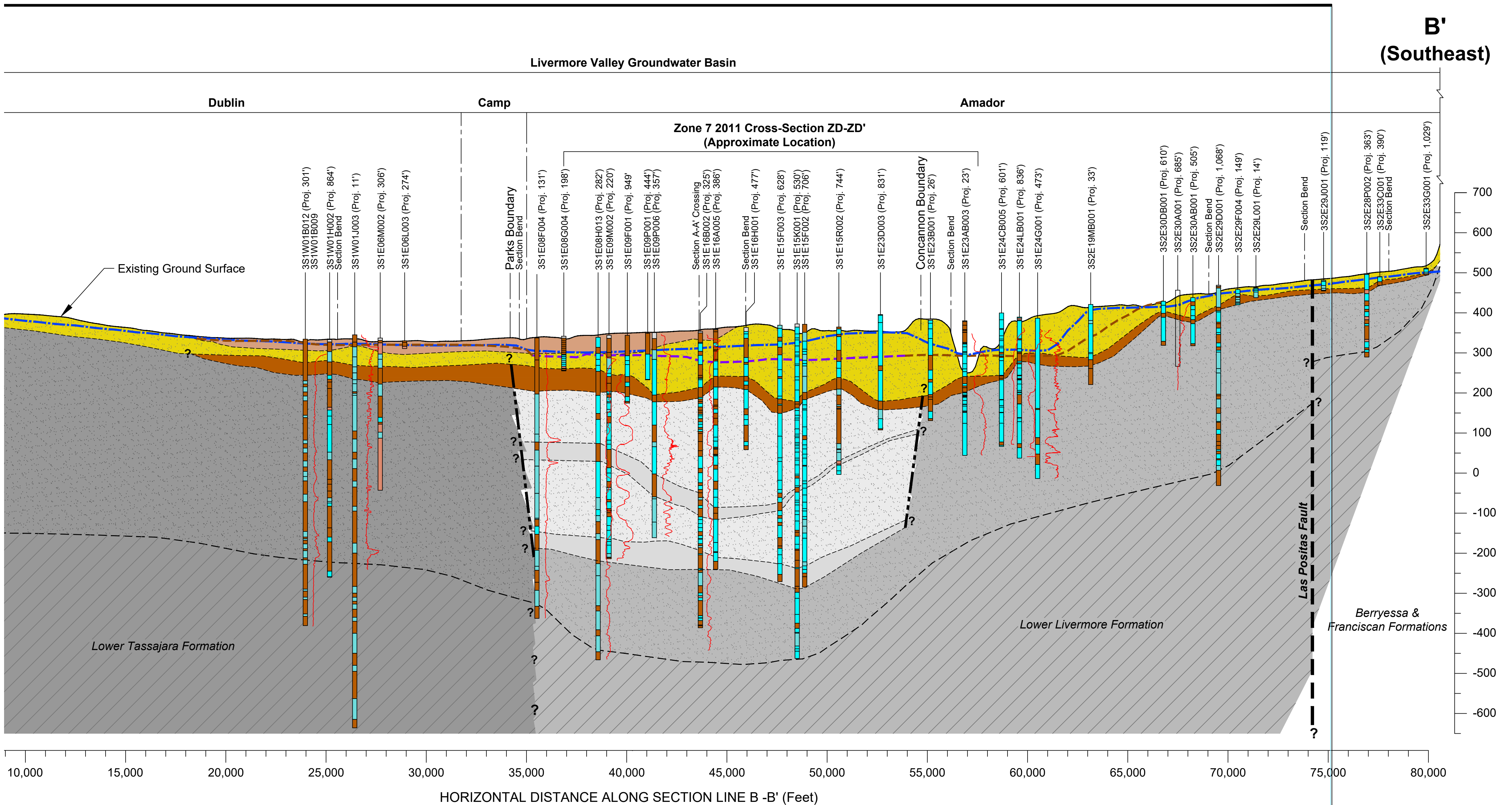
Figure 3b



Cross-Section B - B'

sands)
s)

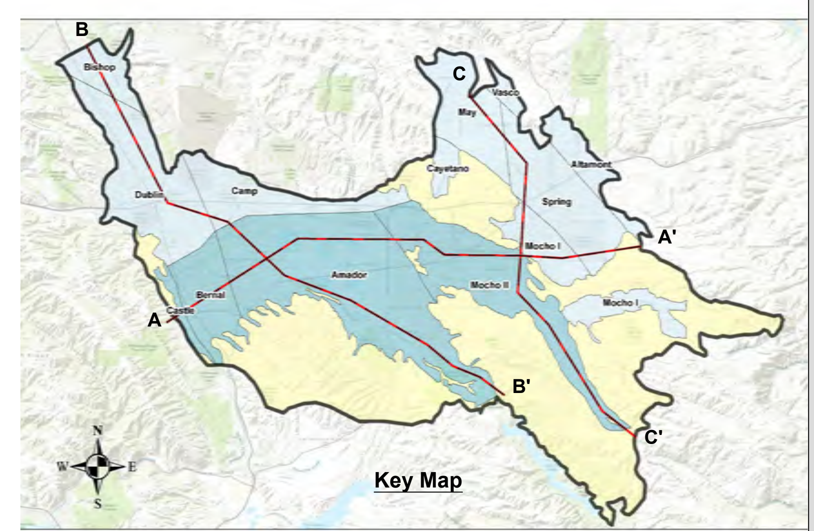
uifer (Fall 2019)
uifer (Fall 2019)
ermore/Tassajara

Lithology
- Topsoil/Fill
- Gravel
- Sand
- Silt
- Clay

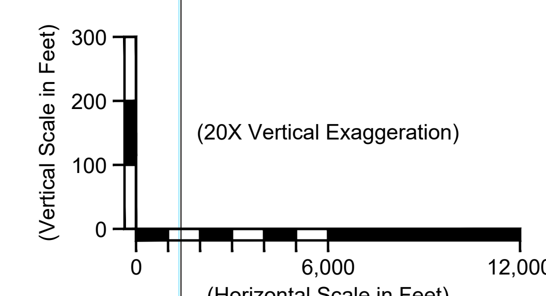
Geophysical
- Long-Normal Resistivity

Map Elements
- A—A' Cross-Section Trace Location
- Livermore Valley Groundwater Basin

Management Area
- Fringe Management Area
- Main Basin Management Area
- Upland Management Area



Key Map



Geologic Cross-Section B - B'

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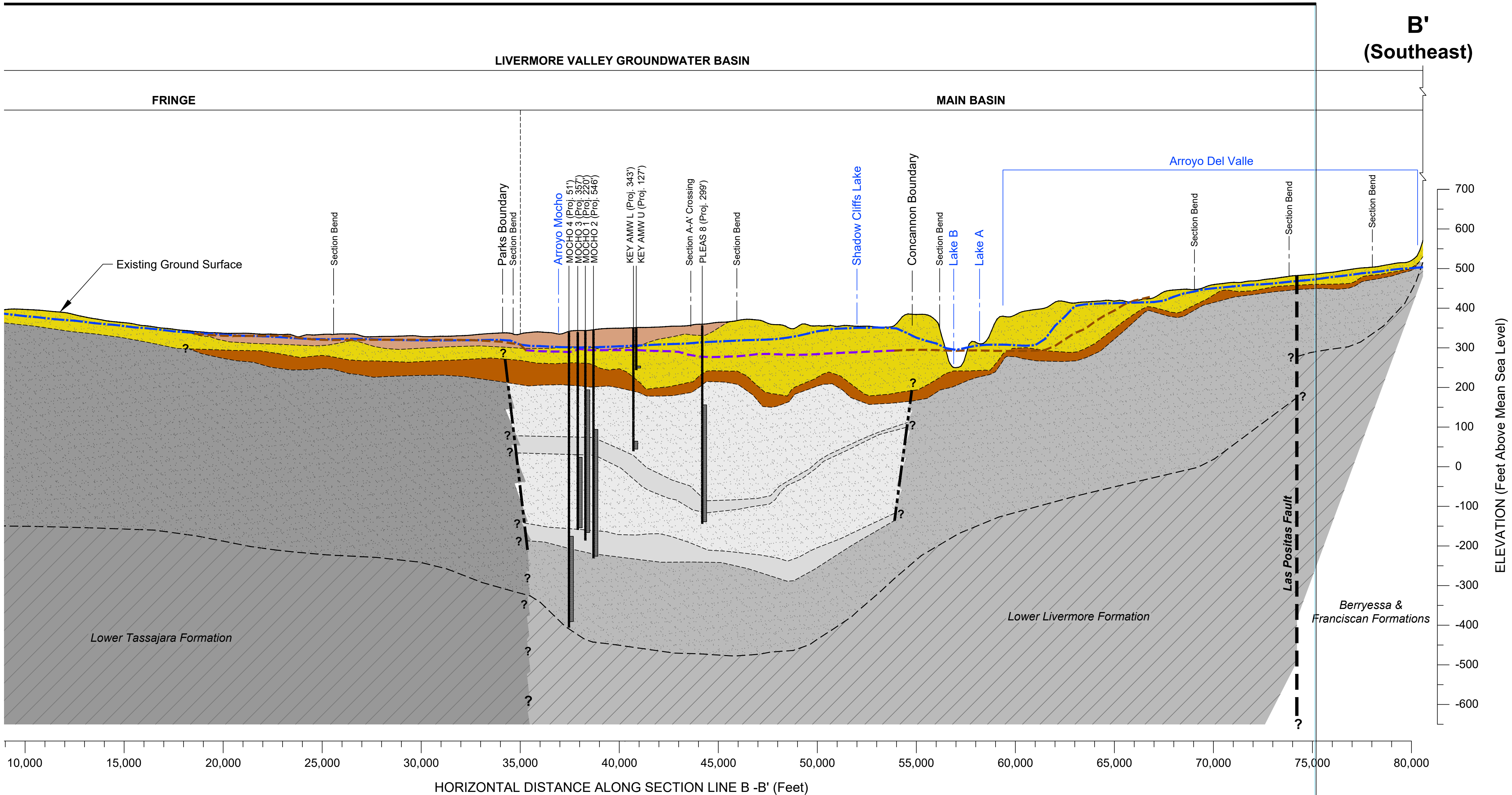
Figure 4a



Cross-Section B - B'

ands)

s)

Well Log

Screen Interval

uifer (Fall 2019)

uifer (Fall 2019)

ermore/Tassajara

Map Elements

A —— A' Cross-Section Trace Location

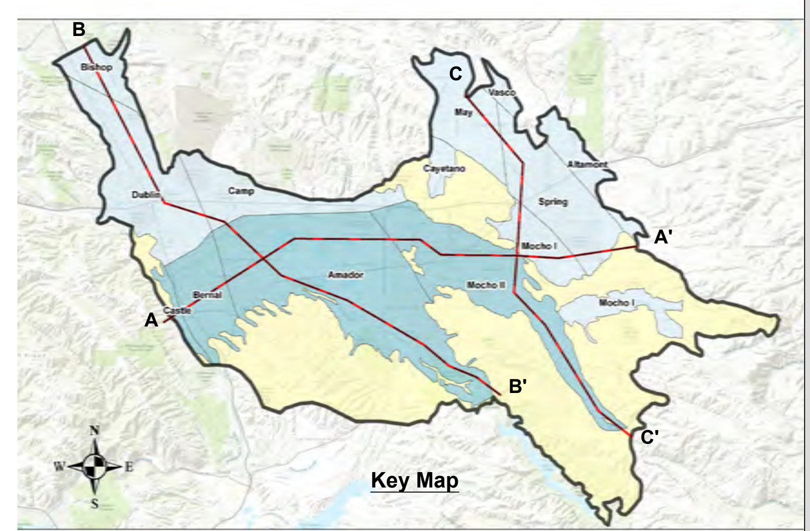
Livermore Valley Groundwater Basin

Management Area

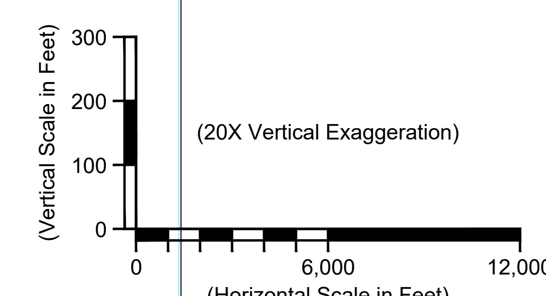
Fringe Management Area

Main Basin Management Area

Upland Management Area



Key Map



Geologic Cross-Section B - B'

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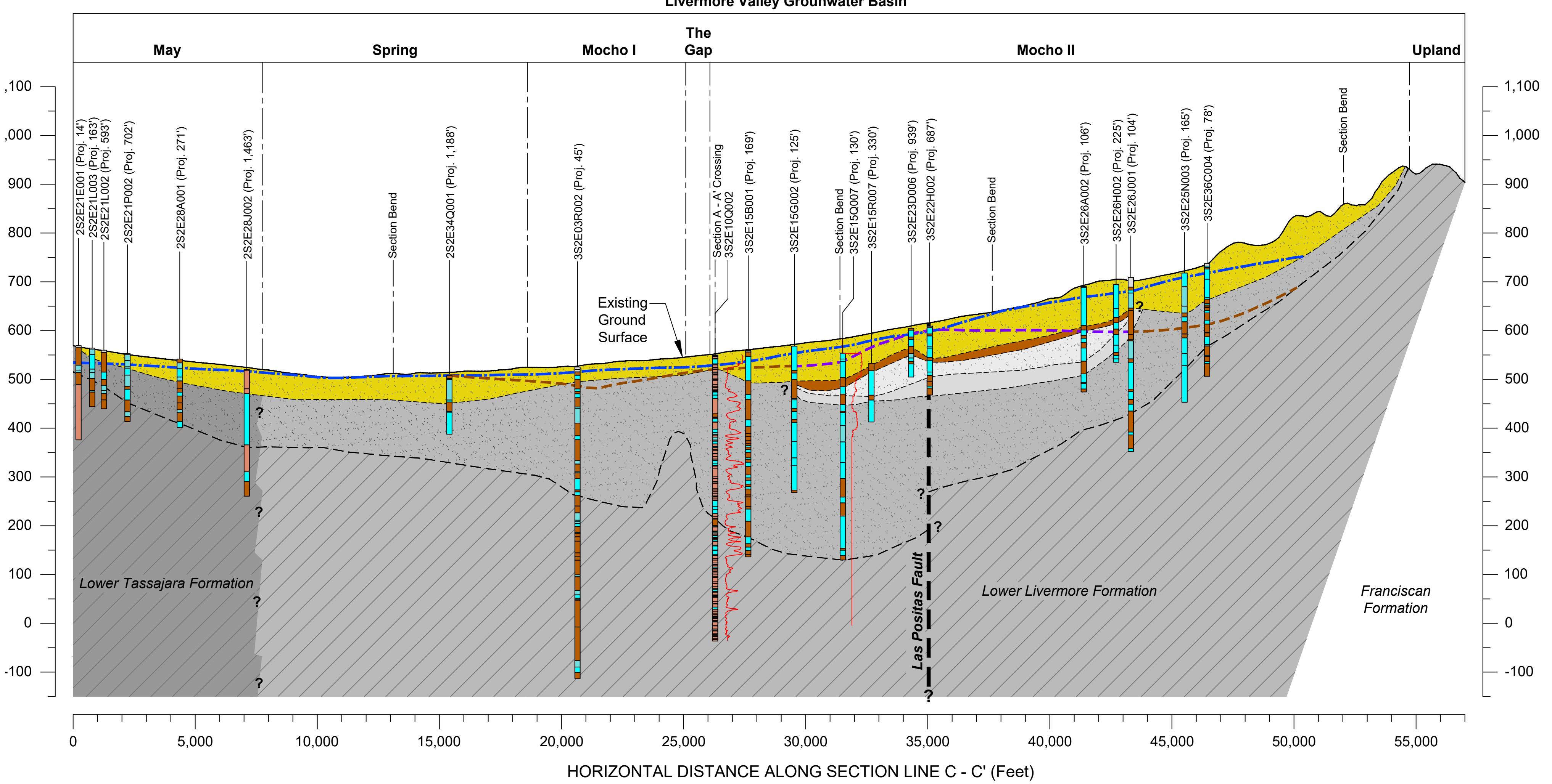
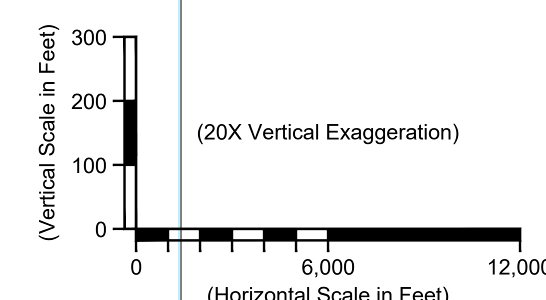
Figure 4b

C (Northwest) — C' (Southeast)



Cross-Section C - C'



...ands)
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...uifer (Fall 2019)
...uifer (Fall 2019)
...ermore/Tassajara

Lithology
- Topsoil/Fill
- Gravel
- Sand
- Silt
- Clay

Geophysical
- Long-Normal Resistivity

Map Elements
- A —— A' Cross-Section Trace Location
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Management Area
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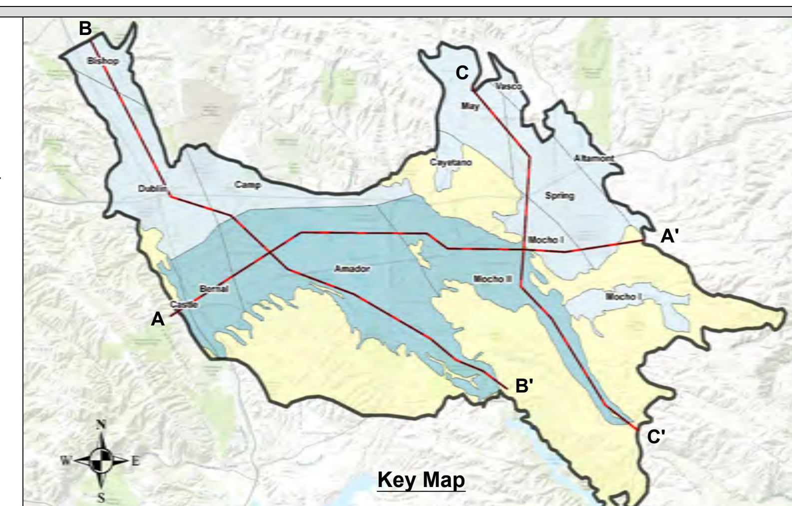
- Upland Management Area



Geologic Cross-Section C - C'

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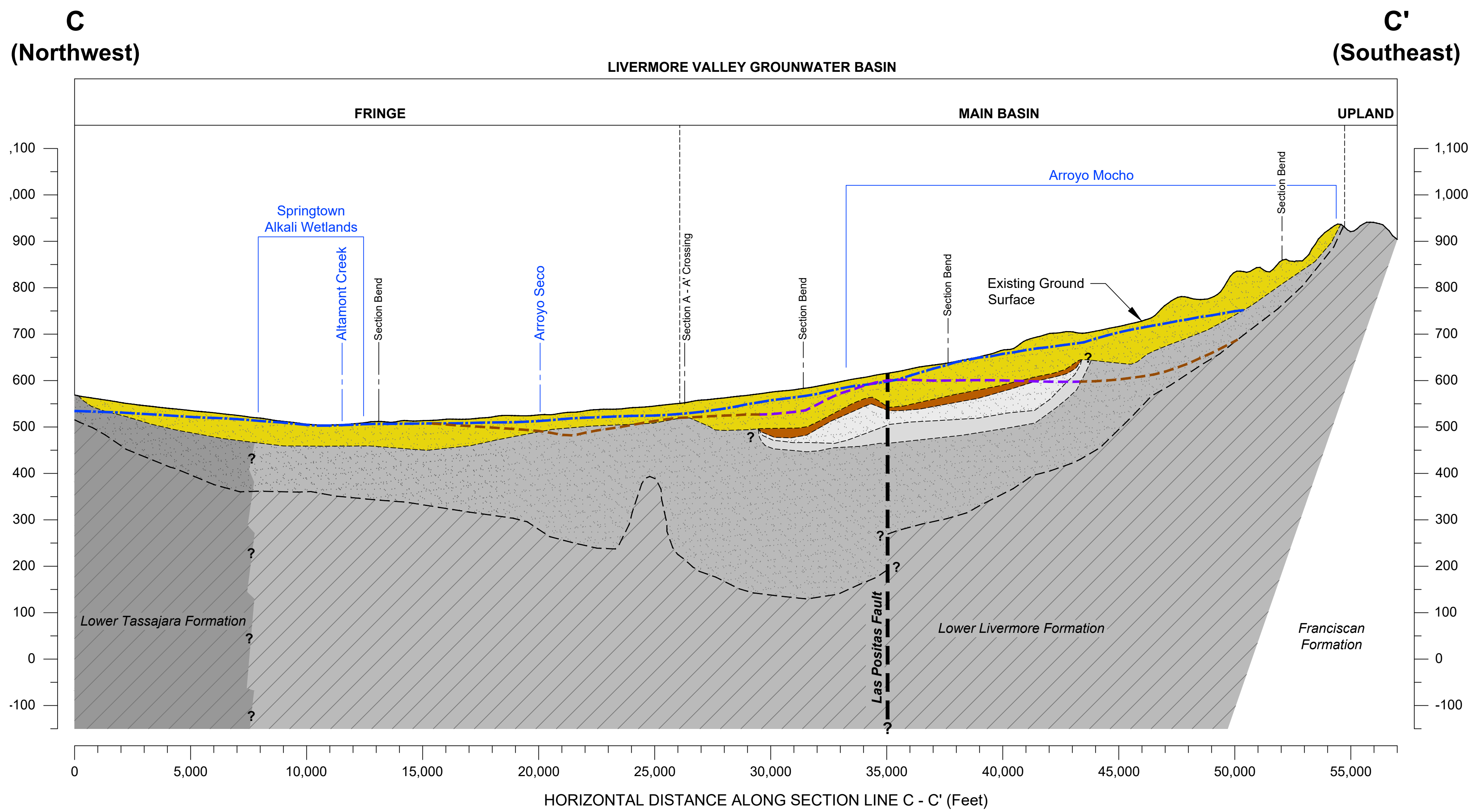
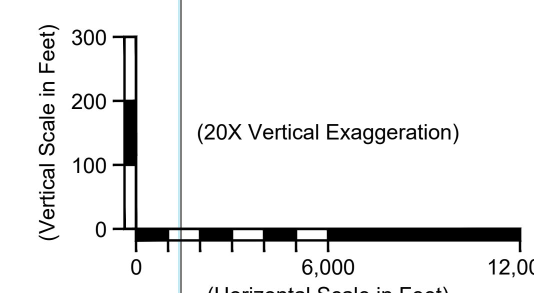
Figure 5a



Cross-Section C - C'



ands)
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uifer (Fall 2019)
uifer (Fall 2019)
ermore/Tassajara

Map Elements

A —— A' Cross-Section Trace Location

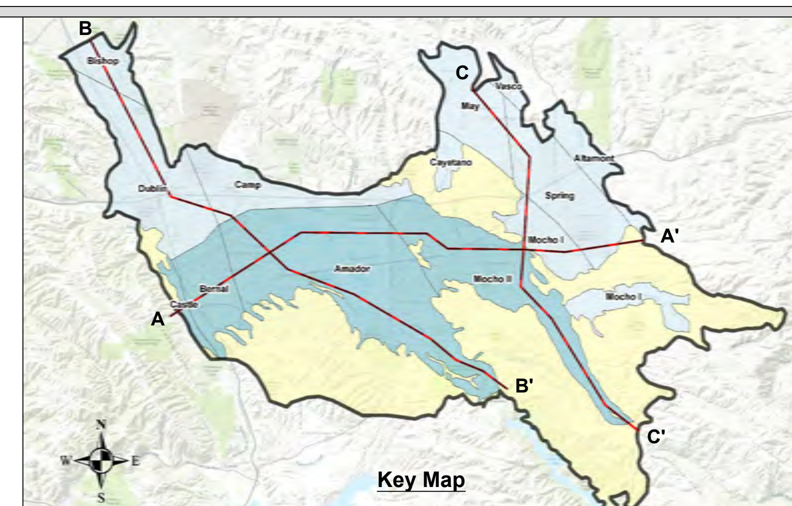
Livermore Valley Groundwater Basin

Management Area

Fringe Management Area

Main Basin Management Area

Upland Management Area



Geologic Cross-Section C - C'

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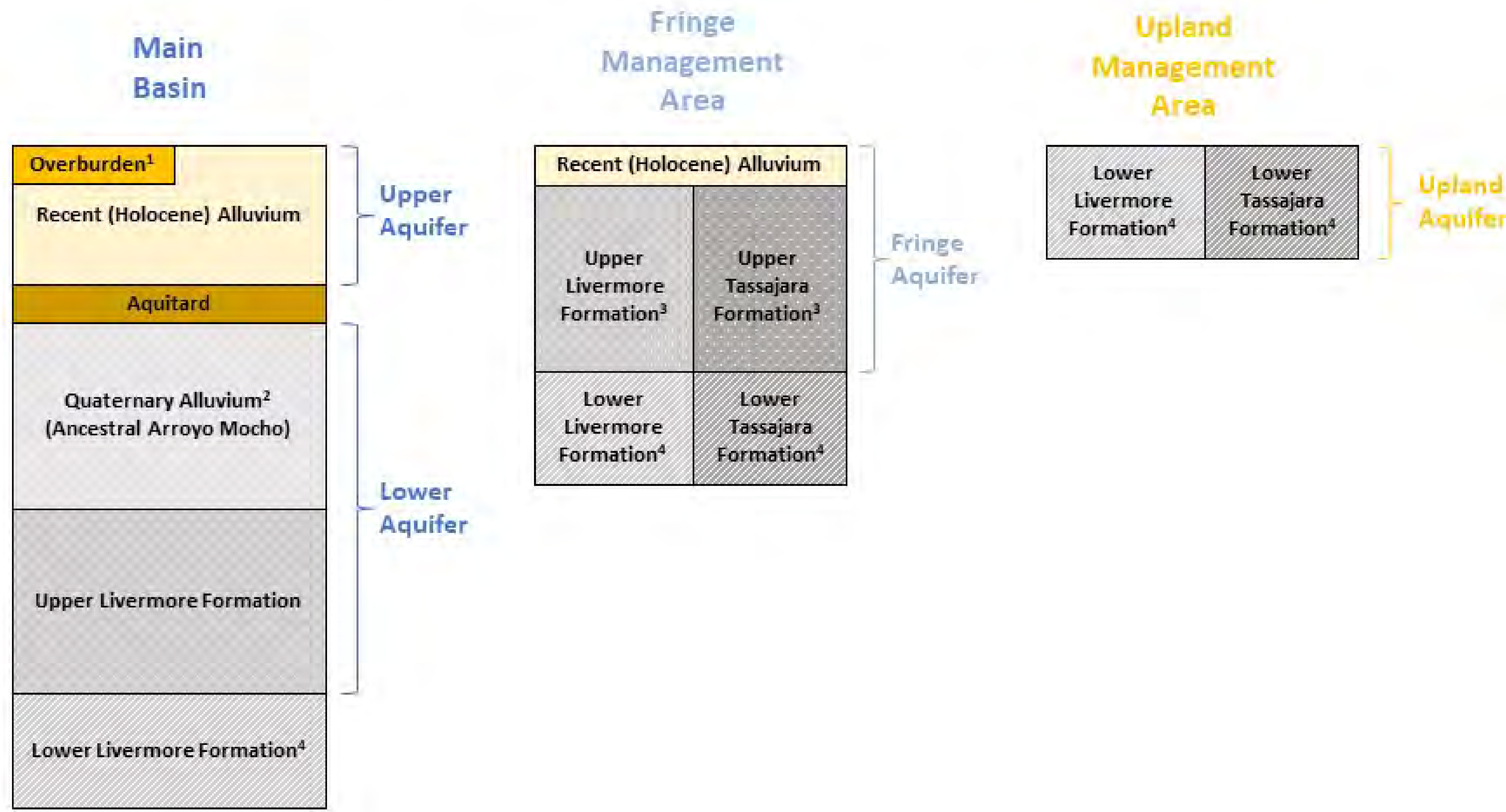
Figure 5b

Livermore Valley Groundwater Basin
Conceptual Hydrostratigraphy Model



Notes:

1 Only encountered in western portion of Main Basin (Bernal, Amador subareas)
2 Only encountered where Ancestral Arroyo Mocho incised valley complex exists (see Norfleet 2004, Figure 3-5)
3 Tassajara Formation encountered in northwestern (Bishop, Dublin, Camp subareas) and northeastern (May, Cayetano subareas) portion of Fringe Management Area; Livermore Formation encountered in all other Fringe subareas
4 Considered generally impermeable and below the bottom of the usable groundwater basin
5 Drawings not to scale; for discussion purposes only

Conceptual Hydrostratigraphy Model

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Figure 6

APPENDIX D

UPDATE OF AERIAL RECHARGE MODEL TO IDC FRAMEWORK TECHNICAL MEMORANDUM

15 September 2021

DRAFT TECHNICAL MEMORANDUM

To: Tom Rooze, PG, Zone 7 Water Agency (Zone 7)
Ken Minn, PE, Zone 7
Colleen Winey, PG, Zone 7
Carol Mahoney, PG, Zone 7

From: Anona Dutton, PG, CHg, EKI Environment & Water, Inc. (EKI)
Aaron Lewis, EIT, EKI
Christina Lucero, PG, EKI
Nigel Chen, PhD, EKI

Subject: **Migration and Update of Aerial Recharge Model to Integrated Water Flow Model Demand Calculator (IDC) Framework**
(EKI C00065.00)

EKI Environment & Water, Inc. (EKI) is pleased to provide to Zone 7 Water Agency (Zone 7) this draft technical memorandum documenting our development of an Integrated Water Flow Model Demand Calculator (IDC) model of the Livermore Valley Groundwater Basin (Basin). The IDC model is intended to serve as a replacement to Zone 7's existing Aerial Recharge Model (ARM) to provide a framework for estimating spatiotemporal recharge and runoff rates within the Basin and to inform updates to Zone 7's Hydrologic Inventory (HI) spreadsheet water budget model of the Basin. We anticipate that a final version of this technical memorandum will be included as an Appendix to the 2022 Alternative Groundwater Sustainability Plan (Alt GSP) being developed for the Basin.

BACKGROUND

Pursuant to Title 23, Section 358.2(a) of the California Code of Regulations (23-CCR §358.2(a)), Groundwater Sustainability Agencies (GSAs) with an approved Alternative Groundwater Sustainability Plan (Alt GSP or Plan) must resubmit an updated Plan to the California Department of Water Resources (DWR) every five years. As part of the five-year update process to the 2016 Alt GSP, Zone 7 contracted EKI to: (1) integrate Zone 7's existing ARM spreadsheet model into the IDC platform and extend coverage of the ARM across the entire Basin; (2) run the IDC model to calculate monthly historical recharge and applied water rates over the last 10 years; (3) calibrate the IDC model to any available historical groundwater recharge and/or pumping data within the Basin; and (4) compare IDC model outputs to the ARM to assess model performance.

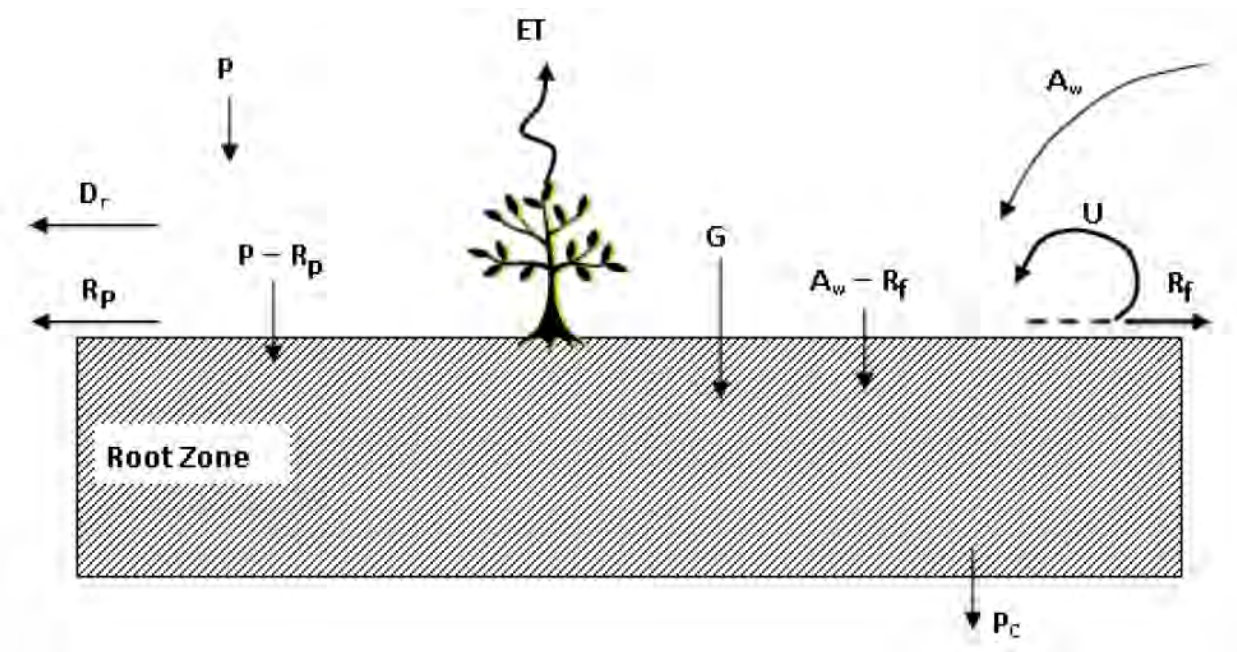
DESCRIPTION OF IDC MODEL FRAMEWORK

IDC is a peer-reviewed, open-source software program developed by the California Department of Water Resources (DWR) designed to simulate root zone flow processes and calculate agricultural and urban applied water demands based on available climate, land use, soil properties, and water supply datasets.

IDC is the stand-alone version of the root zone simulation engine used in DWR's Integrated Water Flow Model (IWFM) finite-element groundwater flow modeling software program.

Figure 1 below provides a schematic representation of the root zone flow processes simulated by IDC. A full description of the IDC model framework (including a full accounting of all root zone components and calculations, instructions for preparing input datasets, and the description of the supporting computational framework) is provided in the IDC Theoretical Documentation and User's Manual (see **Attachment A**).

Figure 1. Schematic representation of root zone flow processes simulated by IDC[1].



The Livermore Valley Groundwater Basin IDC model (herein referred to as "IDC model") was developed using version 2015.0.102 of IDC software (released May 18, 2021).

DEVELOPMENT OF IDC GRID

The existing ARM model is discretized into a rectangular grid composed of 19,920 grid cells at 500 x 500-foot spatial resolution, including 10,743 active grid cells within the Basin. The ARM grid aligns with Zone 7's existing MODFLOW numerical groundwater flow model ("MODFLOW model") grid, which covers most of the Basin except for the eastern portion of the Mocho I subarea (within the Fringe Management Area) and the southeastern corner of the Upland Management Area.

To preserve the capability of linking recharge outputs from the IDC model with Zone 7's existing MODFLOW model, the IDC grid aligns identically with the ARM and MODFLOW grid for all grid cells

---

[1] Dogrul, E.C. & Kadir, T. N., 2021. *IWFM Demand Calculator (IDC-2015, Revision 102). Theoretical Documentation and User's Manual.*

encountered within the Basin and maintains a 500 x 500-foot spatial resolution. Additionally, the IDC grid covers the remaining areas of the Basin that were not previously included in the ARM model.

As IDC is set up using a finite-element formulation, the IDC grid is defined using "Nodes" (i.e., point-based coordinates) that are located at the corners of each grid cell. Each grid cell (herein referred to as "Element") of the IDC model is subsequently linked to four Nodes that comprise the corners of each Element. To limit IDC computational demands, all grid cells from the ARM model that are located outside the Basin boundaries were excluded from the IDC grid. The final IDC model grid is comprised of 12,626 Nodes comprising 12,107 Elements, as shown on **Figure 2**. A comparison of the IDC and ARM model grid is shown on **Figure 3**.

IDC MODEL HISTORICAL SIMULATION PERIOD

The IDC model was set up to simulate historical root zone flow processes for a ten-year period covering DWR Water Years[2] (WY) 2011 through 2020, consistent with the ARM model historical simulation period.

MIGRATION OF ARM DATASETS

To begin population of IDC input datasets, EKI extracted and processed all relevant datasets from Zone 7's existing ARM model for migration into the IDC input file framework and extended those datasets to cover the portions of the Basin that were not previously covered by the ARM model. Datasets extracted from the ARM include:

- **Precipitation Data** (*Daily, station-based)* – EKI extracted the daily "Index" precipitation rates from the ARM model for inclusion into the IDC model. The "Index" precipitation rates represent an average of daily precipitation rates from nearby California Irrigation Management Information System (CIMIS) Stations #15, #191, #17, and #24.
- **Reference Evapotranspiration (ETo) Data** (*Daily, station-based)* – EKI extracted the daily "Index" reference evapotranspiration (ETo) rates from the ARM model for inclusion into the IDC model. The "Index" ETo rates represent a composite of ETo measurements recorded at CIMIS Stations #191 and pan ET measurements at Zone 7's Lake Del Valle (LDV) and Livermore Water Reclamation Plant (LWRP) climate stations. For the LDV and LWRP stations, pan ET was converted to ETo using conversion factors specific to each station
- **Precipitation Multipliers** (*Constants, grid-cell specific)* – EKI extracted grid-cell specific precipitation multipliers from the ARM to scale precipitation rates across the Basin. Precipitation multipliers were originally developed by Zone 7 using a comparison between precipitation rates measured at the CIMIS climate stations and a raster of Alameda County average rainfall rates. The same process was repeated to calculate corresponding precipitation multipliers for IDC Elements located outside the ARM grid. Element-specific precipitation multipliers are shown on **Figure 4**.
- **Land Use Data** (*Annual, grid-cell specific)* – EKI extracted annual land use categories for all grid cells included in the ARM. For IDC Elements located outside the ARM grid, land use data was

[2] The DWR Water Year is defined as October of the previous year through September of the following year. For example, DWR Water Year 2020 covers the period October 1, 2019 through September 30, 2020.

derived from Zone 7's annual land use GIS files. Land use types were subsequently reclassified to fit the land use categories defined in the IDC framework, as further described below. Element-specific land use types for WY 2020 are shown on **Figure 5**.

- **Runoff Curve Numbers** (*Constants, categories)* – EKI extracted runoff curve numbers provided for each land use - hydrologic soil group[3] combination included in Zone 7's original land use and soil type categories included in the ARM. These runoff curve numbers were subsequently employed to define IDC Element-specific runoff curve numbers for each land use and soil type encountered within the Basin.
- **ARM Model Zones** *(Constants, categories)* – EKI extracted various zonal attributes of the ARM grid for later use in comparing IDC model outputs to ARM model outputs in like areas of the Basin. Zonal attributes extracted from the ARM model included the "MdlBasin" attribute (which defines the Management Area of each ARM grid cell), the "DrainsTo" attribute (which defines the contributing watershed of each ARM grid cell), and the "Source" attribute (which defines the source of applied water supplies for each ARM grid cell).

DEVELOPMENT OF IDC INPUT FILES

IDC input files are set up using a tiered file structure as summarized in **Figure 6** below and described in detail in the IDC Theoretical Documentation and User's Manual (see **Attachment A**). A summary of the methods and assumptions used to develop each IDC input file is provided below.

Figure 6. Schematic representation the IDC input file structure[4].

[3] Hydrologic soil groups are derived from the USDA-NRCS SSURGO Soils Database as described in detail below.
[4] Dogrul, E.C. & Kadir, T. N., 2021. *IWFM Demand Calculator (IDC-2015, Revision 102). Theoretical Documentation and User's Manual.*

Main Control File

The main control file (*IDC_MAIN.in)* is used to direct the IDC batch file (*IDC.bat*) and executable file (*IDC2015_x64.exe)* to all other input files required by the IDC software program. Additionally, it allows the user to initialize the model start and end dates (*BDT* and *EDT*) as well as the model time step *(UNITT)*.

As described above, the IDC model was set up to simulate historical root zone flow processes for a ten-year period covering WY 2011 – WY 2020, consistent with the ARM model historical simulation period. The model is initialized on October 1, 2010 and ends on September 30, 2020.

The IDC model is set up to run on a daily timestep, which allows the model to accurately simulate runoff and recharge (otherwise termed "percolation" in IDC output files) processes associated with high-intensity precipitation events. Daily outputs have been compiled into monthly and/or annual timesteps for reporting purposes. The standard length unit used in the IDC simulation is <u>feet</u>.

Grid Files

IDC requires the user to specify the properties of the IDC grid in several input files, including:

- *NodeXY.dat* – specifies the total number of Nodes (*ND* = 12,626), Node identifiers (*ID*), Nodal X and Y coordinates, and a coordinate conversion factor (*FACT* = 1). For the Zone 7 IDC model, Nodal coordinates are specified using the NAD 1983 State Plane Coordinate System for California Zone 3 (NAD 83 SPCS CA III) projected coordinate system, and are listed in units of feet.
- *Element.dat* – specifies the total number of Elements (*NE* = 12,107), Element identifiers (*IE*), and corresponding Node identifiers (*IDE*). Node identifiers for each Element must be listed in counterclockwise fashion starting with any Node.
- *LakeElems.dat* – specifies the total number (*NTELAKE*) and identifier (*IELAKE)* of Elements to be assigned as lakes in the IDC model. IDC removes lakes from all root zone calculations. For the Zone 7 IDC model, 271 Elements were assigned as lakes based on ARM grid cells identified as Water ("Wat") or Mining Area Ponds ("MA-Pond") in Zone 7's land use dataset. Lake Elements are generally limited to the Chain of Lakes areas as well as a few other surface water features scattered throughout the Basin (e.g., Lake del Valle).

Area Files

IDC classifies different land use types into four main categories based on unique methodologies for calculating irrigation demands and recharge/runoff rates: (1) Non-Ponded Crops (i.e., all agricultural lands not using flood irrigation practices); (2) Ponded Crops (i.e., agricultural lands using flood irrigation practices); (3) Native/Riparian Vegetation (i.e., any native lands or non-irrigated lands); and (4) Urban Lands. For Non-Ponded and Ponded Crops[5], any number of crop types can be specified by the user. For Native/ Riparian Vegetation, all lands must be specified as Native or Riparian. For Urban Lands, lands must be grouped by a common area (e.g., municipality or water service area).

[5] There are no Ponded Crops in the IDC model domain, as demonstrated in Table 1 below.

To meet the input file requirements of IDC, EKI reclassified Zone 7's original land use categories provided in the ARM into the following IDC land use categories presented in **Table 1.**

Table 1. Zone 7 Original and IDC Land Use Categories

Zone 7 Original Land Use Category	IDC Land Use Category
URH - Urban Residential High Density	Urban
URM – Urban Residential Medium Density	Urban
URL – Urban Residential Low Density	Urban
RR – Rural Residential	Urban
UP – Urban Park	Urban
UC – Urban Commercial and Industrial	Urban
Pub - Public	Urban
Ro – Roads	Urban
OS – Open Space	Native
MA-Pit – Mining Area Pits	Native
MA-Other – Mining Area Other	Native
Ag-Vine – Vineyards	Non-Ponded Crops (Vineyards)
Ag-Other – Other Ag	Non-Ponded Crops (Misc. Field Crops)
GC – Golf Courses	Non-Ponded Crops (Golf Courses)
MA-Pond – Mining Area Ponds	Lake Element
Wat – Water	Lake Element

Reclassified land use types were subsequently entered into their corresponding input files by Element (i.e., *UrbanArea.dat*, *NonPondedAgArea.dat*, or *NVRVArea.dat*) for each water year included in the simulation. IDC allows the user to specify a fractional area occupied by a particular land use category for each Element; however, EKI elected to assign 100% of the area of each Element to a single land use category consistent with the land use discretization employed in the ARM. The reclassified land use categories are shown for WY 2020 in **Figure 7.**

<u>Climate Files</u>

IDC requires the user to provide normalized precipitation and ET rates at a time unit rate equivalent to the timestep specified for the simulation (i.e., days for the Zone 7 IDC model). IDC allows the user to specify any number of precipitation or ET rates to use for different Elements and/or land use categories, so long as the dataset covers the entire simulation period. Units are in 1/length, where the length unit can be anything so long as an appropriate conversion factor (*FACTRN* or *FACTET*) is provided that converts the normalized values to the standard IDC length unit of feet.

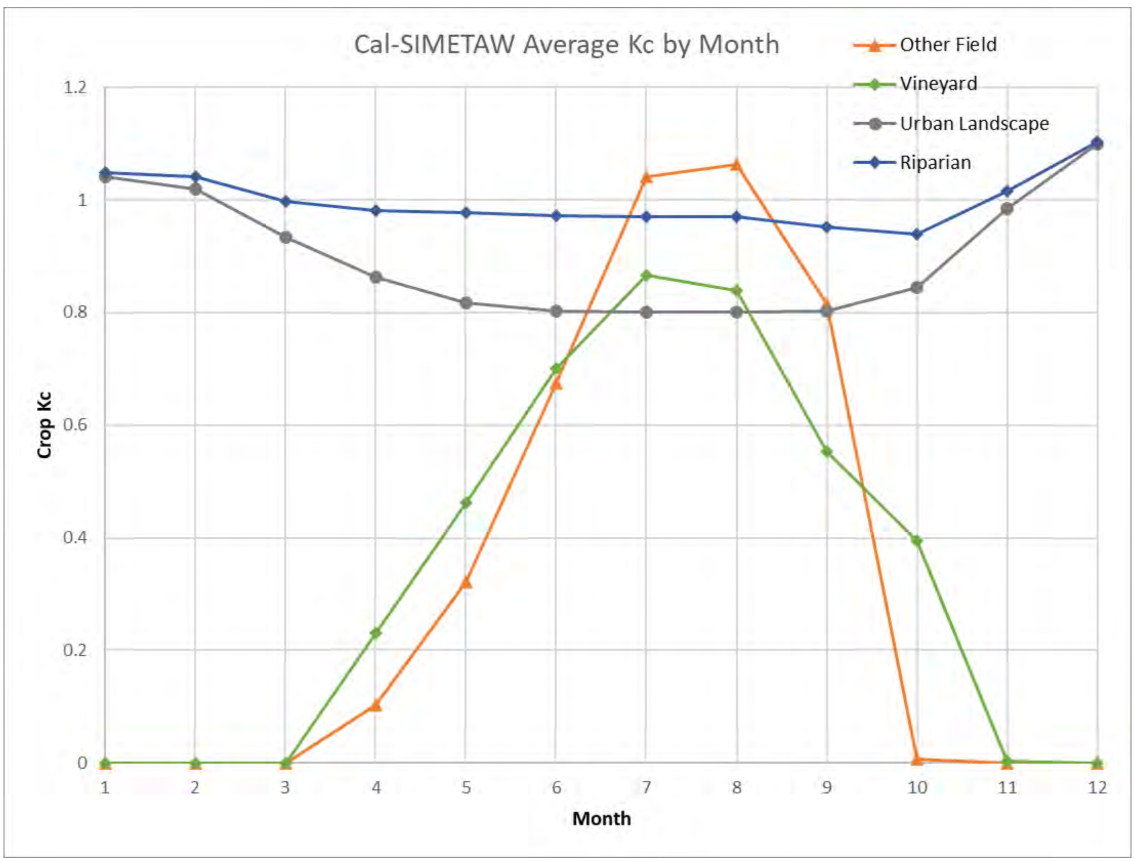
EKI incorporated the daily "Index" precipitation rates extracted from the ARM into the *Precip.dat* file. Precipitation rates are provided in units of inches/day and are subsequently converted to feet/day using *FACTRN* = 0.08333. Precipitation rates are subsequently scaled for each Element using the precipitation multipliers extracted from the ARM as further described below.

For ET, EKI incorporated the daily "Index" ETo rates extracted from the ARM into the *ET_Calsim.dat* file. Additionally, EKI included unique ET rates for four land use categories simulated within the IDC model: (1)

Native/Riparian Lands, (2) Vineyards, (3) Urban Lands, and (4) Other Agriculture (presumed to be Miscellaneous Field Crops). ET rates for these four land use categories were informed by the Cal-SIMETAW historical ET dataset provided by DWR[6]. The Cal-SIMETAW dataset provides monthly estimates of historical ETo and crop ET for 20 crop categories, as well as native/riparian, open water, and urban land use classes for October 1999 – September 2015 based on data from the Parameter-elevation Regressions on Independent Slopes Model (PRISM) and CIMIS datasets. It is a crop coefficient method, meaning an ETo is converted into crop ET using crop coefficients (Kc), where crop ET = ETo x Kc based on assumptions about plant growth rates, harvest timing, et cetera. Estimates are provided for each 4x4 km detailed analysis unit (DAU) by county throughout the state.

EKI calculated average monthly Kc values from the Cal-SIMETAW data for the Livermore DAU (DAU # 45) for the four land use categories mentioned above. The average monthly Kc rates are shown for each category in **Figure 8** below.

Figure 8. Average Crop Coefficient (Kc) Values from Cal-SIMETAW for Livermore DAU



The daily "Index" ETo rates included in the ARM were subsequently multiplied by average monthly Kc values for each land use category to come up with a daily ET rate for Native/Riparian Lands, Vineyards, Urban Lands, and Other Agriculture (Misc. Field Crops) land use types. ET rates for all other land use types

[6] https://data.ca.gov/dataset/cal-simetaw-unit-values

simulated in the Basin were represented by the "Index" ETo dataset. ET rates are provided in units of inches/day and are subsequently converted to feet/day using *FACTET* = 0.08333.

Root Zone Files

The Zone 7 IDC model employs Version 4.11 of the Root Zone package. The features of v4.11 and other versions are described in detail in the IDC Theoretical Documentation and User's Manual.

IDC requires that various soil attributes are provided in the *ROOTZONE_v411_MAIN.dat* file for Each element, including:

- Wilting point (*WP*)
- Field capacity (*FC*)
- Total porosity (*TN*)
- Pore size distribution index (*LAMBDA*)
- Saturated hydraulic conductivity (*K*)
- Capillary rise (*CPRISE*)

To populate the required soil properties, EKI extracted soils data from the United States Department of Agriculture Natural resources Conservation Service's (USDA-NRCS) Soil Survey Geographic Database (SSURGO)[7]. The SSURGO dataset provides GIS files of soil types at a high spatial resolution and is accompanied by an Access database that contains the required soil properties information described above for most soil types. EKI imported SSURGO data for the Basin into GIS and joined soil classes to each Element of the IDC grid. Element-specific SSURGO soil types are shown on **Figure 9**.

Relevant soil properties were then extracted from the SSURGO dataset using the accompanying Soil Data Viewer GIS add-in and applied to each Element based on soil class. EKI choose to use the "Weighted Average" aggregation method included in the SSURGO dataset to define Elemental soil properties, where applicable. Where multiple soil types were contained within a single Element, an area- weighted average was calculated for each soil property contained within that Element. Where the soil types were missing certain soil properties, missing soil properties were inferred from other similar soil types. Select soil properties (e.g., saturated hydraulic conductivity [*K]*) were subsequently adjusted during IDC model calibration, as further described below. Final saturated hydraulic conductivities (*K*) assigned to each element are shown on **Figure 10**.

The *ROOTZONE_v411_MAIN.dat* file also requires the user to specify certain parameters controlling root zone flow processes within the simulation engine, including:

- Method to represent hydraulic conductivity vs. moisture content curve (*RHC*)
- Precipitation multipliers (*FRNE*)
- Pointers to the *PipeLeak.dat* Generic Moisture Source data file by Element (*IMSRC*)
- Destination types (*TYPEDEST*) and locations (*DEST*) for runoff (for use if linking IDC to an IWFM groundwater flow model)

[7] https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_053627

The Zone 7 IDC model employs Campbell's Equation (*RHC* = 1) to represent unsaturated hydraulic conductivities as a function of soil moisture. Precipitation multipliers (*FRNE*) are specified for each Element based on the precipitation multipliers included in the ARM. The Generic Moisture Source package is employed to simulate pipe leakage within urban areas and generic moisture data sources (*ISMRC*) are specified for urban cells based on their corresponding water agency service areas, as further described below. Because IDC is being used as a stand-alone package, all runoff is routed "outside the model area" (*TYPEDEST = 0*). IDC currently does not have the capability to link runoff outflows between adjacent Elements, and therefore runoff occurring on individual Elements cannot contribute to ET or recharge in adjacent Elements.

Finally, the *ROOTZONE_v411_MAIN.dat* file contains several pointer attributes used to direct the IDC executable to accompanying files of the Root Zone package, each of which are further described below.

Non-Ponded Crops Files

The *NonPondedAg_MAIN.dat* file is used to specify certain attributes and pointers to accompanying files for each non-ponded crop type simulated in the IDC model, including:

- Number of non-ponded crops (NBCROP) and crop type codes (*BCCODE*)
- Maximum crop rooting depths (*ROOT*) and pointers for the *RootDepthFrac.dat* fractional rooting depth file (*ICROOT*)
- Curve numbers by Element and crop type (*CN*)
- Pointers to the *ET_CalSim.dat* ET data file by crop type (*ICET*)
- Pointers to the agricultural water supply requirement data file by crop type (*ICAW*) (not in use)
- Pointers to the *IrrigPeriod.dat* irrigation period data file by crop type (*ICIP*)
- Pointers to the *MinSoilMoist.dat* minimum soil moisture data file by crop type (*ICMSM*)
- Pointers to the *TargetSoilMoist.dat* target soil moisture data file by crop type (*ICTRGSM*)
- Pointers to the *ReturnFlowFrac.dat* irrigation water return flow fractions data file by crop type *(ICRTRNF)*
- Pointers to the *ReuseFrac.dat* irrigation water reuse fractions data file by crop type *(ICRUF)*
- Pointers to the minimum percolation fractions data file by crop type (*ICDPF*) (not in use)
- Initial Soil Moisture Conditions (*SOILM*) and fraction of initial soil moisture due to precipitation (*FSOILMP*)

As described earlier, there are three unique non-ponded crop types simulated in the Zone 7 IDC model: (1) Vineyards ("AV"); (2) Other Agriculture (Misc. Field Crops, "AO"); and (3) Golf Courses ("GC"). Vineyards and Other Agriculture are assigned a maximum crop rooting depth (*ROOT*) of 3 feet, while maximum rooting depths for Golf Courses is set at 1 foot. Maximum rooting depths were estimated based on relevant studies of crop rooting depths[8]. It is conservatively assumed that all crop types will remain at 100% rooting depths throughout the entire simulation (*RDFRC* = 1 in the *RootDepthFrac.dat* file).

[8]http://ucmanagedrought.ucdavis.edu/Agriculture/Irrigation_Scheduling/Evapotranspiration_Scheduling_ET/Frequency_of_Irrigation/Crop_Rooting_Depth/

Curve numbers are specified by Element and crop type based on the hydrologic soil group (i.e., A-D) identified for each Element in the SSURGO dataset and the corresponding curve number properties for their respective Zone 7 land use - hydrologic soil group combinations provided in the ARM.

As described earlier, unique ET rates are assigned to Vineyards and Other Ag. (Misc. Field Crops) in the *CalSim_ET.dat* data file based on monthly average crop coefficients provided by Cal-SIMETAW. ET rates for Golf Courses are set at the ETo rate, as it is assumed well-watered turf grasses will closely mimic ETo.

Irrigation periods are specified by crop type in the *IrrigPeriod.dat* data file. Irrigation periods are based on assumptions included in the ARM, and are set as:

- Vineyards: April through October
- Other Ag.: April through September
- Golf Courses: January – December (year-round)

Minimum soil moisture fractions (*SMMIN*, specified as a fraction of Total Available Water [TAW = FC – WP]) are used as a trigger for irrigation events and are generally included in IDC as tunable parameters to control minimum irrigation rates for each crop type. *SMMIN* was set at 0.5 in the *MinSoilMoist.dat* file for all crop types, as is commonly used in other IDC models.

Target soil moisture fractions (*SMTRG,* specified as a fraction of FC) are used to compute irrigation water demands and are generally included in IDC as tunable parameters to control maximum irrigation rates for each crop type. They are also commonly employed to simulate deficit irrigation practices, which is known to be a common practice on Vineyards. *SMTRG* values were estimated by crop type in the *TargetSoilMoist.dat* file and were subsequently adjusted during IDC model calibration, as further described below. Final *SMTRG* values were set at 0.7 for Vineyards, 0.8 for Other Ag., and 0.9 for Golf Courses.

No return flows (i.e., recapture of excess irrigation runoff) or return flow reuse (i.e., recycled irrigation of recaptured return flows) are simulated in the Zone 7 IDC model.

Initial soil moisture conditions (*SOILM)* are set as 50% of TAW (i.e., [FC – WP]/ 2) for all Elements and it is presumed 100% of initial soil moisture is sourced from precipitation (*FSOILMP* = 1) at the first model timestep.

<u>Native/Riparian Vegetation Files</u>

The *NonPondedAg_MAIN.dat* file is used to specify certain attributes and pointers to accompanying files for the native/riparian land use classes simulated in the IDC model, including:

- Native/riparian vegetation rooting depths (*ROOTNV* and *ROOTRV*)
- Curve numbers for native/riparian Elements (*CNRV*)
- Pointers to the *ET_CalSim.dat* ET data file (*ICETNV* and *ICETRV)*
- IWFM stream nodes at which surface water will be used to satisfy unmet riparian ET demands (not in use)
- Initial Soil Moisture Conditions (*SOILM*) and fraction of initial soil moisture due to precipitation (*FSOILMP*)

As described earlier, all Elements with "OS", "MA-Pit", and "MA-Other" Zone 7 land use classes were reclassified as Native Elements in the IDC model. No riparian Elements are simulated, as there is no accompanying IWFM model or stream network simulated to supply unmet riparian vegetative demands.

Native Elements are assigned a rooting depth (*ROOTNV*) of 3 feet based on an analysis of native vegetation classes within the Basin[9] and The Nature Conservancy's (TNC) plant rooting depth database[10].

Curve numbers are specified by Element based on the hydrologic soil group (i.e., A-D) identified for each Element in the SSURGO dataset and the corresponding curve number properties for their respective Zone 7 land use - hydrologic soil group combinations provided in the ARM.

As described earlier, unique ET rates are assigned to Native Elements in the *CalSim_ET.dat* data file based on monthly average crop coefficients provided for Native/Riparian Vegetation by Cal-SIMETAW.

Initial soil moisture conditions (*SOILM)* are set as 50% of TAW for all Elements.

Urban Lands Files

The *Urban_MAIN.dat* file is used to specify certain attributes and pointers to accompanying files for the Urban land use class simulated in the IDC model, including:

- Urban landscape rooting depths (*ROOTURB*)
- Pervious area fractions for Urban Elements (*PERV*)
- Curve numbers for Urban Elements (*CNURB*)
- Pointers to the *Population.dat* population data file used to specify total populations of each Urban area defined in the IDC model
- Pointers to the *WaterUse.dat* water use data file used to specify per capita water demands for each Urban area defined in the IDC model
- Relative proportion of the total Urban demands specified in *WaterUse.dat* at each Urban Element (*FRACDM)*
- Pointers to the *ET_CalSim.dat* ET data file (*ICETURB)*
- Pointers to the *ReturnFlowFrac.dat* irrigation water return flow fractions data file for Urban elements *(ICRTFURB)*
- Pointers to the *ReuseFrac.dat* irrigation water reuse fractions data file for Urban Elements *(ICRUFURB)*
- Pointers to the *UrbanSpecs.dat* urban water use specifications data file used to specify the fraction of total urban water that is used indoors for each Urban area defined in the IDC model
- Initial Soil Moisture Conditions (*SOILM*) and fraction of initial soil moisture due to precipitation (*FSOILMP*)

Urban Elements have been classified into four distinct groups based on the water service areas that they are located in. These include: (1) Dublin San Ramon Services District (DSRSD); (2) Cal Water Livermore; (3) City of Livermore; and (4) City of Pleasanton. Each Urban group will have distinct populations, per capita

[9] Stillwater Sciences, 2021. *Groundwater Dependent Ecosystems of the Livermore Valley Groundwater Basin.*
[10] https://groundwaterresourcehub.org/public/uploads/pdfs/Plant_Rooting_Depth_Database_20180419.xlsx

water demands, and Urban indoor use fractions based on information contained in their respective Urban Water Management Plans (UWMPs), as further described below. The four water service areas in the Basin are shown on **Figure 11**. A fifth group has also been included for roads, and per-capita water demands have been set to zero to avoid any applied water occurring on road Elements. Each Urban Element within a water service area is assumed to have the same proportional population and per-capita water use demands (i.e., *FRACDM* = -1).

Pervious area fractions (*PERV)* were estimated for each Urban Element using DWR's 2021 Landscape Area Estimates Project[11] dataset and accompanying GIS files. As part of this study, DWR contracted Quantum Spatial, Inc., an NV5 company, with support from Eagle Aerial Solutions, to provide landscape area estimates for single-family and multi-family residential parcels for all urban retail water suppliers in California. DWR provided Zone 7 with separate reports and GIS databases of residential urban landscape area estimates at a parcel level for each of the four water service areas included within the Basin. EKI subsequently linked these GIS files to the IDC grid to calculate a representative PERV value for each Urban Element. An average *PERV* value was also calculated for each of Zone 7's original urban land use classes ("URH", "URM", etc.) to assign to Urban Elements located outside of the DWR Landscape Area study area. *PERV* values were subsequently adjusted during IDC model calibration, as further described below. Final *PERV* values assigned to each Urban Element are shown on **Figure 12**.

Urban populations (*POPUL)*, per-capita water use rates *(WU*), and indoor water use fractions (*URINDR*) are estimated for each water service area based on information contained in their individual UWMPs. *POPUL, WU, and URINDR* rates were compiled from the 2010, 2015, and 2020 UWMPs for each water service area and were subsequently interpolated for WY 2011 – 2020. *POPUL* estimates were downscaled based on the percentage of each water service area located within the Basin. Indoor water use fractions (*URINDR*) were further adjusted to reflect the monthly variability in indoor/outdoor water use trends observed throughout the year. *URINDR* values were rescaled by month based on analyses of indoor/outdoor water use trends included in Woodward & Curran's 2020 Tri-Valley Municipal and Industrial Water Demand Study[12] prepared for Zone 7.

Urban Elements are assigned a rooting depth (*ROOTNV*) of 1 foot based on relevant studies of turf grass rooting depths[13].

Curve numbers are specified by Element based on the hydrologic soil group (i.e., A-D) identified for each Element in the SSURGO dataset and the corresponding curve number properties for their respective Zone 7 land use - hydrologic soil group combinations provided in the ARM.

As described earlier, unique ET rates are assigned to Urban Elements in the *CalSim_ET.dat* data file based on monthly average crop coefficients provided for Urban Landscaping by Cal-SIMETAW.

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[11] Quantum Spatial, Inc., 2021. *California Department of Water Resources Landscape Area Estimates Project.* Contract No. EA-133C-16-CQ-0044

[12] Woodward & Curran, 2020. *2020 Tri-Valley Municipal and Industrial Water Demand Study.*

[13] http://ucmanagedrought.ucdavis.edu/Agriculture/Irrigation_Scheduling/Evapotranspiration_Scheduling_ET/Frequency_of_Irrigation/Crop_Rooting_Depth/

Initial soil moisture conditions (*SOILM)* are set as 50% of TAW for all Elements.

Optional Packages

EKI has activated two additional (optional) IDC packages to simulate: (1) leakage from water supply distribution systems within the Basin; and (2) shallow groundwater uptake from known groundwater dependent ecosystems (GDEs) within the Basin. Each of these packages are described in further detail below.

Pipe Leakage (Generic Moisture Source Package)

Leakage rates (i.e. "losses") from water supply distribution systems are simulated using IDC's optional Generic Moisture Source package. Leakage rates are specified by water service area in Zone 7's 2010 and 2015 UWMPs and in the 2020 Tri-Valley Demand Study. These leakage rates were normalized by the total area of Urban Elements within each water service area and were interpolated to calculate annual normalized leakage rates (in units of ft/yr) within each Urban Element for WY 2011 – 2020. Normalized leakage rates were entered into the *MSRC* columns of the *PipeLeak.dat* generic moisture source file, and appropriate *IMSRC* pointers were specified by Element by water service area in the *ROOTZONE_V411_MAIN.dat* root zone file. Urban Elements with an assigned leakage rate in the generic moisture source package are shown on **Figure 13.**

GDE Groundwater Uptake (Root Water Uptake from Groundwater Package)

Shallow groundwater uptake from known GDE communities within the Basin are simulated using IDC's optional Root Water Uptake from Groundwater package. Simulation of GDE groundwater uptake was limited to the five major GDE areas in the Basin based on Stillwater Sciences recent evaluation of GDE communities[14]. These GDE areas include: (1) Arroyo Mocho – Riparian Mixed Hardwood & Sycamore; (2) Arroyo Mocho – Valley Oak; (3) Arroyo Valle – Riparian Mixed Hardwood; (4) Arroyo Valle – Sycamore Grove; and (5) Springtown Alkali Sink. In total, ~947 acres of GDEs are included in these areas, representing approximately 90% of the total GDE acreage within the Basin (~1,051 acres) reported in the Stillwater Sciences study. A comparison of GDE areas simulated in the IDC model and GDE areas mapped by Stillwater Sciences is shown on **Figure 14.**

Monthly depth to groundwater within the GDE areas was estimated from nearby Upper Aquifer monitoring wells included in Zone 7's Program Wells Monitoring Program. Well IDs and their locations are also shown on **Figure 14**. Depth to water rates were specified for each GDE area in the *DGW* columns of the *DepthtoGW.dat* file, and appropriate pointers were provided for each GDE element in the *IDGW* attribute. Specific Yield (*SY*) was assumed to be 0.2 based on available aquifer storage properties information for the Upper Aquifer. The *GWUPTK* flag was turned on in the *ROOTZONE_V411_MAIN.dat* root zone file, and capillary rise (*CPRISE*) was set at 10 feet based on a recommendation from the IDC head developer (Can Dogrul).

[14] Stillwater Sciences, 2021. *Groundwater Dependent Ecosystems of the Livermore Valley Groundwater Basin*.

IDC MODEL CALIBRATION

Individual root zone flow processes (such as recharge, ET uptake, and runoff rates) are very hard to measure directly. In the events where soil moisture probes or other monitoring devices are used to evaluate root zone flows over time, these monitoring data are typically only relevant at a local (e.g., parcel) scale and may not completely represent root zone dynamics or their variability at a Basin level. As such, Basin-level root zone flow simulations are typically evaluated and "calibrated" based on comparisons to other existing root zone flow models within the study area along with other qualitative means of analysis.

The following evaluations were made to assess IDC model performance and inform updates to root zone and/or crop parameters in order to improve the reliability of IDC recharge and runoff estimates throughout the Basin:

- Comparison to ARM outputs within common model areas
- Evaluation of watershed-based runoff estimates
- Evaluation of irrigation efficiencies, applied water rates, and ET uptake rates
- Evaluation of normalized recharge, runoff, and ET rates and their spatial distribution

Each of these evaluations are described in greater detail below.

<u>Comparison to ARM Outputs</u>

Monthly and annual outputs from IDC were compiled for Elements also included within the ARM grid, and results between the two models were compared to determine how closely the IDC model replicates core root zone flow components estimated by the ARM. This comparison informed further adjustment of IDC parameters (e.g., scaling of hydraulic conductivity [*K*] and urban pervious area fractions [*PERV*]) to more closely replicate the spatiotemporal trends in recharge, runoff, and total applied water rates observed in the ARM.

An annual comparison of total recharge, runoff, and total applied water rates between the ARM and calibrated IDC models in common areas is shown in **Figures 15 through 17** below. All values are reported in units of acre-feet per year (AFY).

On average, the calibrated IDC model estimates approximately 90% recharge, 106% runoff, and 92% total applied water compared to the ARM in common model areas, indicating that the two models are reasonably comparable. The recharge, runoff, and total applied water rates also track well throughout the 10-year historical model simulation period, indicating that the IDC model does not present any significant change in root zone dynamics relative to the ARM.

Figure 15. Comparison of Annual Recharge Rates between IDC and ARM Models

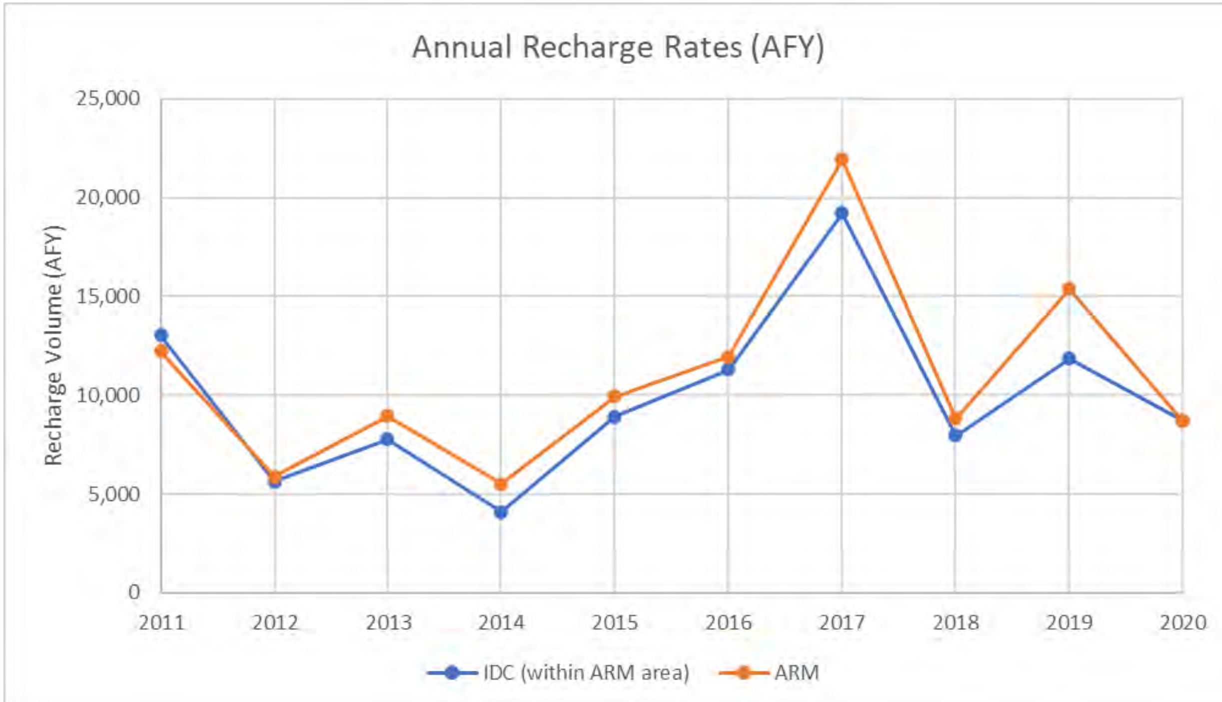


Figure 16. Comparison of Annual Runoff Rates between IDC and ARM Models

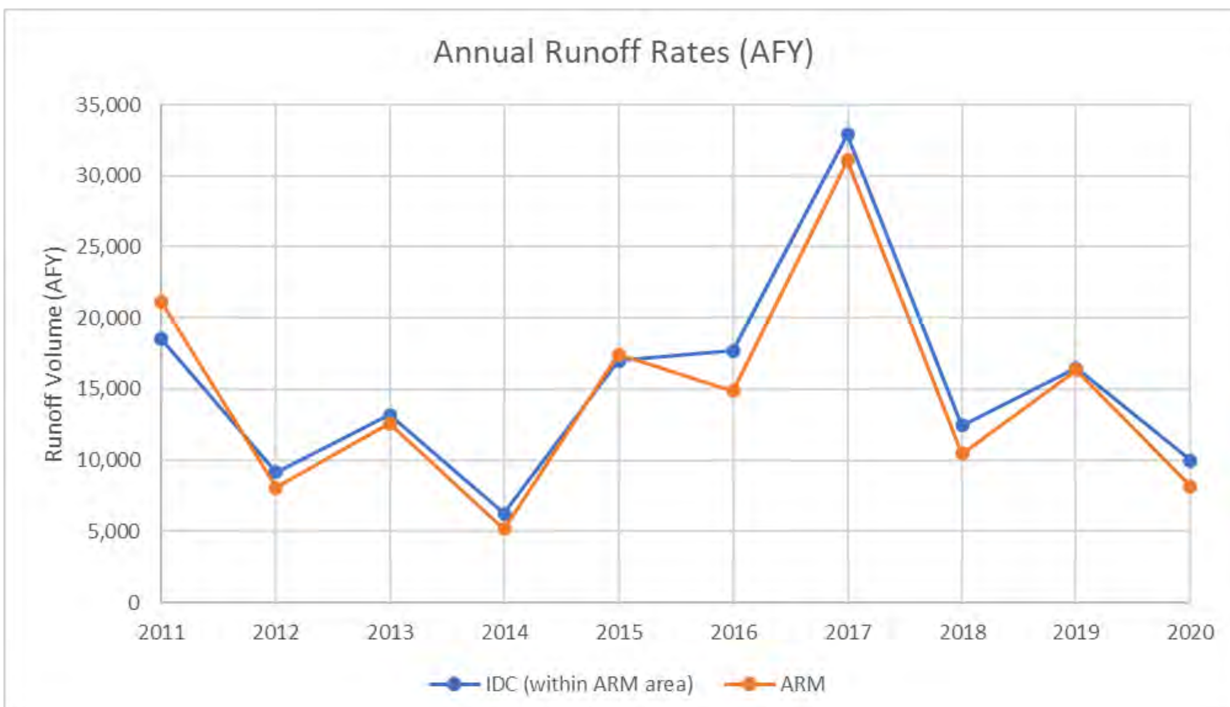
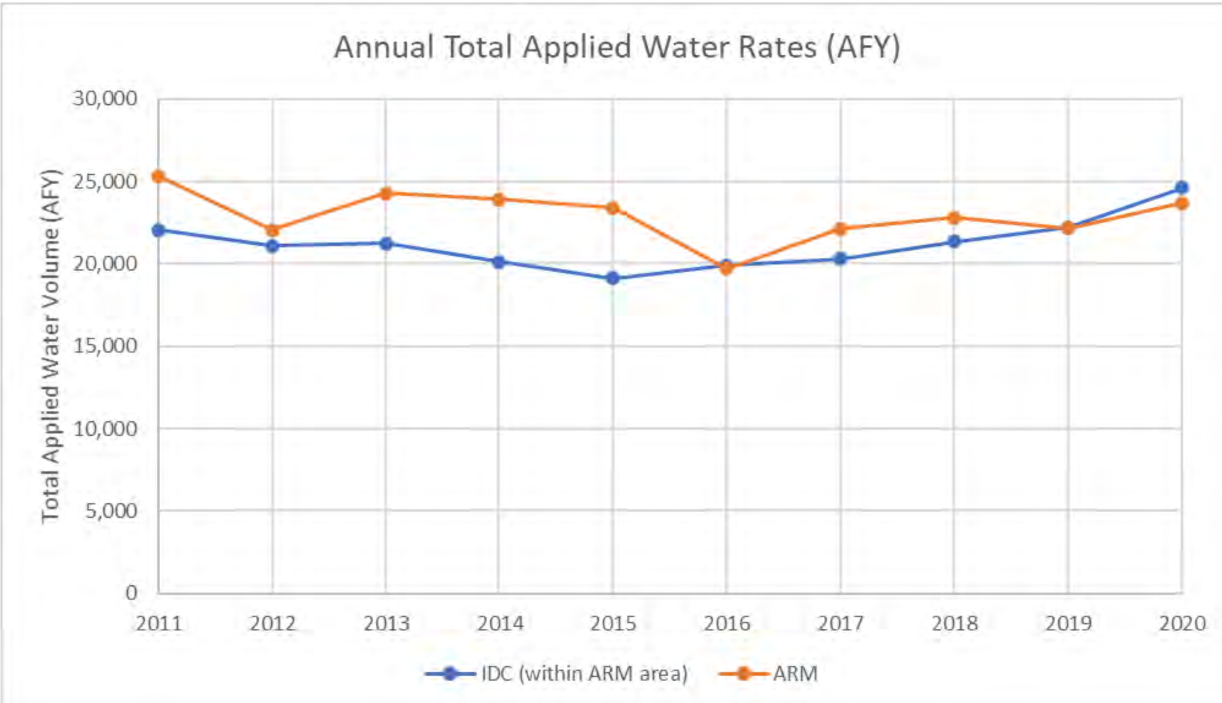


Figure 17. Comparison of Annual Total Applied Water Rates between IDC and ARM Models



Evaluation of Watershed Based Runoff Estimates

Monthly runoff outputs were extracted from the IDC model for three major watersheds that drain into the Arroyo Valle, Arroyo Mocho, and Arroyo Las Positas creeks within the Basin. These values were subsequently compared to analogous outputs from the ARM as well as prior estimates of runoff rates into each major creek based on empirical formulas derived from streamflow records and mass balance assessments. This exercise was completed to evaluate if IDC can reasonably predict contributing runoff to major streams within the Basin relative to other existing methods, and to inform any adjustments to soil parameters accordingly.

A monthly comparison of average runoff rates between the ARM, calibrated IDC model, and empirical formulas are presented for the Arroyo Valle, Arroyo Mocho (Reaches 1 – 3), and Arroyo Las Positas contributing watersheds in **Figures 18 through 20** below. All values are reported in cubic feet per second (cfs).

In the Arroyo Valle watershed, IDC runoff rates track very closely with both the ARM and Zone 7's empirical formula, both in magnitude and in temporal patterns. Average runoff rates from IDC were approximately 95% of the ARM rate, and approximately 91% of the empirical formula-derived rate.

In the Arroyo Mocho watershed, IDC runoff rates track reasonably closely with the ARM, though both IDC and ARM runoff rates are much higher on average than the empirical formula-derived rate. Average runoff rates from IDC were approximately 118% of the ARM rate, and approximately 256% of the empirical formula-derived rate. Based on the graph presented in **Figure 19**, it appears the empirical formula does not simulate as much runoff during low-to-medium intensity precipitation events as the IDC or ARM models, which may explain why average runoff rates from both root zone models are over twice as high as the empirical formula-derived runoff rates.

In the Arroyo Las Positas watershed, IDC runoff rates are significantly lower than reported by the ARM, but are closer to the runoff rates calculated by the empirical formula. Average runoff rates from IDC were approximately 41% of the ARM rate, and 180% of the empirical formula-derived rate. In this instance, it appears the ARM drastically overestimates runoff within the Arroyo Las Positas watershed during high-intensity precipitation events while the IDC model produces more comparable (but still higher) results relative to the empirical formula.

It is important to note that IDC runoff rates are currently being routed “outside the model area”, and thus there is no further tracking of runoff once it leaves an IDC Element. This results in 100% of runoff within a contributing watershed being counted as a source of inflow to the streams outlined above. In reality, runoff will pass over adjacent lands and migrate into and through contributing tributaries to each of these major stream networks, which may result in additional recharge (either on adjacent lands or within the tributaries) before runoff reaches the major stream. A more reliable approach for estimating runoff into major streams would be to link runoff rates from the IDC model to individual stream reaches that are explicitly simulated as part of a larger, integrated groundwater flow model (either using IWFM or MODFLOW’s streamflow routing package). Explicitly simulating runoff into individual stream reaches may produce more accurate estimates of contributing runoff to streamflow within these major stream networks because it allows for a more spatially resolved tracking of runoff migration throughout the Basin and can account for any additional recharge resulting from runoff as it migrates through the Basin before reaching the major stream networks.

Figure 18. Comparison of Average Monthly Runoff Rates in the Arroyo Valle Contributing Watershed

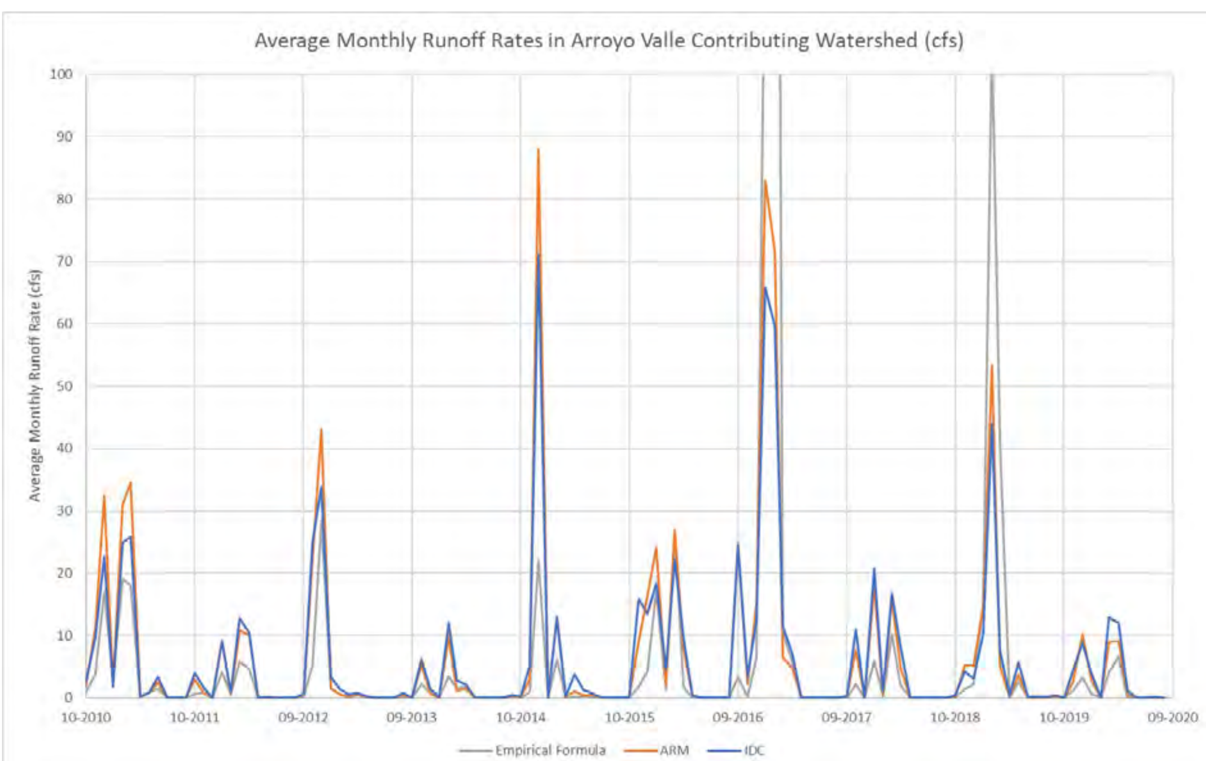


Figure 19. Comparison of Average Monthly Runoff Rates in the Arroyo Mocho Contributing Watershed

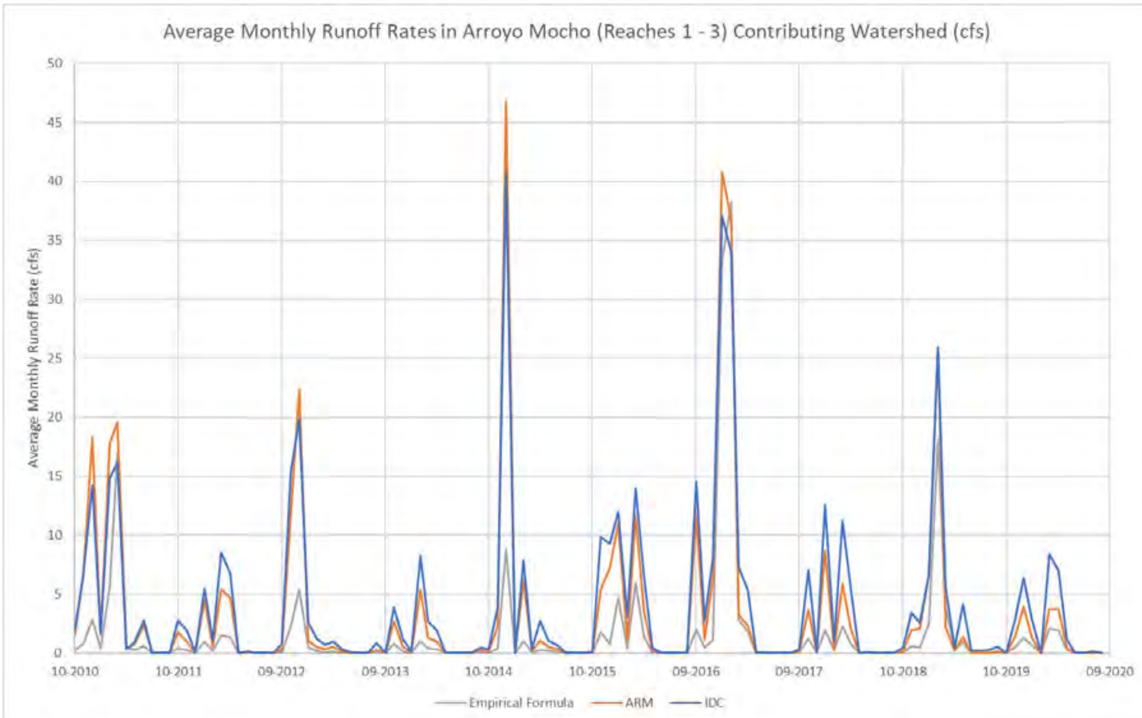
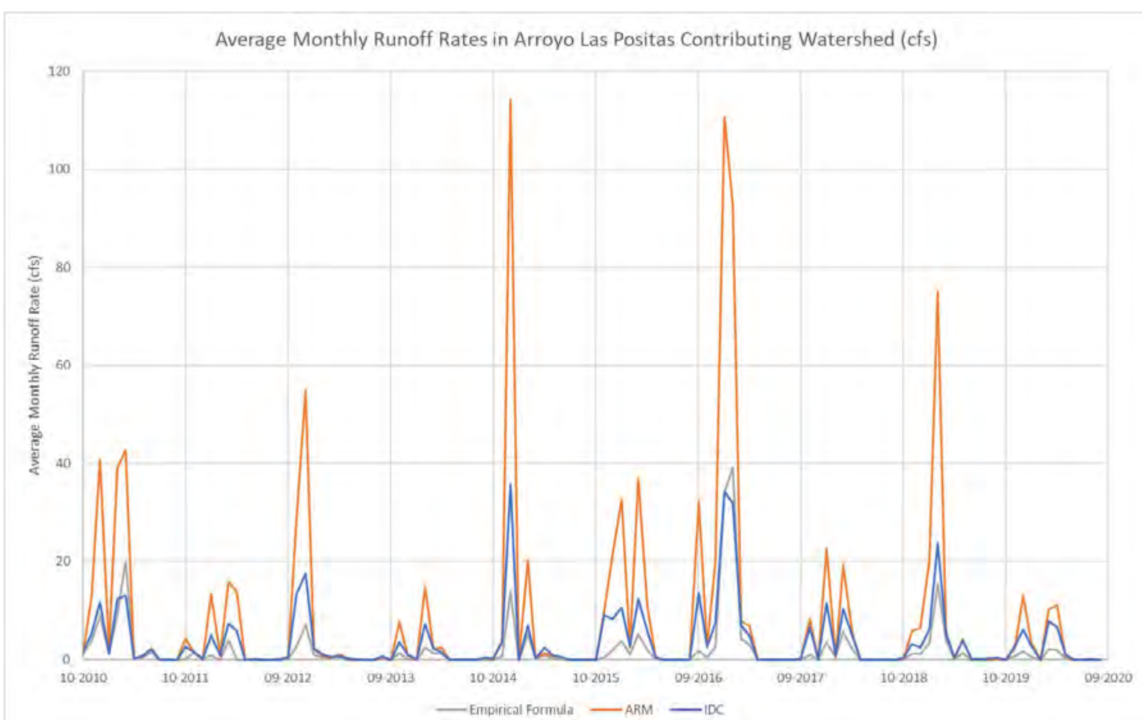


Figure 20. Comparison of Average Monthly Runoff Rates in the Arroyo Las Positas Contributing Watershed



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Evaluation of Irrigation Efficiencies, Applied Water Rates, and ET Uptake Rates

To evaluate the performance of the Non-Ponded Crops component of the IDC model, average irrigation efficiencies, applied water unit rates, and ET uptake rates were calculated for each non-ponded crop being simulated in the IDC model (i.e., Vineyards, Other Ag. [Misc. Field Crops], and Golf Courses). These values were subsequently compared to representative values from relevant studies[15,16,17,18] to inform adjustments to parameters within the non-ponded crops domain (e.g., target soil moisture *[ICTRGSM]*).

The following average irrigation efficiencies were calculated from the calibrated IDC model outputs:

- Vineyards – 84%
- Other Ag. (Misc. Field Crops) – 75%
- Golf Courses – 87%

These irrigation efficiencies are in line with estimates for high-efficiency sprinkler to micro-drip irrigation systems provided in the literature and help to confirm that total applied water rates and applied water recharge rates calculated for non-ponded crops are reasonable.

The following applied water unit rates were calculated from the calibrated IDC model outputs:

- Vineyards – 1.1 feet/yr
- Other Ag. (Misc. Field Crops) – 1.96 ft/yr
- Golf Courses – 4.0 ft/yr

These applied water unit rates are in line with estimates reported in the literature for each crop category. They also help to confirm that Vineyards are being simulated under realistic deficit irrigation practices, which is common practice for wine growers.

The following ET uptake rates (actual ET / potential ET) were calculated from the calibrated IDC model outputs:

- Vineyards – 57%
- Other Ag. (Misc. Field Crops) – 90%
- Golf Courses – 96%

These ET uptake rates help to confirm that actual ET rates are in line with the irrigation practices designed for each crop category. Specifically, they show that Vineyards are being managed under deficit irrigation practices to limit ET uptake in order to provide for more fruit-heavy vines. Other Ag. (Misc. Field Crops) and Golf Courses are being irrigated to near field capacity to maximize plant yields or maintain healthy, green fairways.

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[15] https://aic.ucdavis.edu/publications/Economic%20wine%20and%20water.pdf
[16] https://www.gcsaa.org/docs/default-source/Environment/phase-2-water-use-survey-full-report.pdf?sfvrsn=2b39123e_4
[17] http://www.fao.org/3/t7202e/t7202e08.htm
[18] http://www.itrc.org/reports/pdf/californiacrop.pdf

Evaluation of Normalized Recharge, Runoff, and ET Rates and their Spatial Distribution

Another method used to evaluate IDC model performance at a Basin-level was by comparing normalized recharge, runoff and ET rates to precipitation and total applied water rates. These metrics help inform how inputs to the root zone are being distributed proportionally between recharge, runoff, and ET.

The Basin received approximately 14 inches of precipitation per year on average over WY 2011 – 2020. Based on calibrated IDC model outputs, another 4.3 inches of total applied water was introduced to the root zone from irrigation practices along with 0.3 inches from pipe leakage, equating to 18.6 inches of total inflows to the root zone. Approximately 30% of these inflows became runoff (5.6 inches), 55% of went to satisfying ET requirements (10.3 inches), and the remaining 15% became groundwater recharge (2.8 inches).

Annual Elemental recharge and runoff outputs from IDC are shown in **Figure 21** and **Figure 22**, respectively. Recharge rates (**Figure 21**) are generally highest in: (1) irrigated agricultural areas, (2) pervious urban areas, and (3) topographic low areas and/or areas with soils of high hydraulic conductivity, including within the Arroyo Valle and Arroyo Mocho stream corridors. Runoff rates (**Figure 22**) are generally highest in: (1) impervious urban areas, (2) along foothills and other high-sloping areas, and (3) areas of low hydraulic conductivity, including in the Upland Management Area and North Fringe subarea. The spatial distribution in recharge and runoff intensity closely mimic what is observed in the ARM and are in line with what is expected based on their relationships to soil properties, topography and land and water use characteristics.

RESULTS

The *ZoneBudget* IDC postprocessing tool was used to aggregate outputs from IDC for five distinct Management Area zones. Management Areas within the Basin include the (1) Main Basin, (2) North Fringe, (3) Northeast Fringe, (4) East Fringe, and (5) Upland Management Areas, as shown in **Figure 23.**

Annual results from the IDC model are presented by Water Year and Management Area, along with a Basin-wide summary, in **Tables 2 through 7.**

LIST OF TABLES

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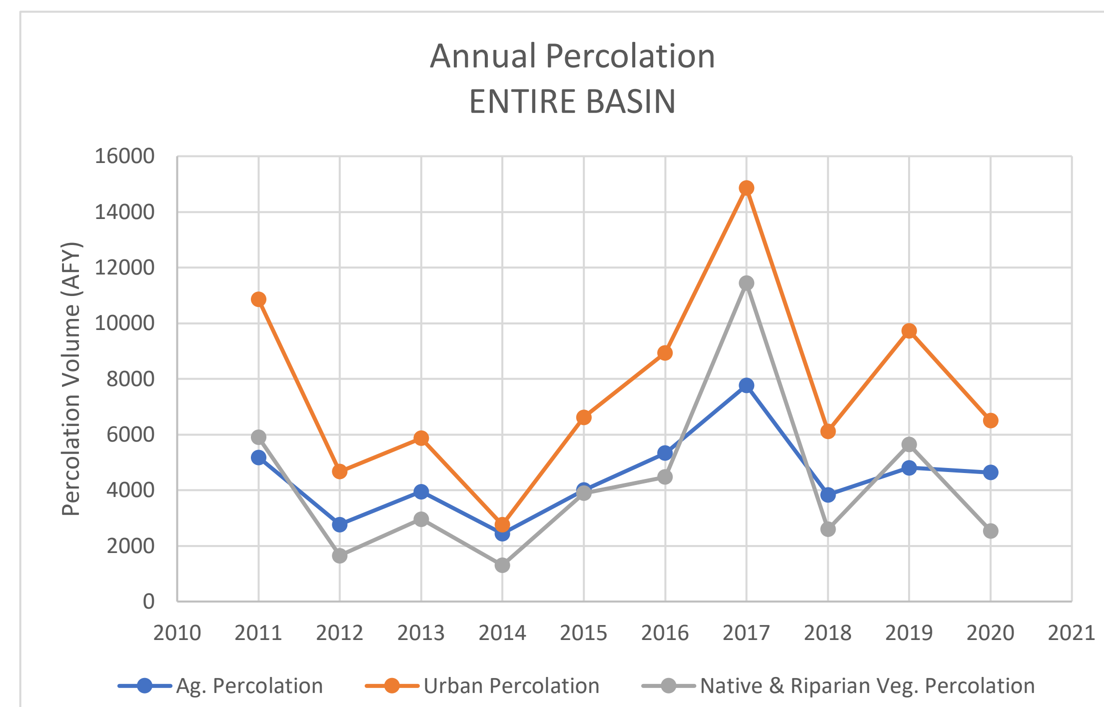
TABLE 2
IDC RESULTS BY WATER YEAR
ENTIRE BASIN SUMMARY

	NON-PONDED AGRICULTURAL AREAS					URBAN AREAS						NATIVE & RIPARIAN AREAS					TOTAL				
Water Year	Ag. Precipitation	Ag. Applied Water	Ag. Actual ET	Ag. Percolation	Ag. Runoff	Urban Precipitation	Urban Applied Water	Generic Soil Moisture:	Urban Actual ET	Urban Percolation	Urban Runoff	Native&Riparian Veg. Precipitation	Native & Riparian Veg. Groundwater Inflow	Native & Riparian Veg. Actual ET	Native & Riparian Veg. Percolation	Native & Riparian Veg. Runoff	Total Precipitation	Total Applied Water	Total Actual ET	Total Percolation	Total Runoff
2011	7,740	8,351	9,946	5,177	1,241	43,630	30,226	2,087	27,023	10,851	24,730	51,350	2,755	41,041	5,900	12,429	102,720	38,577	78,010	21,928	38,400
2012	4,308	9,991	10,990	2,769	463	24,102	28,131	2,010	25,281	4,668	12,586	26,251	2,805	22,364	1,649	4,756	54,662	38,123	58,636	9,085	17,805
2013	5,588	11,120	11,605	3,946	1,105	29,343	27,203	1,924	22,814	5,872	17,471	31,479	2,869	21,151	2,961	9,533	66,409	38,323	55,570	12,779	28,109
2014	3,141	11,148	11,608	2,442	219	17,299	25,633	1,850	21,799	2,758	8,645	18,689	2,456	17,174	1,304	2,689	39,129	36,781	50,581	6,505	11,553
2015	6,288	10,716	11,324	4,001	1,677	34,449	24,362	1,767	20,897	6,623	22,067	37,160	2,872	22,073	3,888	14,404	77,896	35,078	54,295	14,512	38,147
2016	7,561	10,365	11,365	5,333	1,217	42,416	25,099	1,849	25,337	8,932	23,975	45,635	3,044	32,174	4,477	11,720	95,611	35,464	68,877	18,743	36,912
2017	12,292	9,618	11,073	7,766	3,070	68,845	26,011	1,930	26,448	14,862	43,364	74,676	2,949	38,132	11,441	27,966	155,813	35,629	75,653	34,070	74,400
2018	5,332	10,300	10,984	3,838	805	29,934	27,053	2,013	23,382	6,120	16,852	32,516	2,943	24,998	2,593	7,883	67,782	37,353	59,364	12,551	25,540
2019	7,181	9,666	11,065	4,807	970	40,386	28,386	2,096	25,277	9,726	22,574	43,724	2,912	31,063	5,642	9,532	91,291	38,052	67,405	20,175	33,075
2020	4,557	12,279	11,506	4,636	570	25,323	29,157	2,178	23,143	6,497	13,848	26,061	3,004	21,426	2,537	5,384	55,941	41,436	56,074	13,670	19,802
AVERAGE	**6,399**	**10,355**	**11,147**	**4,471**	**1,134**	**35,573**	**27,126**	**1,970**	**24,140**	**7,691**	**20,611**	**38,754**	**2,861**	**27,160**	**4,239**	**10,630**	**80,725**	**37,481**	**62,446**	**16,402**	**32,374**
in/yr	*13.2*	*21.4*	*23.0*	*9.2*	*2.3*	*15.0*	*11.4*	*0.8*	*10.2*	*3.2*	*8.7*	*13.8*	*1.0*	*9.7*	*1.5*	*3.8*	*13.9*	*6.5*	*10.8*	*2.8*	*5.6*

<u>Abbreviations:</u>
Ag. = Agricultural
ET = Evapotranspiration
IDC = Integrated Water Flow Demand Calculator
in/yr = inches per year
Veg. = Vegetation

<u>Notes:</u>
1) All values listed in units of acre-feet per year (AFY) unless specified otherwise.



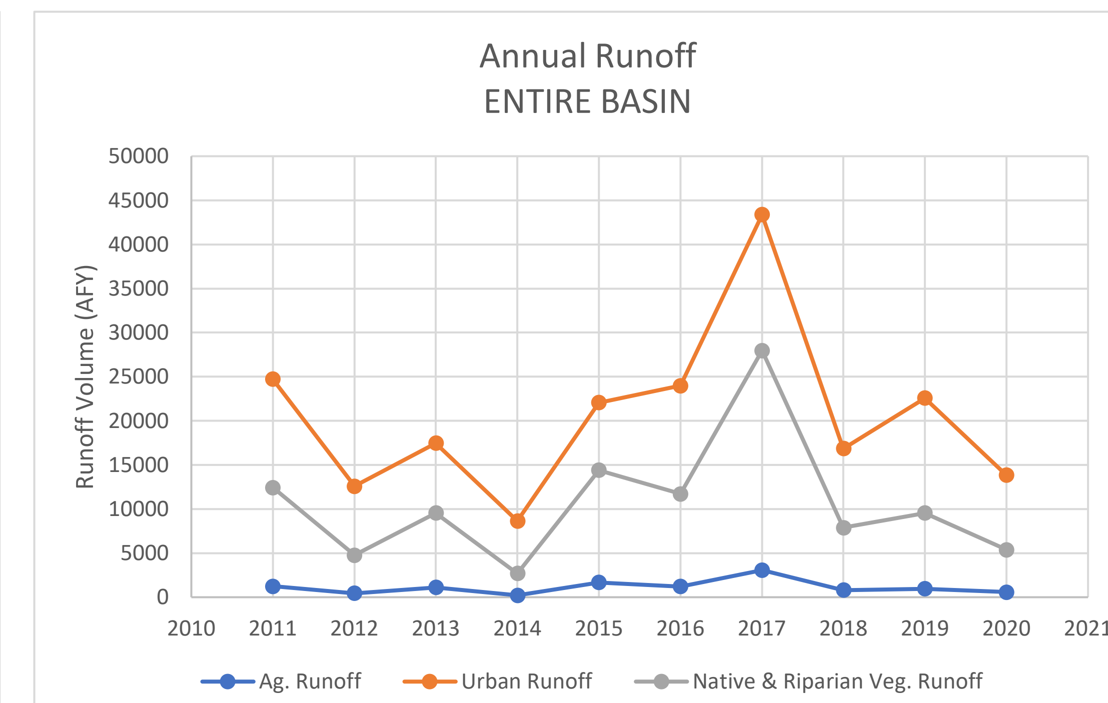
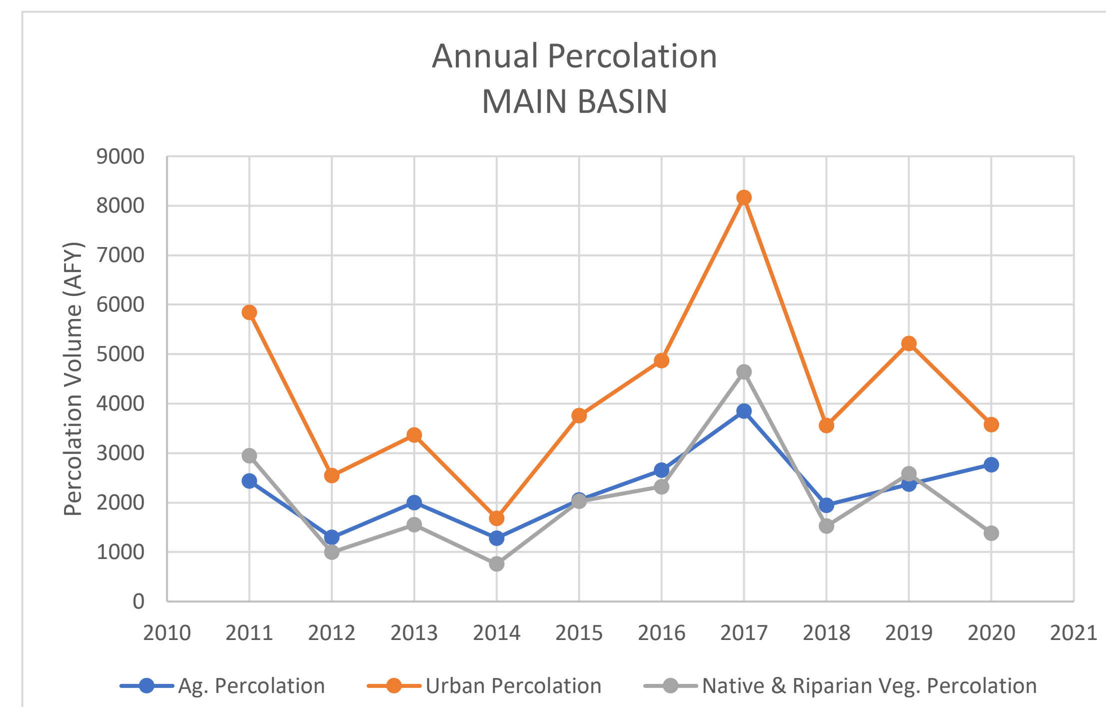


TABLE 3
IDC RESULTS BY WATER YEAR
MAIN BASIN MANAGEMENT AREA

Water Year	NON-PONDED AGRICULTURAL AREAS					URBAN AREAS						NATIVE & RIPARIAN AREAS					TOTAL				
	Ag. Precipitation	Ag. Applied Water	Ag. Actual ET	Ag. Percolation	Ag. Runoff	Urban Precipitation	Urban Applied Water	Generic Soil Moisture:	Urban Actual ET	Urban Percolation	Urban Runoff	Native&Riparian Veg. Precipitation	Native & Riparian Veg. Groundwater Inflow	Native & Riparian Veg. Actual ET	Native & Riparian Veg. Percolation	Native & Riparian Veg. Runoff	Total Precipitation	Total Applied Water	Total Actual ET	Total Percolation	Total Runoff
2011	2,754	3,493	3,676	2,434	187	16,823	13,673	792	10,839	5,840	8,695	8,875	1,898	7,155	2,946	1,355	28,453	17,166	21,670	11,220	10,236
2012	1,367	3,689	3,694	1,294	56	9,023	12,372	789	9,993	2,542	4,360	4,751	1,877	5,031	996	529	15,141	16,062	18,718	4,832	4,946
2013	2,040	4,588	4,363	2,004	234	11,062	11,857	780	9,159	3,362	6,009	5,293	1,929	4,372	1,549	1,139	18,395	16,445	17,894	6,915	7,382
2014	1,129	4,456	4,263	1,284	33	6,482	10,834	777	8,546	1,684	3,077	3,228	1,547	3,725	758	282	10,838	15,290	16,534	3,726	3,391
2015	2,282	4,326	4,180	2,055	366	12,904	10,180	771	8,148	3,753	7,464	6,390	1,938	4,520	2,023	1,815	21,577	14,506	16,848	7,831	9,645
2016	2,832	4,394	4,360	2,654	207	16,073	10,906	825	9,957	4,871	8,234	7,579	2,096	6,074	2,321	1,227	26,484	15,301	20,391	9,846	9,668
2017	4,565	4,066	4,208	3,846	574	25,870	11,327	880	10,323	8,169	14,510	12,724	2,030	6,843	4,640	3,225	43,159	15,393	21,373	16,656	18,309
2018	1,970	4,300	4,184	1,949	138	11,254	11,930	938	9,385	3,556	5,801	5,551	2,026	5,164	1,522	896	18,775	16,230	18,733	7,026	6,835
2019	2,654	4,084	4,201	2,371	164	15,174	12,806	993	10,203	5,216	7,756	7,459	2,005	5,726	2,579	1,075	25,287	16,891	20,130	10,165	8,995
2020	1,705	6,238	5,087	2,766	101	9,465	13,335	1,048	9,618	3,577	4,758	4,325	2,066	4,440	1,383	581	15,495	19,573	19,144	7,726	5,440
AVERAGE	**2,330**	**4,363**	**4,222**	**2,266**	**206**	**13,413**	**11,922**	**859**	**9,617**	**4,257**	**7,066**	**6,618**	**1,941**	**5,305**	**2,072**	**1,212**	**22,360**	**16,286**	**19,144**	**8,594**	**8,485**
in/yr	*13.7*	*25.7*	*24.8*	*13.3*	*1.2*	*14.8*	*13.2*	*0.9*	*10.6*	*4.7*	*7.8*	*14.2*	*4.2*	*11.4*	*4.4*	*2.6*	*13.5*	*9.8*	*11.6*	*5.2*	*5.1*

Abbreviations:
Ag. = Agricultural
ET = Evapotranspiration
IDC = Integrated Water Flow Demand Calculator
in/yr = inches per year
Veg. = Vegetation

Notes:
1) All values listed in units of acre-feet per year (AFY) unless specified otherwise.



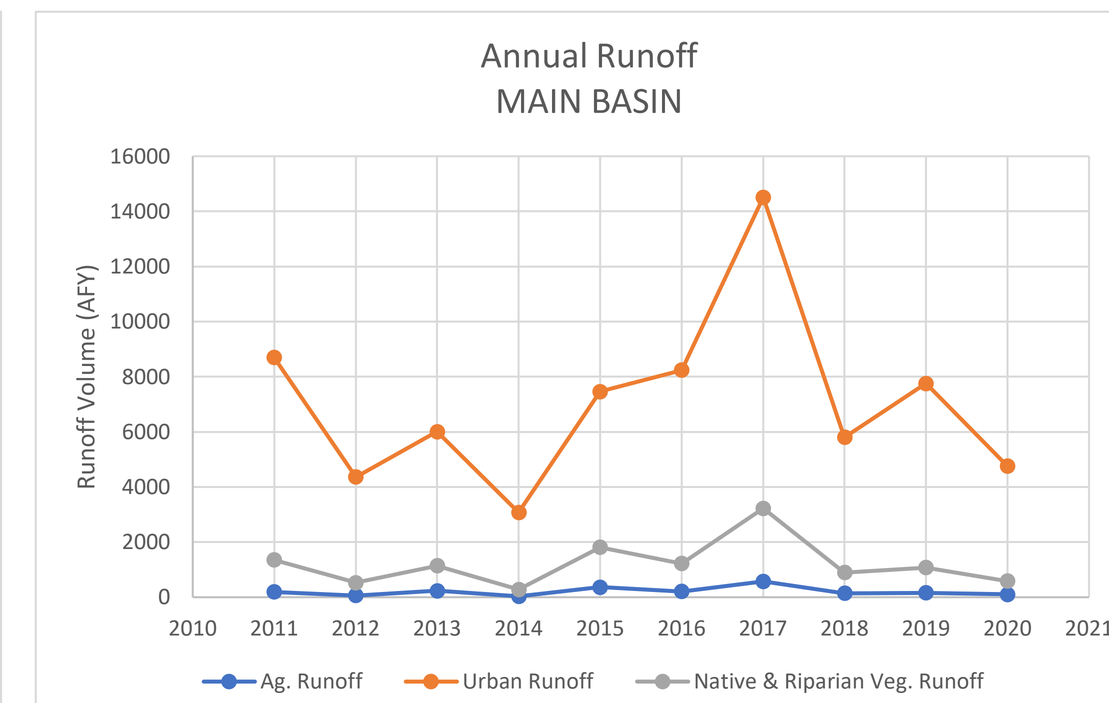
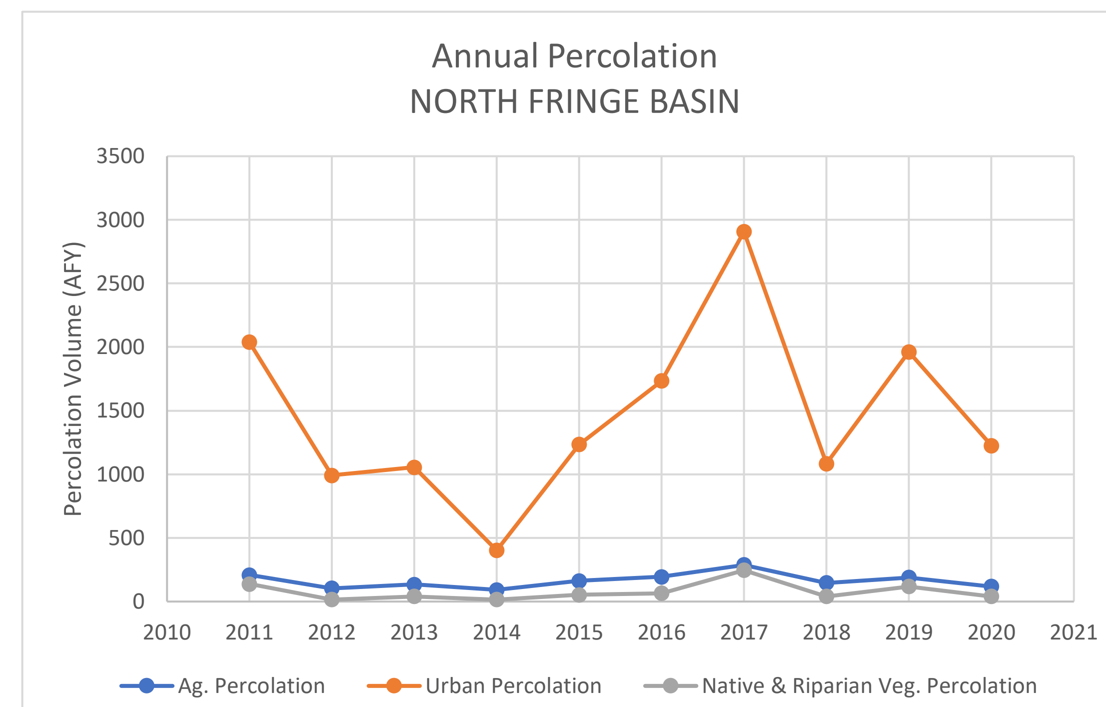


TABLE 4
IDC RESULTS BY WATER YEAR
NORTH FRINGE MANAGEMENT AREA

Water Year	NON-PONDED AGRICULTURAL AREAS					URBAN AREAS						NATIVE & RIPARIAN AREAS					TOTAL				
	Ag. Precipitation	Ag. Applied Water	Ag. Actual ET	Ag. Percolation	Ag. Runoff	Urban Precipitation	Urban Applied Water	Generic Soil Moisture:	Urban Actual ET	Urban Percolation	Urban Runoff	Native&Riparian Veg. Precipitation	Native & Riparian Veg. Groundwater Inflow	Native & Riparian Veg. Actual ET	Native & Riparian Veg. Percolation	Native & Riparian Veg. Runoff	Total Precipitation	Total Applied Water	Total Actual ET	Total Percolation	Total Runoff
2011	395	809	943	208	49	13,999	5,189	305	6,145	2,038	8,908	2,701	0	2,046	137	805	17,095	5,997	9,135	2,383	9,762
2012	200	874	959	104	13	8,096	5,290	305	5,868	992	4,726	801	0	554	15	170	9,097	6,164	7,382	1,111	4,909
2013	243	907	972	133	45	9,826	5,104	304	5,186	1,055	6,474	983	0	544	41	336	11,052	6,011	6,703	1,230	6,855
2014	143	964	1,007	92	6	5,782	4,945	304	4,975	402	3,205	586	0	446	15	103	6,512	5,909	6,428	509	3,314
2015	285	935	981	162	77	11,509	4,700	302	4,826	1,234	8,176	1,169	0	593	53	513	12,964	5,635	6,400	1,448	8,766
2016	379	917	1,054	195	47	13,980	4,804	302	6,136	1,733	8,906	1,553	0	881	66	474	15,912	5,720	8,072	1,993	9,427
2017	617	835	1,022	287	144	22,809	5,266	300	6,653	2,908	16,122	2,504	0	1,121	246	1,137	25,930	6,101	8,796	3,440	17,403
2018	269	929	1,019	146	33	9,915	5,397	297	5,538	1,083	6,231	1,097	0	726	39	328	11,280	6,327	7,283	1,269	6,592
2019	362	883	1,010	189	42	13,380	5,657	295	6,134	1,961	8,342	1,450	0	919	119	399	15,193	6,540	8,064	2,269	8,782
2020	218	540	546	118	33	8,340	5,771	295	5,247	1,225	5,102	751	0	525	40	196	9,310	6,311	6,318	1,383	5,332
AVERAGE	**311**	**859**	**951**	**163**	**49**	**11,764**	**5,212**	**301**	**5,671**	**1,463**	**7,619**	**1,360**	**0**	**836**	**77**	**446**	**13,434**	**6,071**	**7,458**	**1,703**	**8,114**
in/yr	*15.6*	*43.2*	*47.8*	*8.2*	*2.5*	*17.0*	*7.5*	*0.4*	*8.2*	*2.1*	*11.0*	*16.3*	*0.0*	*10.0*	*0.9*	*5.4*	*16.8*	*7.6*	*9.3*	*2.1*	*10.2*

Abbreviations:
Ag. = Agricultural
ET = Evapotranspiration
IDC = Integrated Water Flow Demand Calculator
in/yr = inches per year
Veg. = Vegetation

Notes:
1) All values listed in units of acre-feet per year (AFY) unless specified otherwise.



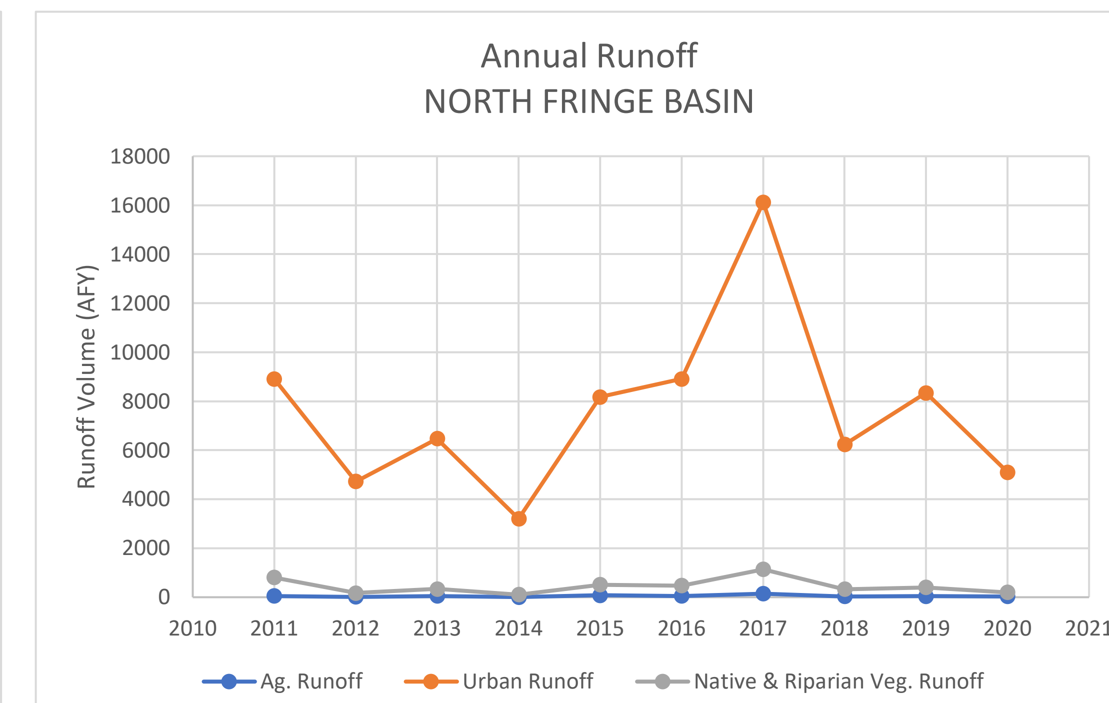
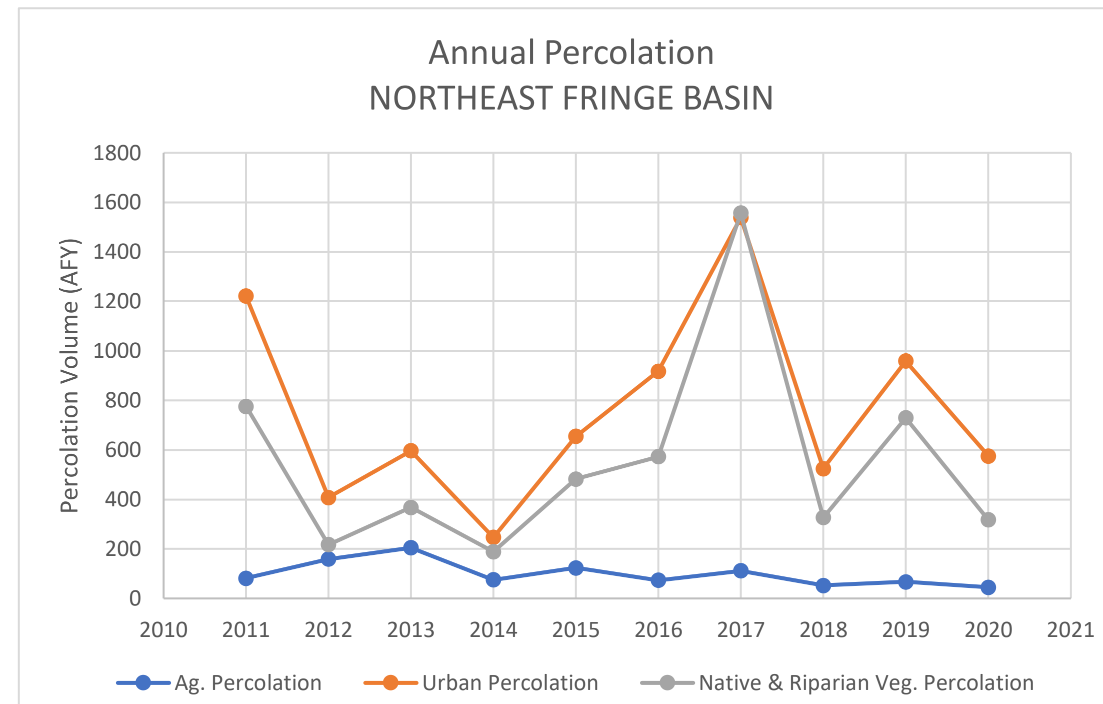


TABLE 5
IDC RESULTS BY WATER YEAR
NORTHEAST FRINGE MANAGEMENT AREA

	NON-PONDED AGRICULTURAL AREAS					URBAN AREAS						NATIVE & RIPARIAN AREAS					TOTAL				
Water Year	**Ag. Precipitation**	**Ag. Applied Water**	**Ag. Actual ET**	**Ag. Percolation**	**Ag. Runoff**	**Urban Precipitation**	**Urban Applied Water**	**Generic Soil Moisture:**	**Urban Actual ET**	**Urban Percolation**	**Urban Runoff**	**Native&Riparian Veg. Precipitation**	**Native & Riparian Veg. Groundwater Inflow**	**Native & Riparian Veg. Actual ET**	**Native & Riparian Veg. Percolation**	**Native & Riparian Veg. Runoff**	**Total Precipitation**	**Total Applied Water**	**Total Actual ET**	**Total Percolation**	**Total Runoff**
2011	149	215	268	82	19	5,700	5,500	588	4,551	1,221	3,447	8,805	699	7,771	775	2,166	14,654	5,715	12,590	2,078	5,633
2012	193	732	733	159	9	3,042	5,042	518	4,167	408	1,734	4,562	757	4,200	217	854	7,798	5,774	9,100	784	2,596
2013	235	794	787	205	33	3,680	5,123	449	3,833	596	2,363	5,559	767	4,112	367	1,720	9,474	5,917	8,732	1,169	4,115
2014	97	670	689	75	3	2,180	5,024	382	3,760	247	1,203	3,305	796	3,451	189	479	5,582	5,693	7,900	511	1,685
2015	193	646	671	123	43	4,341	4,918	313	3,622	654	2,959	6,579	774	4,359	482	2,588	11,113	5,563	8,652	1,260	5,589
2016	131	273	317	74	15	5,629	4,723	315	4,215	918	3,419	7,879	774	6,002	572	2,051	13,640	4,996	10,533	1,564	5,484
2017	214	252	308	112	46	9,228	4,565	318	4,208	1,538	6,167	12,787	749	7,096	1,556	4,875	22,228	4,817	11,612	3,207	11,088
2018	93	276	307	52	10	4,014	4,630	320	3,775	524	2,424	5,562	748	4,627	326	1,362	9,670	4,907	8,708	903	3,796
2019	125	261	307	67	12	5,432	4,489	325	3,851	959	3,265	7,466	740	5,777	730	1,619	13,024	4,751	9,935	1,756	4,897
2020	93	201	212	45	11	3,411	4,284	327	3,444	576	2,003	4,477	765	4,061	317	930	7,981	4,485	7,717	938	2,944
AVERAGE	**152**	**432**	**460**	**100**	**20**	**4,666**	**4,830**	**385**	**3,943**	**764**	**2,898**	**6,698**	**757**	**5,146**	**553**	**1,864**	**11,516**	**5,262**	**9,548**	**1,417**	**4,783**
in/yr	*11.2*	*31.7*	*33.7*	*7.3*	*1.5*	*12.2*	*12.6*	*1.0*	*10.3*	*2.0*	*7.6*	*12.9*	*1.5*	*9.9*	*1.1*	*3.6*	*12.5*	*5.7*	*10.4*	*1.5*	*5.2*

Abbreviations:
Ag. = Agricultural
ET = Evapotranspiration
IDC = Integrated Water Flow Demand Calculator
in/yr = inches per year
Veg. = Vegetation

Notes:
1) All values listed in units of acre-feet per year (AFY) unless specified otherwise.



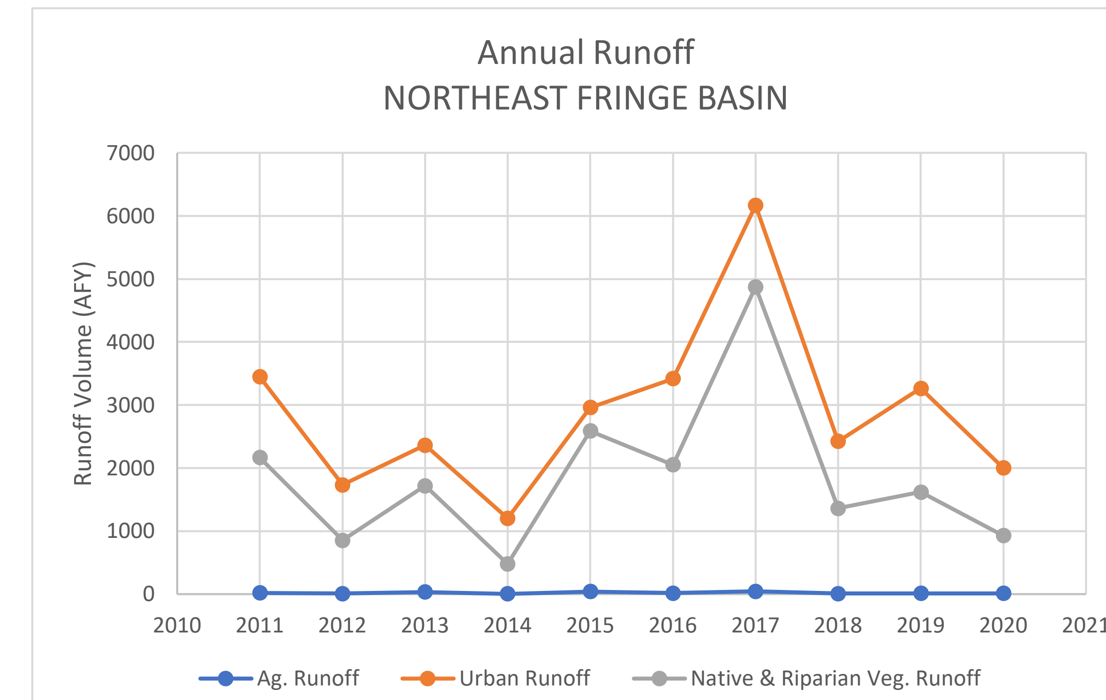
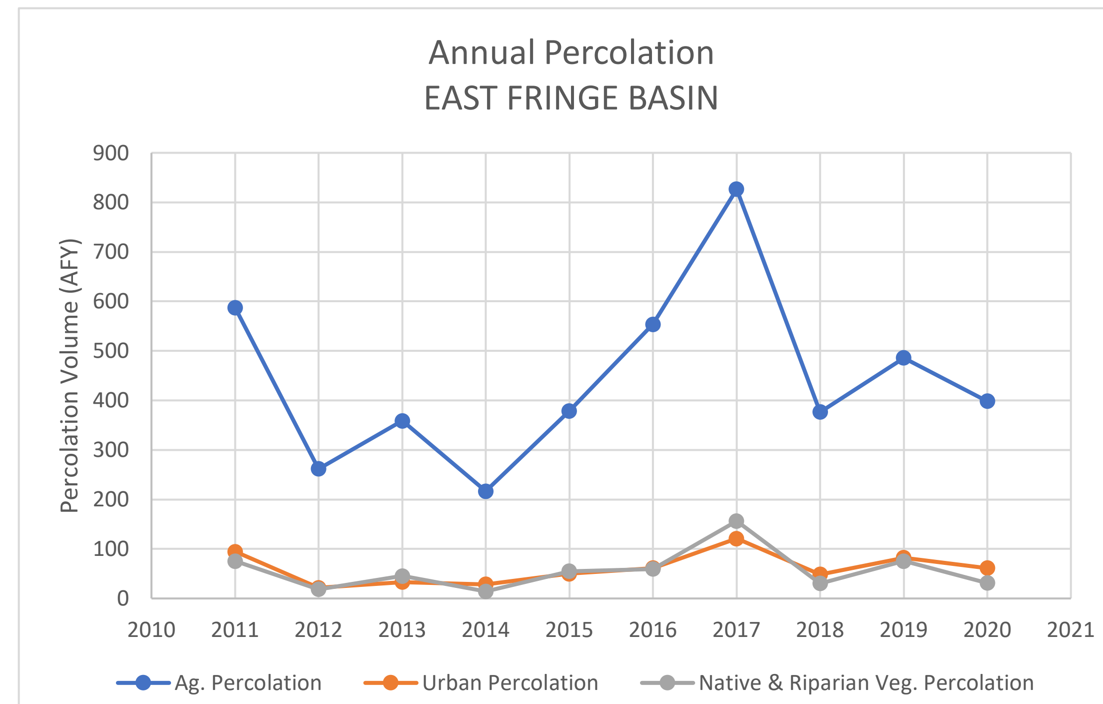


TABLE 6
IDC RESULTS BY WATER YEAR
EAST FRINGE MANAGEMENT AREA

	NON-PONDED AGRICULTURAL AREAS					URBAN AREAS						NATIVE & RIPARIAN AREAS					TOTAL				
Water Year	Ag. Precipitation	Ag. Applied Water	Ag. Actual ET	Ag. Percolation	Ag. Runoff	Urban Precipitation	Urban Applied Water	Generic Soil Moisture:	Urban Actual ET	Urban Percolation	Urban Runoff	Native&Riparian Veg. Precipitation	Native & Riparian Veg. Groundwater Inflow	Native & Riparian Veg. Actual ET	Native & Riparian Veg. Percolation	Native & Riparian Veg. Runoff	Total Precipitation	Total Applied Water	Total Actual ET	Total Percolation	Total Runoff
2011	894	640	863	587	139	295	331	17	305	95	102	504	0	401	75	91	1,693	971	1,569	757	333
2012	476	746	914	261	46	111	208	16	186	22	30	314	0	238	19	38	901	954	1,338	302	115
2013	578	774	875	359	117	135	193	16	167	33	53	382	0	234	45	95	1,094	967	1,276	437	264
2014	341	818	921	217	21	99	221	15	192	28	23	206	0	174	14	19	645	1,039	1,288	259	63
2015	678	774	892	379	181	196	205	15	181	50	90	409	0	225	55	134	1,284	979	1,298	484	405
2016	811	770	896	554	132	241	224	18	238	62	80	523	0	369	59	99	1,576	994	1,502	675	311
2017	1,322	733	888	826	341	426	248	22	273	121	191	820	0	417	156	246	2,568	981	1,577	1,104	778
2018	575	767	880	377	85	185	269	26	240	48	65	357	0	263	30	64	1,117	1,036	1,383	456	214
2019	775	710	899	486	100	249	290	29	266	82	83	480	0	323	76	76	1,504	1,001	1,489	644	260
2020	471	954	981	399	53	161	323	33	258	61	54	290	0	221	31	42	922	1,277	1,460	491	148
AVERAGE	**692**	**769**	**901**	**444**	**122**	**210**	**251**	**21**	**231**	**60**	**77**	**428**	**0**	**286**	**56**	**90**	**1,330**	**1,020**	**1,418**	**561**	**289**
in/yr	*11.9*	*13.2*	*15.5*	*7.7*	*2.1*	*12.0*	*14.4*	*1.2*	*13.2*	*3.4*	*4.4*	*11.8*	*0.0*	*7.9*	*1.5*	*2.5*	*11.9*	*9.1*	*12.7*	*5.0*	*2.6*

Abbreviations:
Ag. = Agricultural
ET = Evapotranspiration
IDC = Integrated Water Flow Demand Calculator
in/yr = inches per year
Veg. = Vegetation

Notes:
1) All values listed in units of acre-feet per year (AFY) unless specified otherwise.



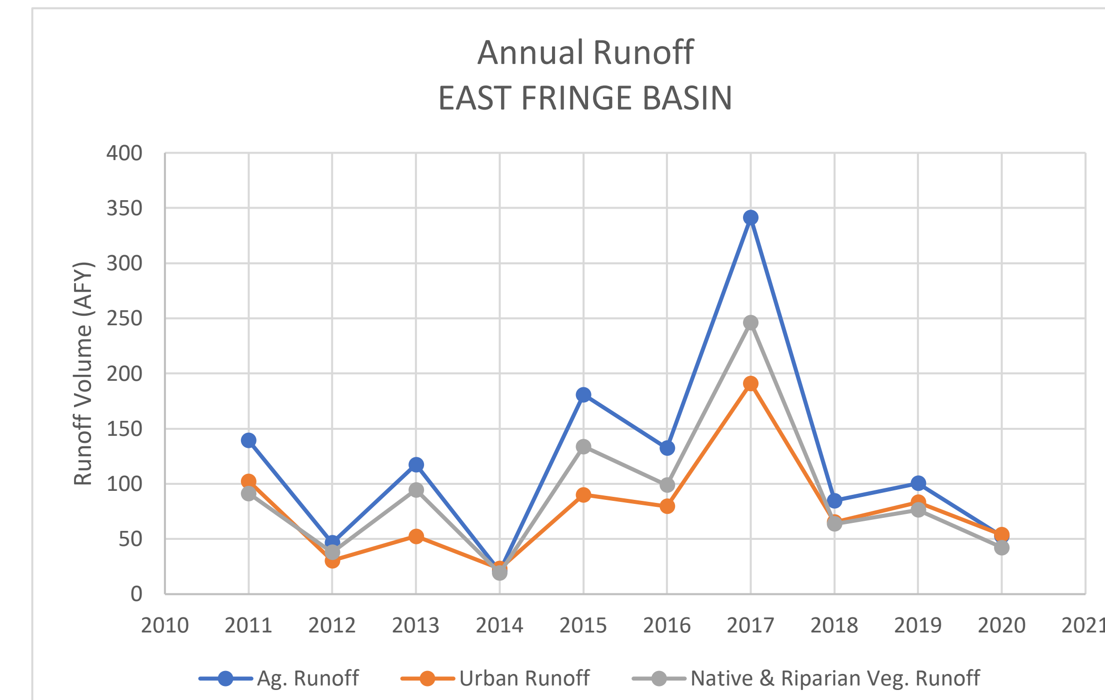
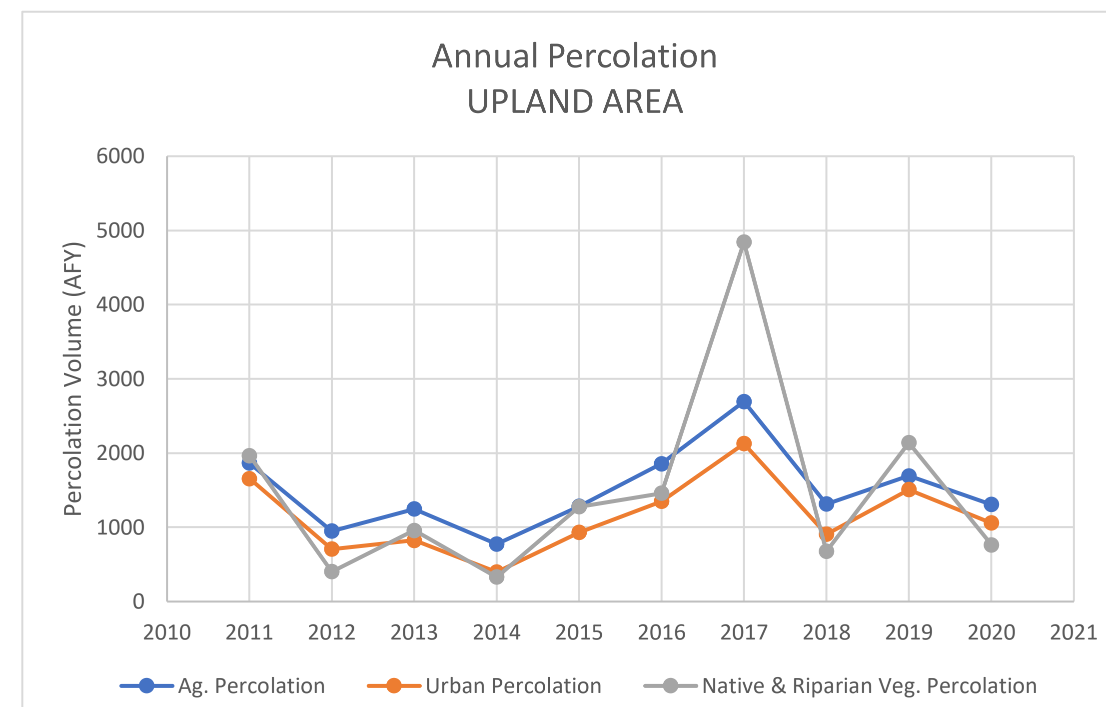


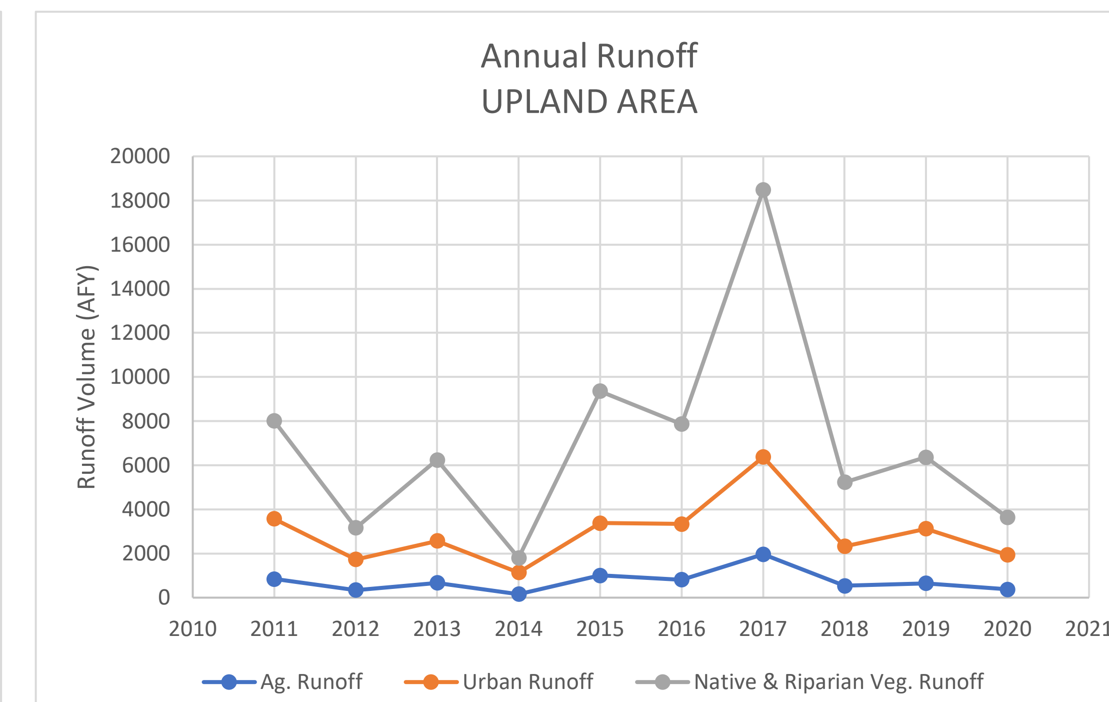
TABLE 7
IDC RESULTS BY WATER YEAR
UPLAND MANAGEMENT AREA

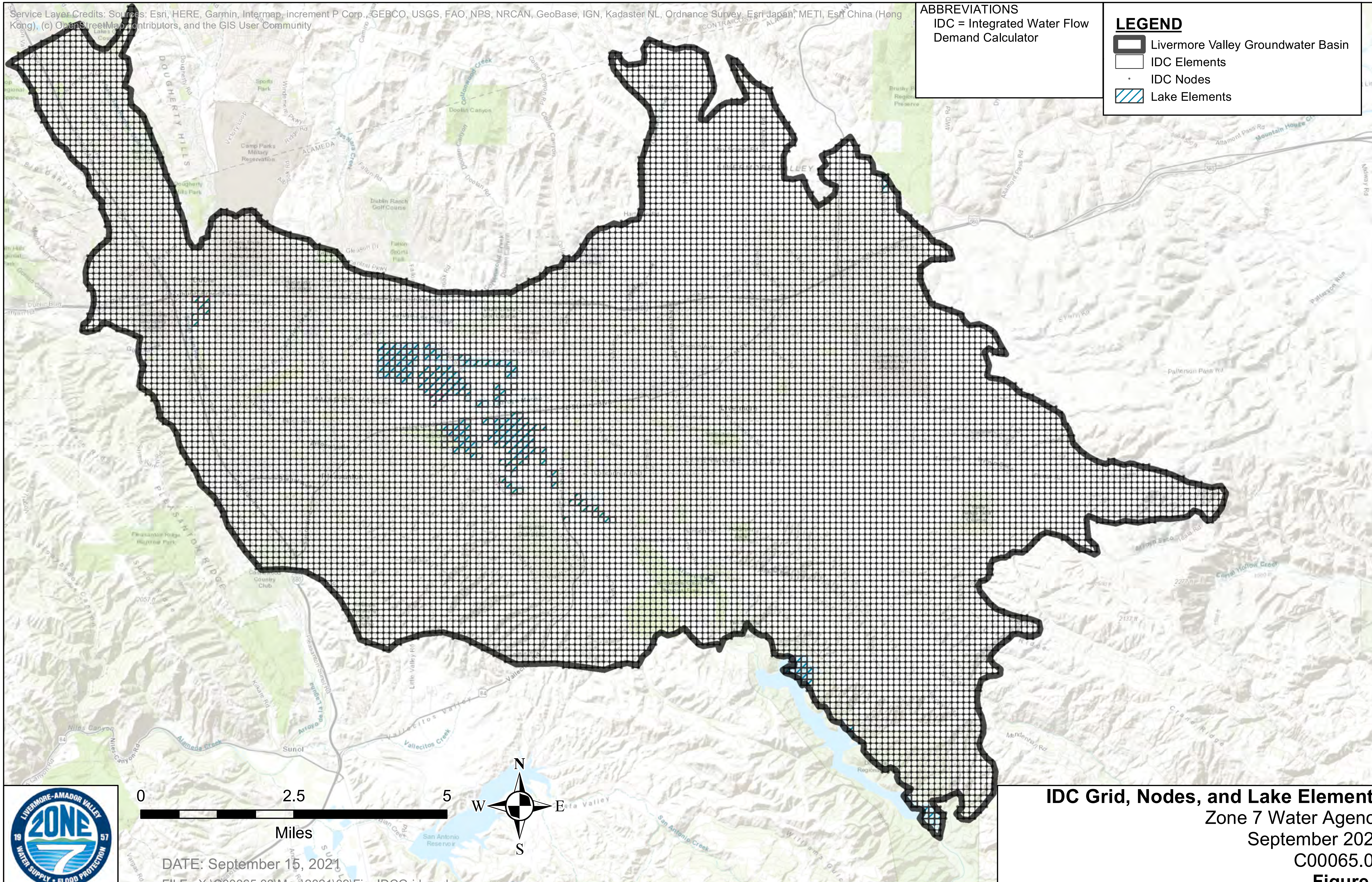
Water Year	NON-PONDED AGRICULTURAL AREAS					URBAN AREAS						NATIVE & RIPARIAN AREAS					TOTAL				
	Ag. Precipitation	Ag. Applied Water	Ag. Actual ET	Ag. Percolation	Ag. Runoff	Urban Precipitation	Urban Applied Water	Generic Soil Moisture:	Urban Actual ET	Urban Percolation	Urban Runoff	Native&Riparian Veg. Precipitation	Native & Riparian Veg. Groundwater Inflow	Native & Riparian Veg. Actual ET	Native & Riparian Veg. Percolation	Native & Riparian Veg. Runoff	Total Precipitation	Total Applied Water	Total Actual ET	Total Percolation	Total Runoff
2011	3,548	3,194	4,195	1,865	846	6,813	5,533	386	5,183	1,658	3,577	30,465	159	23,667	1,966	8,013	40,826	8,727	33,046	5,489	12,436
2012	2,072	3,949	4,690	950	339	3,830	5,219	382	5,067	705	1,735	15,823	171	12,341	402	3,165	21,725	9,168	22,098	2,056	5,240
2013	2,491	4,056	4,609	1,246	676	4,640	4,926	376	4,468	825	2,574	19,263	173	11,889	959	6,243	26,394	8,982	20,965	3,029	9,492
2014	1,431	4,240	4,728	775	156	2,756	4,610	372	4,326	397	1,138	11,364	113	9,377	328	1,806	15,552	8,849	18,430	1,500	3,100
2015	2,849	4,036	4,600	1,282	1,010	5,498	4,359	367	4,119	931	3,378	22,612	160	12,376	1,275	9,355	30,960	8,395	21,095	3,488	13,742
2016	3,408	4,011	4,738	1,857	815	6,493	4,442	388	4,792	1,349	3,337	28,100	175	18,849	1,460	7,870	38,000	8,453	28,378	4,666	12,022
2017	5,572	3,733	4,648	2,695	1,965	10,513	4,604	410	4,991	2,126	6,374	45,842	169	22,656	4,843	18,483	61,927	8,336	32,295	9,663	26,822
2018	2,424	4,028	4,594	1,314	539	4,566	4,826	432	4,445	908	2,331	19,949	169	14,219	676	5,233	26,940	8,854	23,257	2,898	8,104
2019	3,265	3,727	4,648	1,694	651	6,150	5,143	454	4,821	1,508	3,128	26,869	167	18,317	2,139	6,363	36,283	8,870	27,787	5,341	10,142
2020	2,069	4,347	4,680	1,307	373	3,947	5,443	475	4,576	1,059	1,931	16,217	173	12,178	765	3,635	22,233	9,790	21,434	3,131	5,938
AVERAGE	**2,913**	**3,932**	**4,613**	**1,498**	**737**	**5,521**	**4,911**	**404**	**4,679**	**1,147**	**2,950**	**23,650**	**163**	**15,587**	**1,481**	**7,017**	**32,084**	**8,843**	**24,879**	**4,126**	**10,704**
in/yr	*13.1*	*17.7*	*20.7*	*6.7*	*3.3*	*14.6*	*13.0*	*1.1*	*12.3*	*3.0*	*7.8*	*14.0*	*0.1*	*9.2*	*0.9*	*4.1*	*13.9*	*3.8*	*10.8*	*1.8*	*4.6*

Abbreviations:
- Ag. = Agricultural
- ET = Evapotranspiration
- IDC = Integrated Water Flow Demand Calculator
- in/yr = inches per year
- Veg. = Vegetation

Notes:
1) All values listed in units of acre-feet per year (AFY) unless specified otherwise.







IDC Grid, Nodes, and Lake Elements

Zone 7 Water Agency

September 2021

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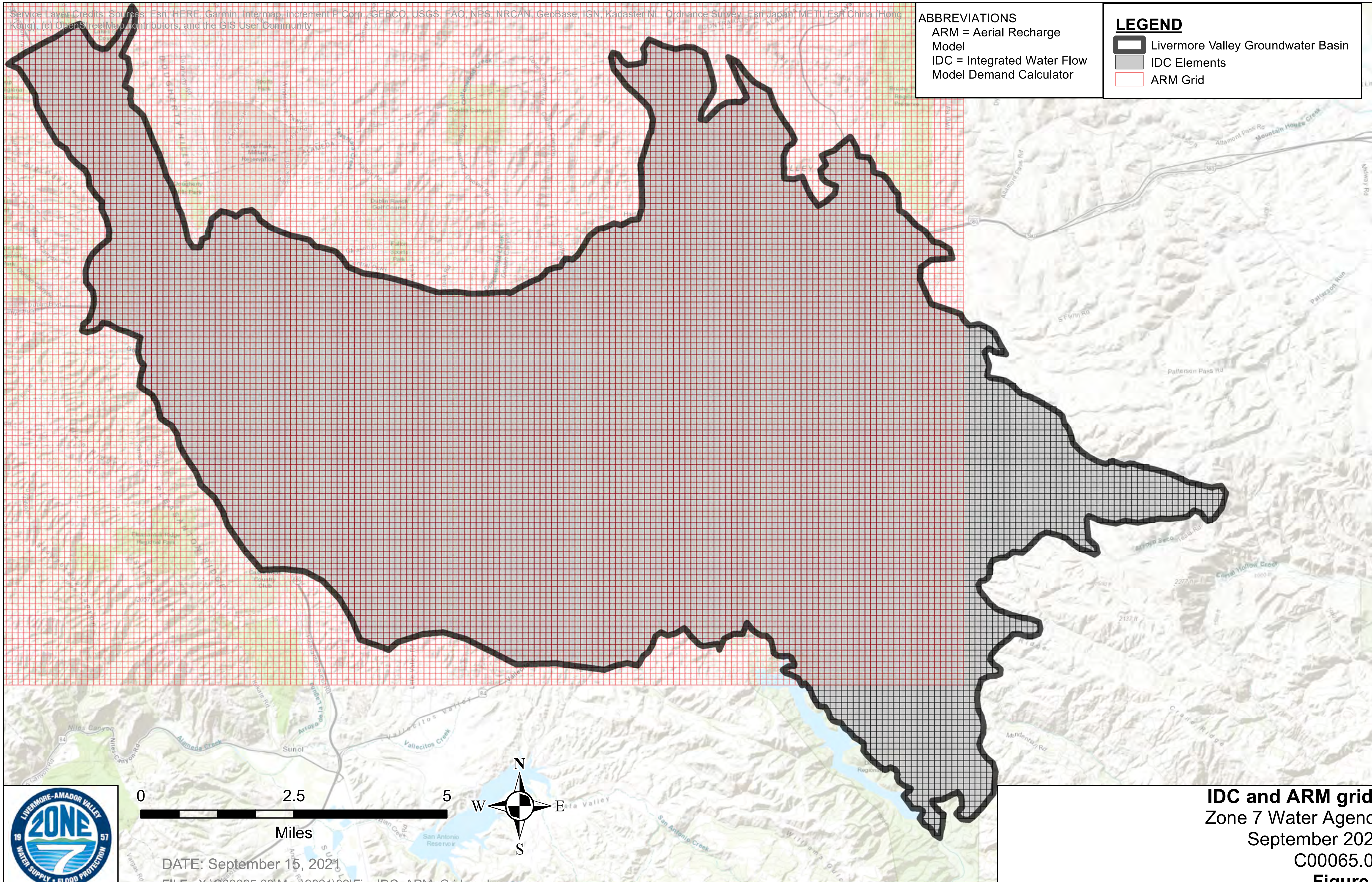
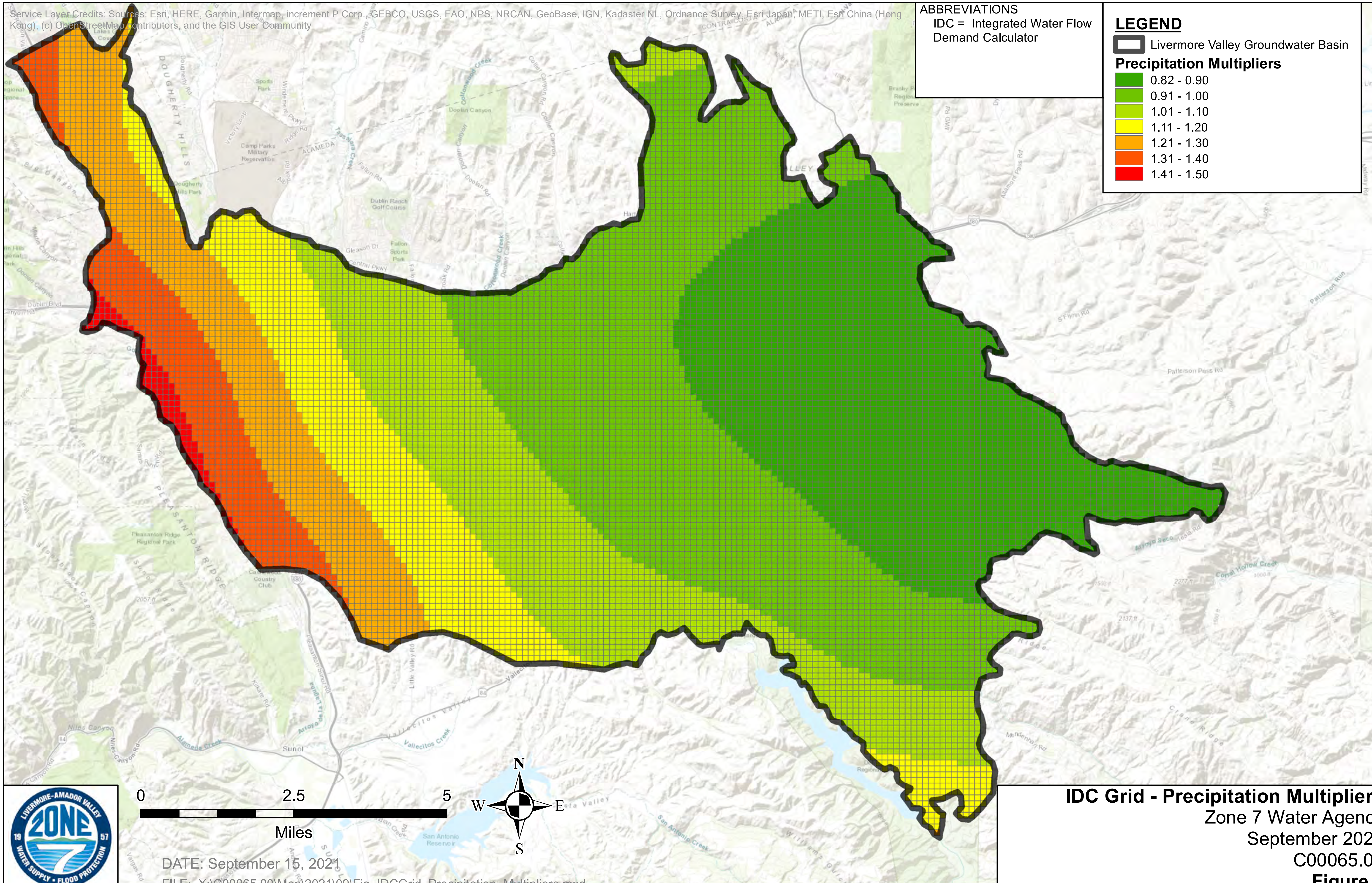
Figure 2



IDC and ARM grids
Zone 7 Water Agency
September 2021
C00065.00
Figure 3



IDC Grid - Precipitation Multipliers
Zone 7 Water Agency
September 2021
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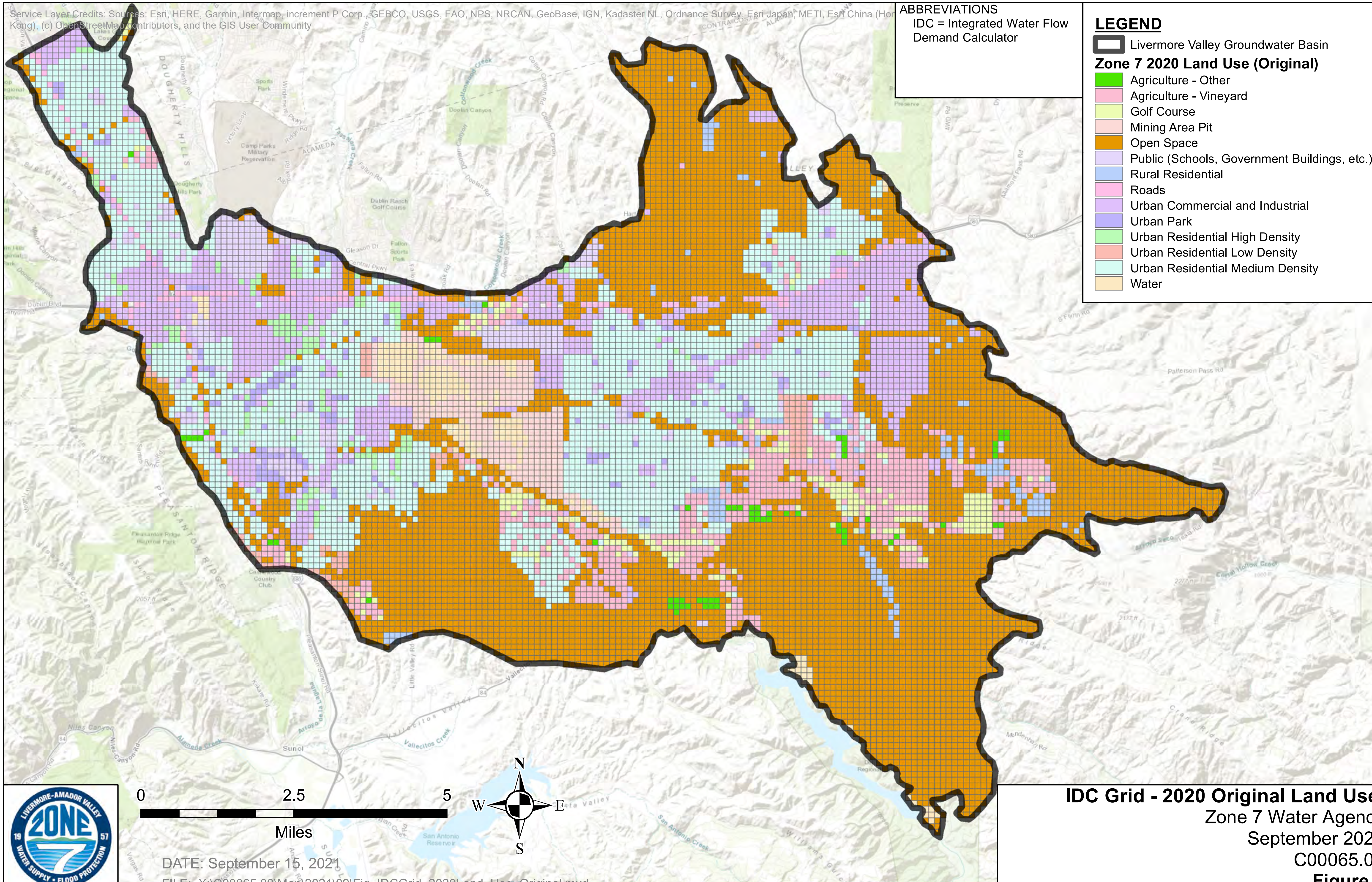
Figure 4



IDC Grid - 2020 Original Land Use

Zone 7 Water Agency

September 2021

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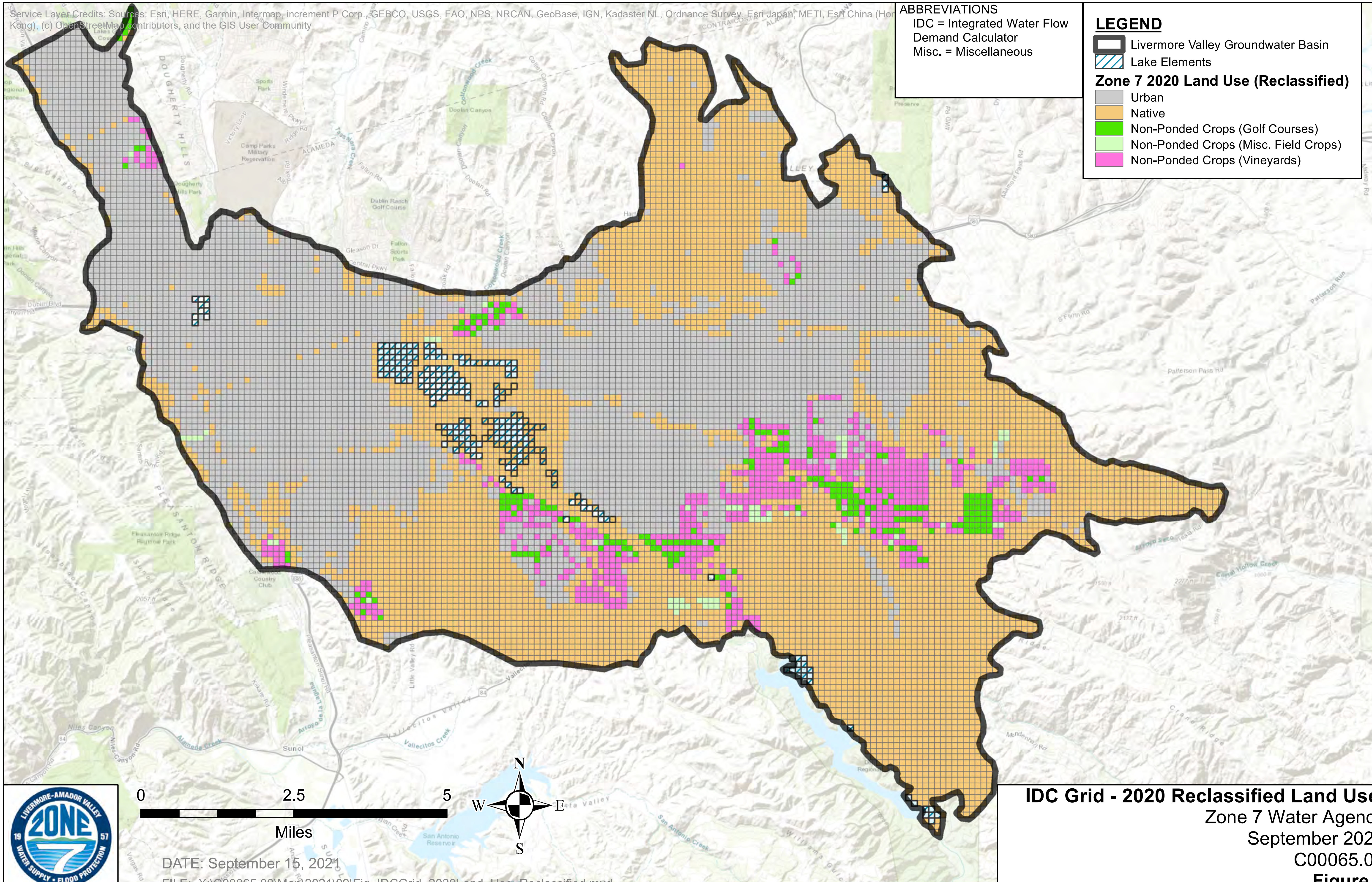
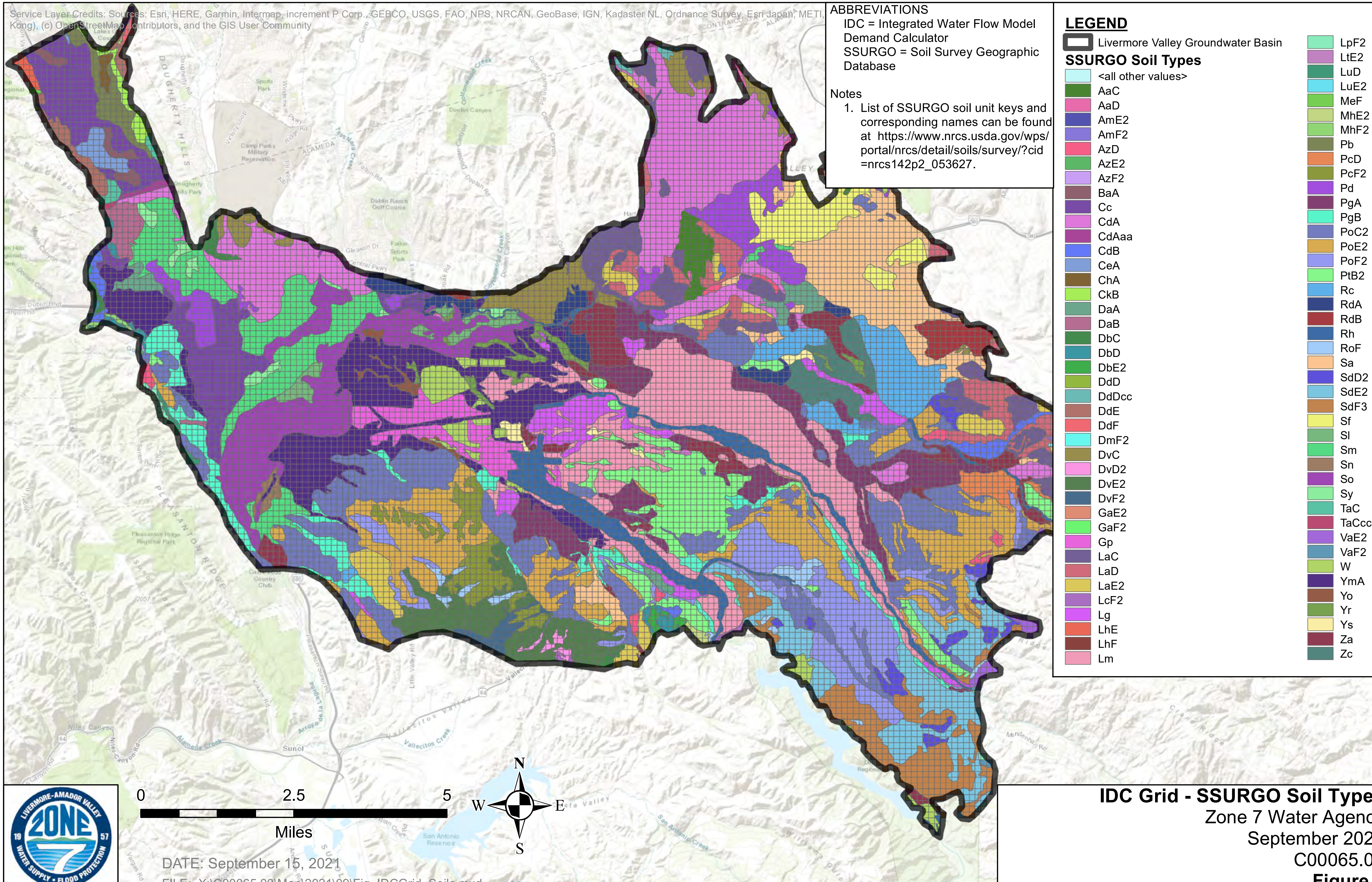
Figure 5



IDC Grid - 2020 Reclassified Land Use
Zone 7 Water Agency
September 2021
C00065.00
Figure 7



IDC Grid - SSURGO Soil Types

Zone 7 Water Agency

September 2021

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Figure 9

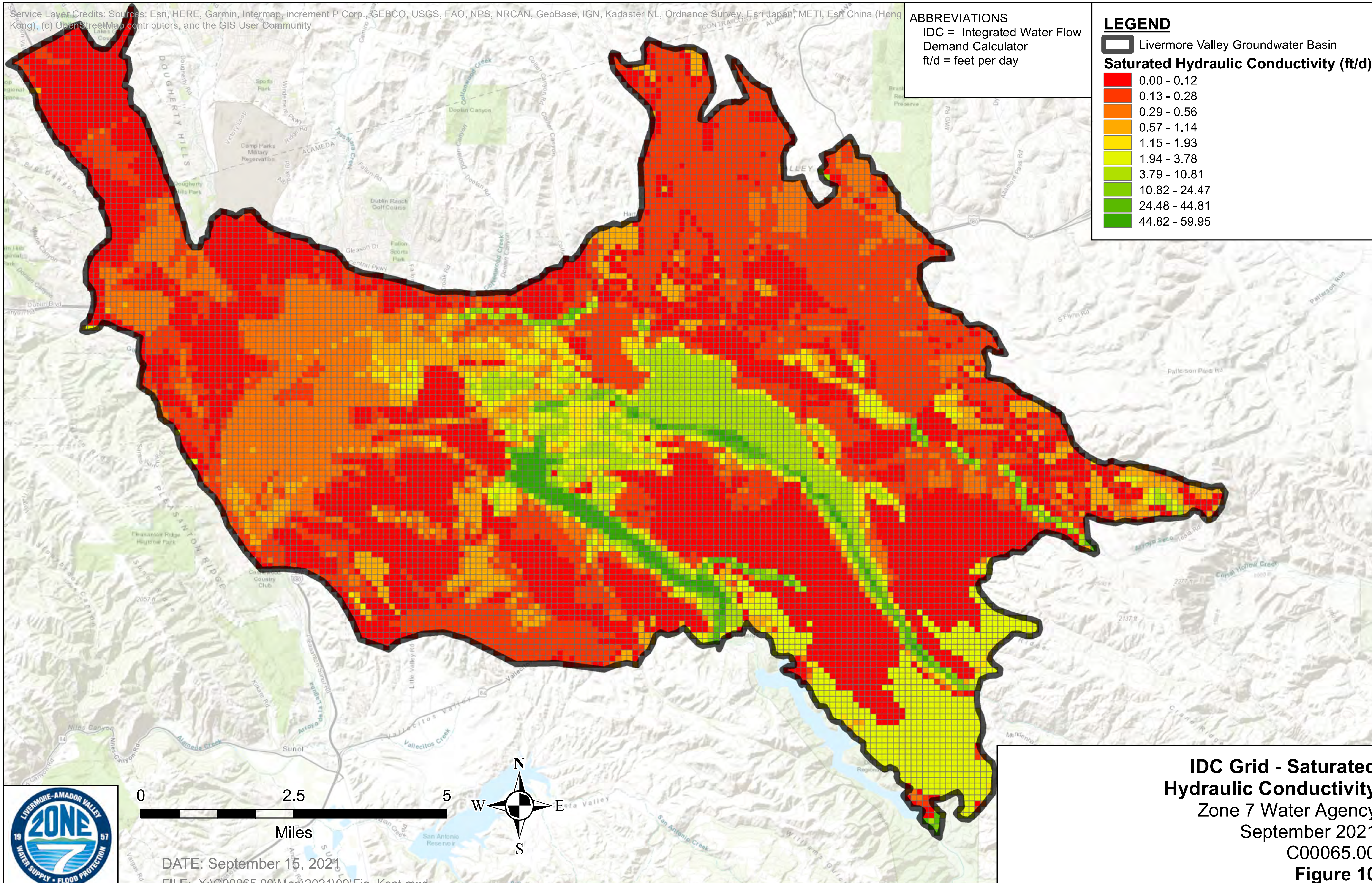
Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community
ABBREVIATIONS
IDC = Integrated Water Flow Demand Calculator
ft/d = feet per day
LEGEND
Livermore Valley Groundwater Basin
Saturated Hydraulic Conductivity (ft/d)
0.00 - 0.12
0.13 - 0.28
0.29 - 0.56
0.57 - 1.14
1.15 - 1.93
1.94 - 3.78
3.79 - 10.81
10.82 - 24.47
24.48 - 44.81
44.82 - 59.95
0
2.5
5
Miles
N
W
E
S
DATE: September 15, 2021
FILE: X:\C00065.00\Map\2021\09\Fig_Ksat.mxd
IDC Grid - Saturated Hydraulic Conductivity
Zone 7 Water Agency
September 2021
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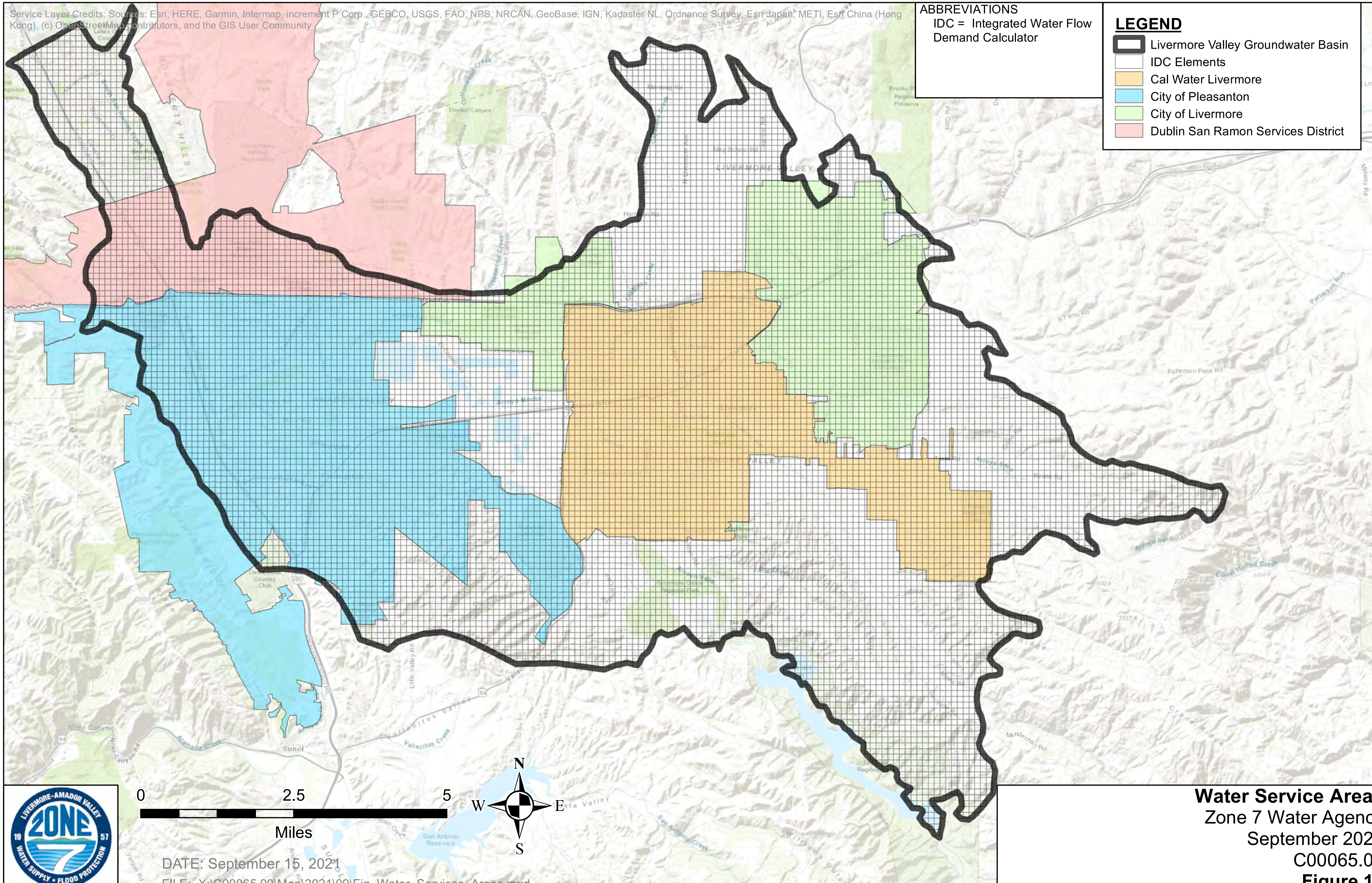
Figure 10



Water Service Areas
Zone 7 Water Agency
September 2021
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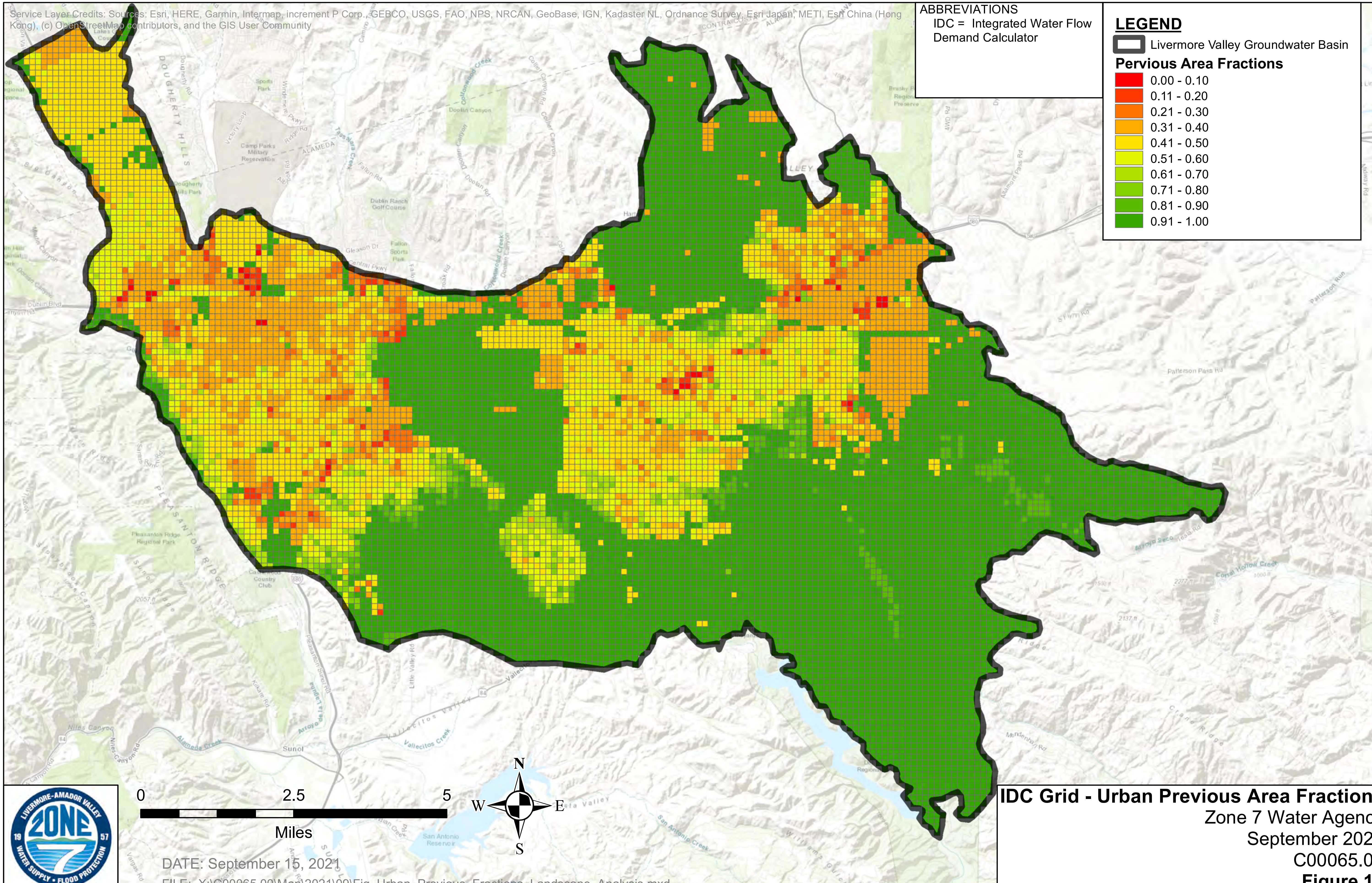
Figure 11



IDC Grid - Urban Previous Area Fractions
Zone 7 Water Agency
September 2021
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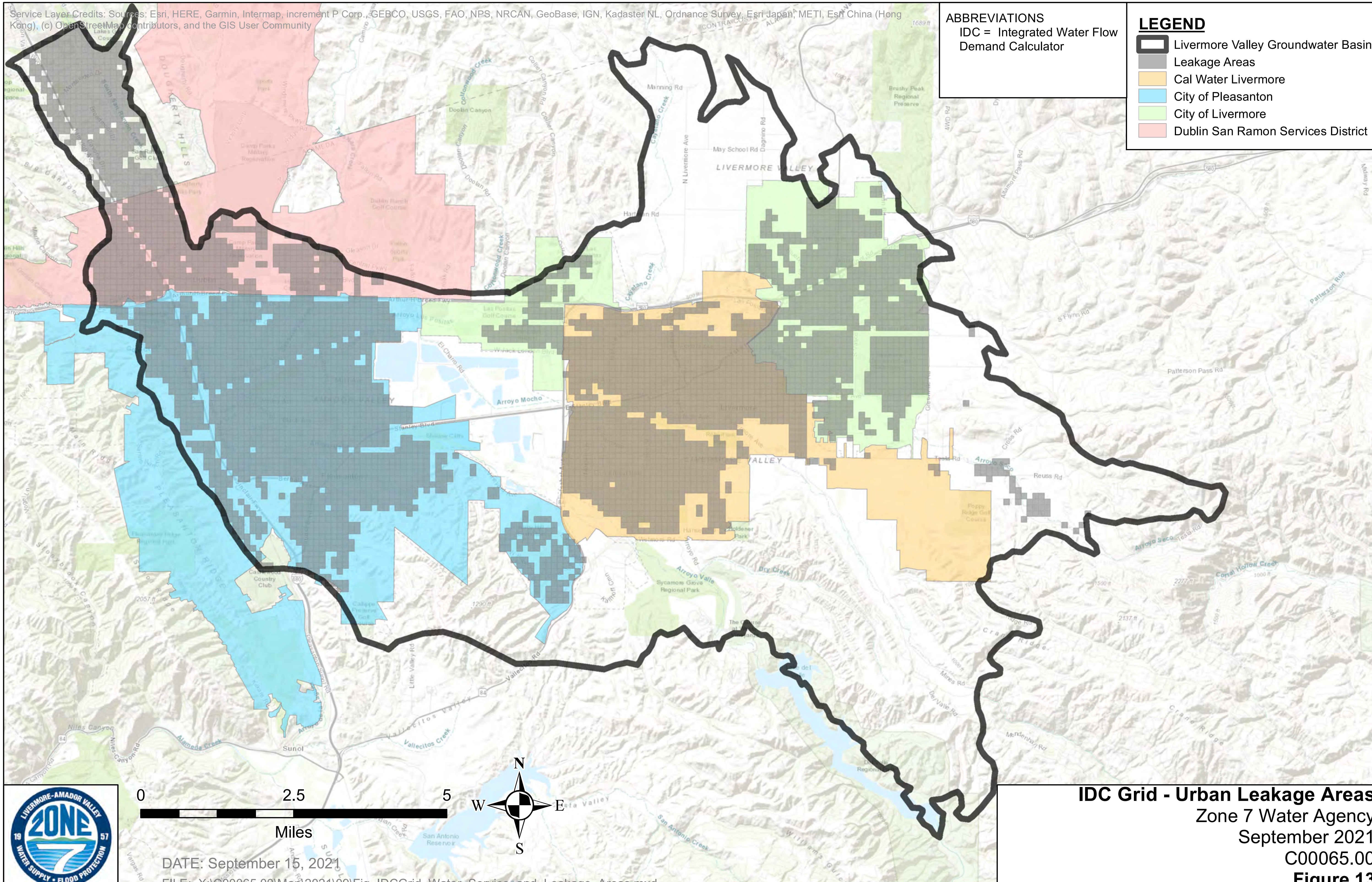
Figure 12



IDC Grid - Urban Leakage Areas
Zone 7 Water Agency
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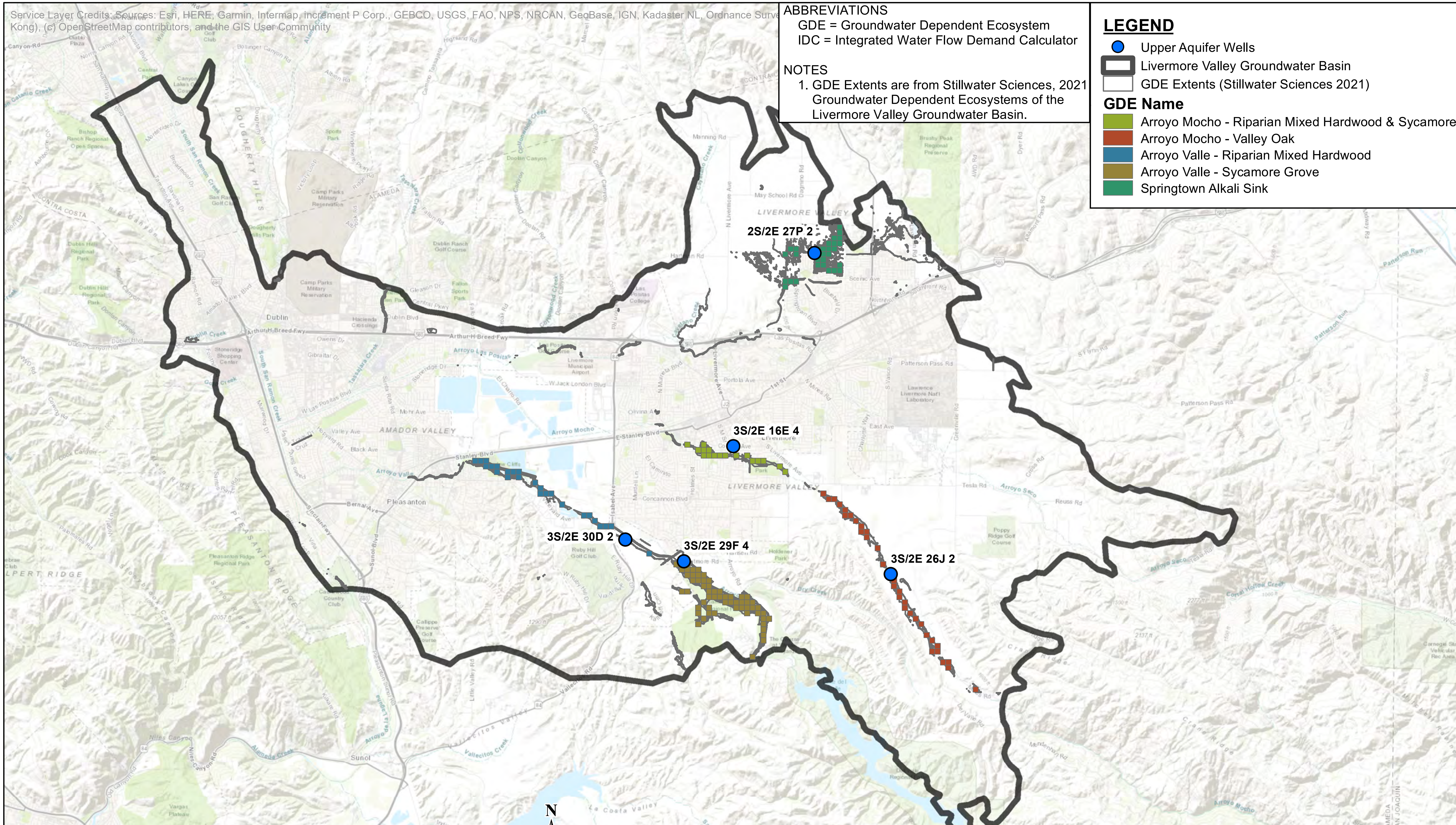
Figure 13



ABBREVIATIONS
GDE = Groundwater Dependent Ecosystem
IDC = Integrated Water Flow Demand Calculator

NOTES
1. GDE Extents are from Stillwater Sciences, 2021 Groundwater Dependent Ecosystems of the Livermore Valley Groundwater Basin.

LEGEND
- Upper Aquifer Wells
- Livermore Valley Groundwater Basin
- GDE Extents (Stillwater Sciences 2021)

GDE Name
- Arroyo Mocho - Riparian Mixed Hardwood & Sycamore
- Arroyo Mocho - Valley Oak
- Arroyo Valle - Riparian Mixed Hardwood
- Arroyo Valle - Sycamore Grove
- Springtown Alkali Sink

DATE: September 15, 2021
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IDC Grid - Groundwater Dependent Ecosystem Areas
Zone 7 Water Agency
September 2021
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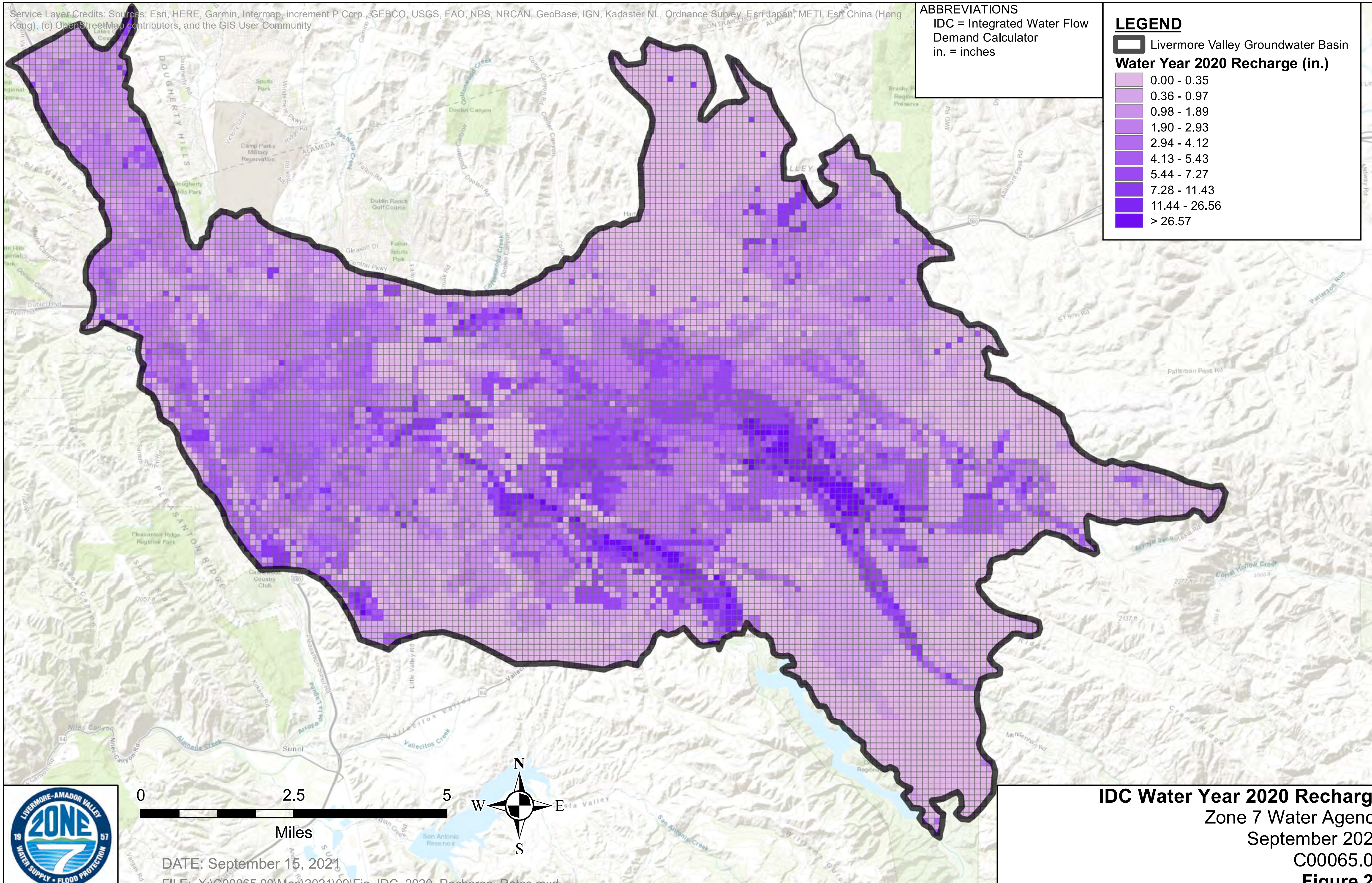
Figure 14



IDC Water Year 2020 Recharge
Zone 7 Water Agency
September 2021
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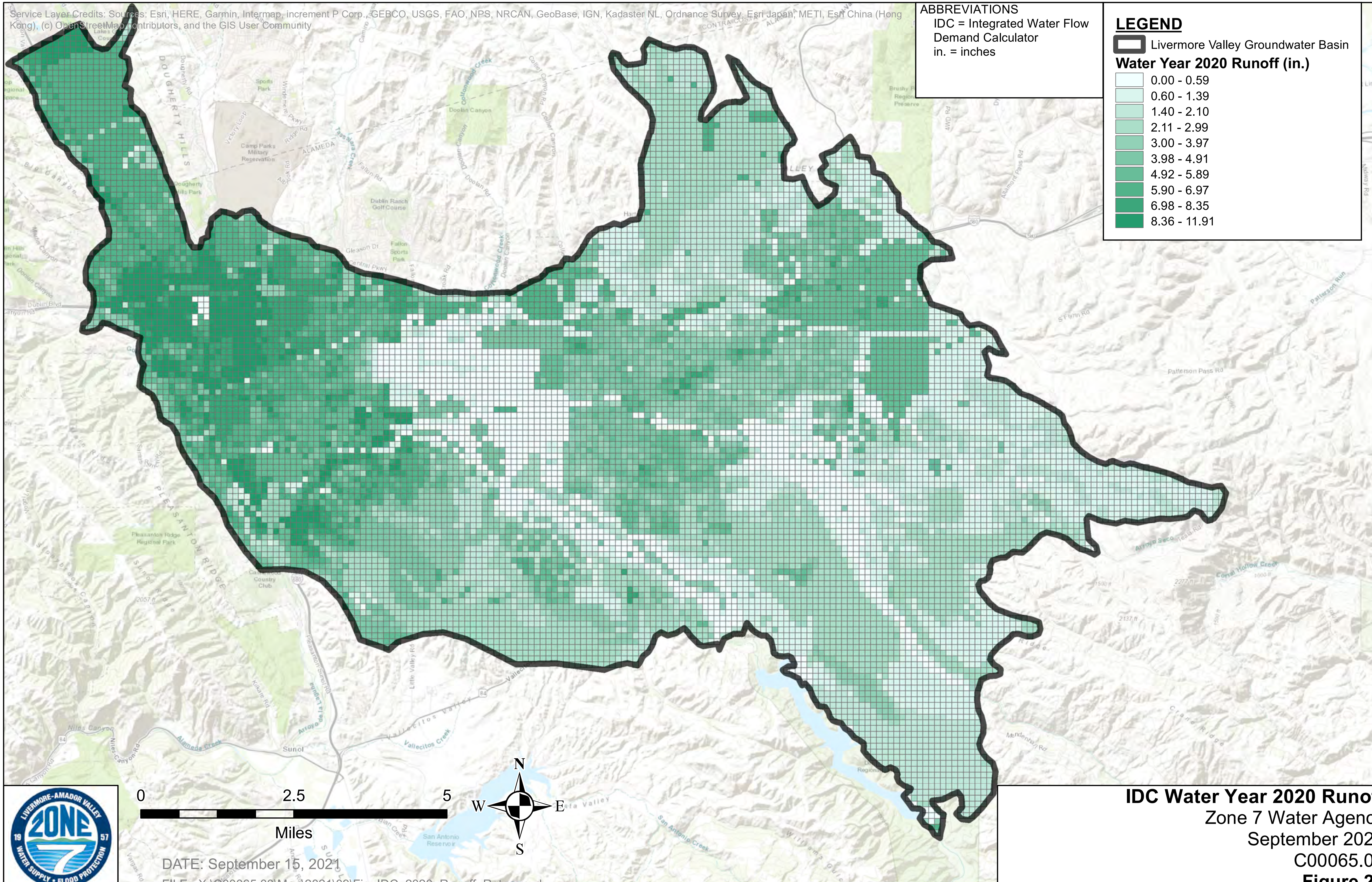
Figure 21



IDC Water Year 2020 Runoff
Zone 7 Water Agency
September 2021
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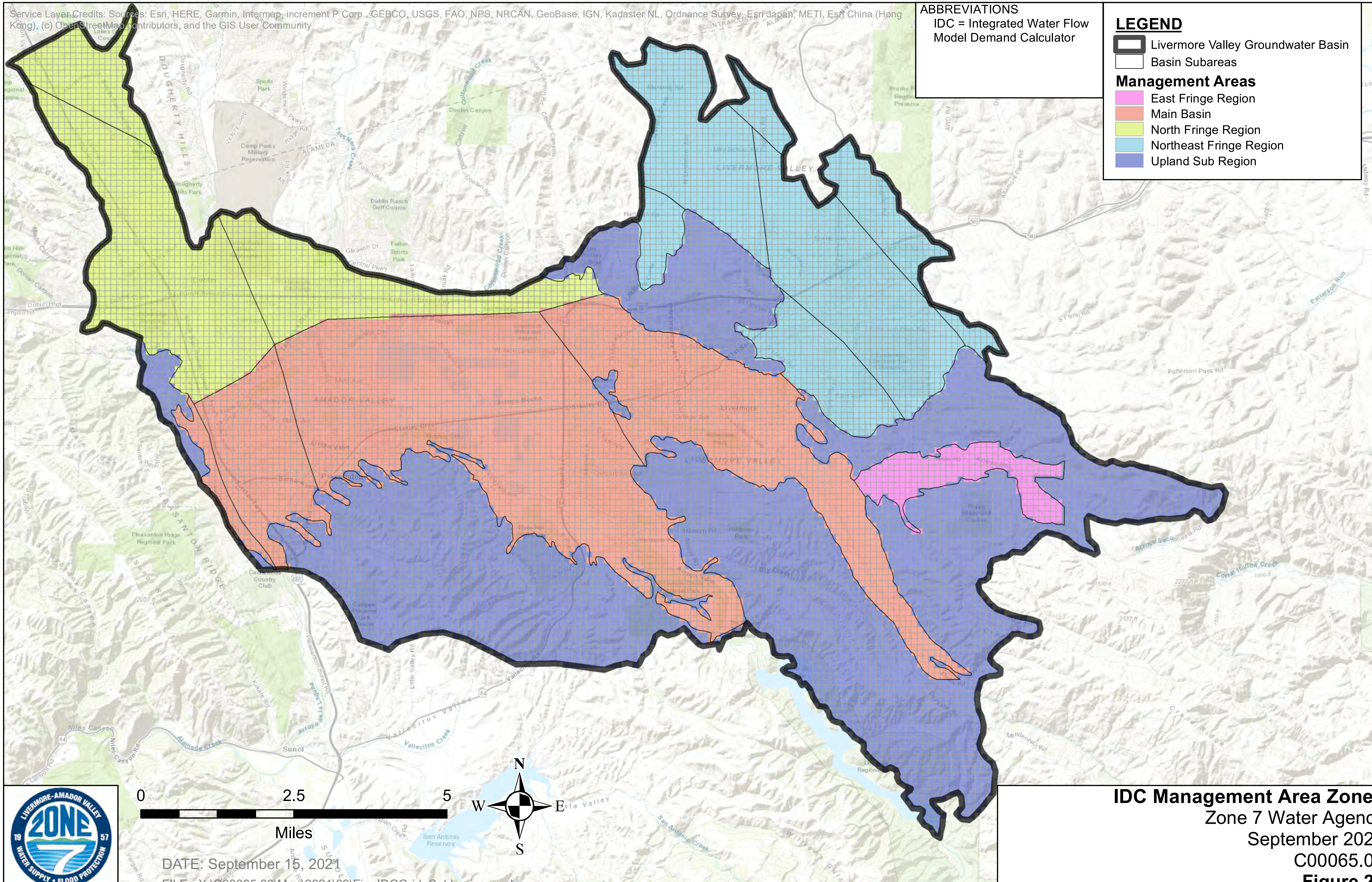
Figure 22



IDC Management Area Zones
Zone 7 Water Agency
September 2021
C00065.00
Figure 23

Attachment A

IDC Theoretical Documentation and User's Manual

DWR Technical Memorandum

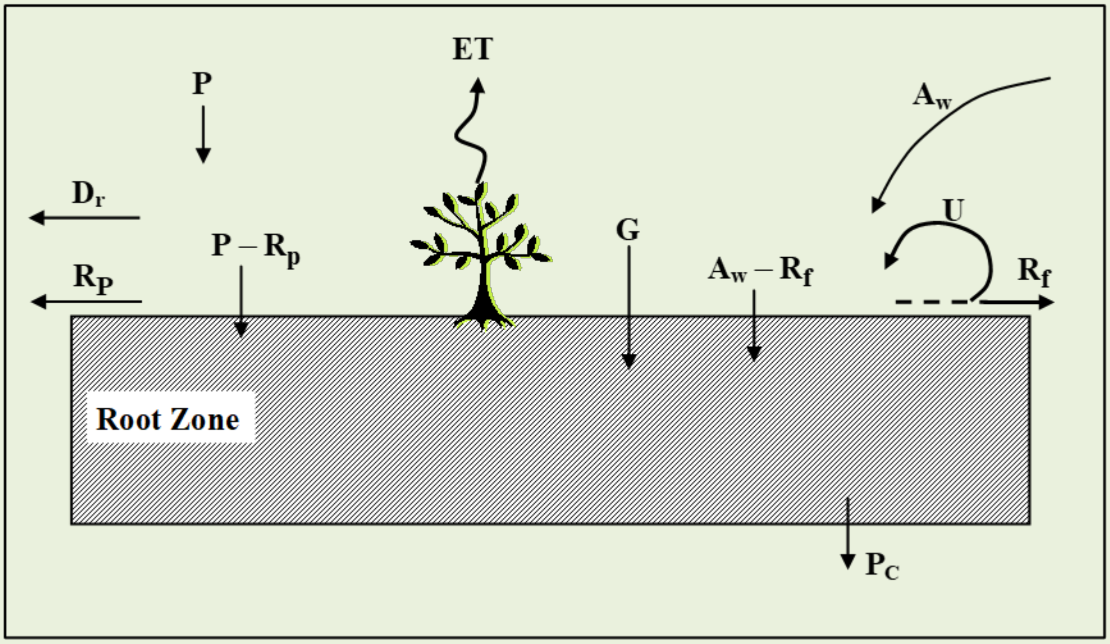
IWFM Demand Calculator

IDC-2015

Revision 102

Theoretical Documentation and User's Manual

Emin C. Dogrul and Tariq N. Kadir



Bay-Delta Office, California Department of Water Resources, 1416 Ninth Street, Sacramento, CA 95814

May 2021

DWR Technical Memorandum

IWFM Demand Calculator

IDC-2015

Revision 102

Theoretical Documentation and User's Manual

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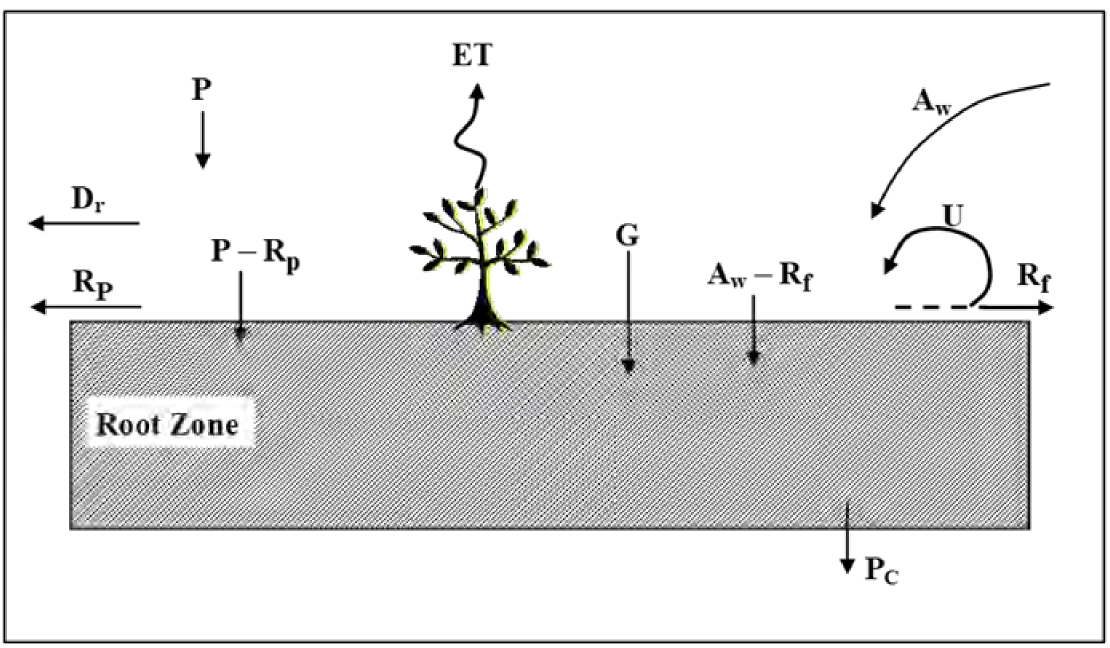


Bay-Delta Office, California Department of Water Resources, 1416 Ninth Street, Sacramento, CA 95814

May 2021

DWR Technical Memorandum: Theoretical Documentation and User's Manual for IWFM Demand Calculator (IDC-2015), Revision 102
Authors: Emin C. Dogrul and Tariq N. Kadir
Modeling software and documentation originated and maintained by the Bay-Delta Office, California Department of Water Resources, 1416 Ninth Street, Sacramento, CA 95814
https://www.water.ca.gov/Library/Modeling-and-Analysis/Modeling-Platforms/Integrated-Water-Flow-Model-Demand-Calculator
This report describes methods and files used in IDC-2015 Revision 102, released in May 2021.

Table of Contents

List of Figures

List of Tables

Summary of Features of the Root Zone Component Versions

IWFM Demand Calculator 2015 (IDC-2015) provides access to several different versions of the root zone flow computation schemes. For a given application, the user is supposed to choose one of these versions.

To aid the user in choosing the right component version, below is a summary of the simulation capabilities these root zone component versions offer.

Version	Capabilities
4.0	• Simulation of non-ponded and ponded (rice and managed refuges) crops, urban lands, native and riparian vegetation at each element • Simulation of generic moisture (seepage from extra source of water, fog, etc.) • Ability to deliver water to an element, group of elements or a subregion to meet water demand • Ability to compute physical crop water demand dynamically based on crop, irrigation management, soil and atmospheric conditions or to pre-specify water demand to represent contractual demand
4.01	• All features listed for version 4.0 above • Optional Z-Budget output for root zone as well as land and water use budgets for zone budget generation
4.1	• All features listed for version 4.0 above • Simulation of riparian vegetation access to stream water to meet all or part of their evapotranspirative water demand • Simulation of root water uptake from groundwater that meets part or all of the plant evapotranspirative demand
4.11	• All features listed for version 4.1 above • Optional Z-Budget output for root zone as well as land and water use budgets for zone budget generation
5.0	• Simulation for agricultural water demand, root zone and land surface flow processes for an average, representative crop • Agricultural and urban water demand simulated at subregion level • Ability to compute physical crop water demand dynamically based on crop, irrigation management, soil and atmospheric conditions or to pre-specify water demand to represent contractual demand

1. Introduction

In developed watersheds, the stresses on surface and subsurface water resources are generally created by groundwater pumping and surface water deliveries to satisfy agricultural and urban water requirements. The application of pumping and surface water deliveries to meet these requirements also affects the surface and subsurface water system through recharge of the aquifer and surface runoff back into the streams. The agricultural crop water requirement is a function of climate, soil and land surface physical properties as well as land use management practices which are spatially distributed and evolve in time. In almost all integrated hydrologic models pumping and surface water deliveries are specified as predefined stresses and are not included in the simulation as an integral and dynamic component of the hydrologic cycle that depend on other hydrologic components as well as water resources operational practices. On the other hand, in irrigation scheduling models that route the moisture through the root zone and compute the irrigation water requirement based on the moisture content, the root zone is completely detached from the rest of the hydrologic cycle. These models generally assume that the water demand is always met and they cannot simulate the effect of extreme hydrologic and operational conditions that may limit the pumping and surface water deliveries. Therefore, both integrated hydrologic models and irrigation scheduling models can be coupled to benefit from each other's features. This document discusses a new model developed by the California Department of Water Resources (CADWR) that estimates the irrigation water requirements and route the soil moisture through root zone in the context of integrated hydrologic modeling.

Integrated hydrologic modeling has received much attention in the last few decades. Models such as PRMS (Leavesley et al. 1983), MIKE SHE (DHI 1999), SWATMOD (Sophocleous et al. 1999), WEHY (Kavvas et al. 2004), GSFLOW (Markstrom et al. 2008), IWFM (Dogrul 2021a), HydroGeoSphere (Therrien et al. 2009) and Modflow with Farm Process (Schmid et al. 2009) are developed to route the water through the components of the hydrologic cycle and to simulate the interactions between them. Integrated hydrologic models include the simulation of the land use based runoff processes and the plant consumptive use, and their effects on surface and subsurface flow dynamics. However, except for IWFM, Modflow with Farm Process and SWATMOD, they do not simulate agricultural and urban water demands and the conjunctive use of surface and subsurface water resources to meet these demands. Essentially, they are descriptive models; i.e. given all the stresses on the hydrologic system modeled, they describe where and how fast the water flows.

However, having to pre-specify the stresses such as pumping and surface water deliveries may pose difficulties in a modeling study. For instance, in the State of California pumping records are proprietary or not measured and often are unavailable. Therefore, for a historical or a calibration model run, the modeler is required to estimate the historical pumping rates to meet an externally computed demand. For instance, Williamson et al. (1989) used electric power records to estimate the historical groundwater pumping in the Central Valley of California. However, such approaches may introduce additional uncertainties to the simulation. On the other hand, in a projection model run where future hydrologic and water resources operational conditions are simulated, pre-specifying pumping and surface water deliveries is almost impossible. First, the agricultural and urban water requirements that pumping and surface water deliveries are used to meet are not known until after the future conditions are actually simulated. Second, amount of pumping and surface water deliveries may be limited by physical (aquifer storage, stream flow capacity, etc.) and contractual limitations which will affect agricultural and urban water requirements, in turn affecting the flow dynamics. This suggests that pumping and surface water deliveries in a projection model run are dynamic and depend on other components of hydrologic cycle simulated. They cannot be pre-specified and can only be simulated as an integral part of the evolving hydrologic cycle, and irrigation and urban water requirements that depend on the cycle.

Another type of modeling tool, irrigation-scheduling-type models, treats the root zone component of the hydrologic cycle as detached from other components. Given the climatic, soil and crop properties, these models simulate the evolution of the soil moisture in the root zone and the agricultural water requirement that depends on the soil moisture content (Kincaid and Heerman 1974, Camp et al. 1988, Smith 1991, George et al. 2000, Orang et al. 2004, Snyder et al. 2004, Raes et al. 2009). Generally, these models include a complex representation of the flow dynamics in the root zone and solve a soil moisture balance equation. Some of these models can also be used in evaluating the effect of different farm management scenarios such as regulated deficit irrigation on crops and in computing leaching requirements (Tayfur et al. 1995, Corwin et al. 2007, Heng et al. 2009).

Because of the treatment of the root zone as a component disconnected from the rest of the hydrologic cycle, irrigation-scheduling-type models cannot address situations where applied water is different than the crop irrigation water requirement in a dynamic sense. Similar to the integrated hydrologic models, they require applied water to be pre-defined. The pre-defined applied water can be assumed equal to the crop irrigation requirement, it can be pre-defined as being less than the irrigation requirement to simulate deficit irrigation conditions, or it can be defined to be greater than the irrigation requirement. However, it is not possible to simulate conditions where, throughout the simulation period, aquifer storage or stream flows are depleted such that the pre-defined applied water cannot be met. Another drawback of irrigation-scheduling-type models is that they cannot be calibrated or verified when they are used in regional scale applications. Since they are not connected to the stream network or the underlying aquifer system, it is generally not possible to verify the accuracy of the simulated percolation or the simulated surface runoff due to irrigation and precipitation.

In general, the two types of modeling approaches, integrated hydrologic and the irrigation-scheduling-type models, can benefit from each other's capabilities if they are coupled. Integrated hydrologic models need a root zone component that is developed in an irrigation-scheduling-type approach that responds to the hydrologic and farm operational conditions, and compute corresponding water demands. On the other hand, irrigation-scheduling-type models need to be connected to the rest of the hydrologic cycle through coupling with an integrated hydrologic model to receive feedback from the aquifer system and the stream network in terms of simulated pumping and surface water deliveries that are actually available.

CADWR has been developing and maintaining the Integrated Water Flow Model (IWFM), a surface-subsurface hydrologic model that couples the integrated hydrologic modeling approach with a root zone component that uses the irrigation-scheduling-type approach (CADWR 2018). Over the years, both IWFM as a whole and its root zone component have evolved to incorporate accurate simulation techniques and to address the issues CADWR have been facing. The root zone simulation engine of IWFM is designed such that it can either be used as a stand-alone irrigation-scheduling-type model or can easily be linked to integrated hydrologic models other than IWFM.

The stand-alone root zone modeling tool is named as IWFM Demand Calculator (IDC). As a stand-alone modeling tool, IDC assumes that the applied water is equal to the computed irrigation water requirements. When IDC's underlying root zone simulation engine is linked to IWFM or any other integrated hydrologic model, applied water is defined as the sum of simulated pumping and surface water deliveries computed by the integrated hydrologic model. In this case, depending on the state of the aquifer and the stream flows, the applied water can be equal or less than the water demand computed by the root zone simulation engine. The percolation, surface runoff due to precipitation and irrigation return flow computed by the root zone simulation engine are passed to the integrated hydrologic model as stresses to the aquifer and the stream network.

This document describes the methods used in IDC (the stand-alone version of the root zone simulation engine) to solve the soil moisture balance in the root zone and to compute agricultural and urban water demands. However, this document should also serve as a guide for the simulation engine when linked to integrated hydrologic models since the methods as well as the input and output data files remain exactly the same.

2. Computational Framework

A computational grid is required when using IDC to compute irrigation water requirements and route moisture through the root zone. This computational grid can be a regular grid (such as a finite difference grid) or an irregular grid (e.g. a finite element grid). However, IDC expects the computational grid to be defined in a manner similar to a finite element grid; i.e. cells and the node numbers that surround each cell should be listed along with the coordinates of the nodes (it should be noted that finite difference grids can easily be defined in this manner). Grid cells are grouped into subregions that are defined by the user. These subregions may represent different types of boundaries and scales (e.g. hydrologic regions, water districts, counties, regions where irrigation and water management data are collected, etc.) depending on the requirements of the IDC application. Although IDC requires a computational grid to be defined, it does not use the finite element or the finite difference approach to solve the conservation equation for the soil moisture in the root zone. The reasons for and benefits of using a computational grid are explained later in this section.

Each grid cell area is distributed between native and riparian vegetation, urban, rice, refuge (specifically wetland refuges for waterfowl) and user-specified number of non-ponded agricultural crop lands. Rice lands are further distributed between lands where rice residue is decomposed by flooding (flooded decomp), where it is decomposed without any flooding (non-flooded decomp) and where it is not decomposed at all. Refuges are divided into two groups of seasonal and permanent refuges. Rice and refuge lands are collectively referred to as ponded crop lands. Even though refuges are not agricultural crops, the refuge ponds are managed in a way that is similar to rice ponds, allowing the simulation methods for rice fields to be used for refuges as well. For this reason, refuges are included in the ponded-crop category in IDC. Non-ponded crops are agricultural crops that are not grown in standing water like rice. The number of non-ponded crops simulated in an IDC application is specified by the user. Therefore, in an IDC application where there are N number of non-ponded crops, the total number of land use types that are simulated at each grid cell will be equal to N+8 (N for non-ponded crops, 5 for ponded crops, 1 for urban, 1 for native vegetation and 1 for riparian vegetation). Even though N+8 land use types are simulated, a grid cell can have the area of one or more land use types set to zero. This tells IDC that those land use types do not exist in that grid cell and the simulation of these land use types is skipped. IDC allows time series land use areas defined for each grid cell, so a particular land use type that does not exist in a grid cell in earlier times of the simulation period can exist in the same cell in the later times, or an existing land use type can disappear from a cell (this feature allows, for instance, to simulate the effects of agricultural lands and native vegetation areas being converted into urban lands).

IDC computes applied water demands for ponded and non-ponded crops at each grid cell under user-specified climatic and irrigation management settings. Urban water demand is computed based on user-specified population and per-capita water usage. Native and riparian vegetations are not irrigated; therefore applied water demands for these land use types are not computed.

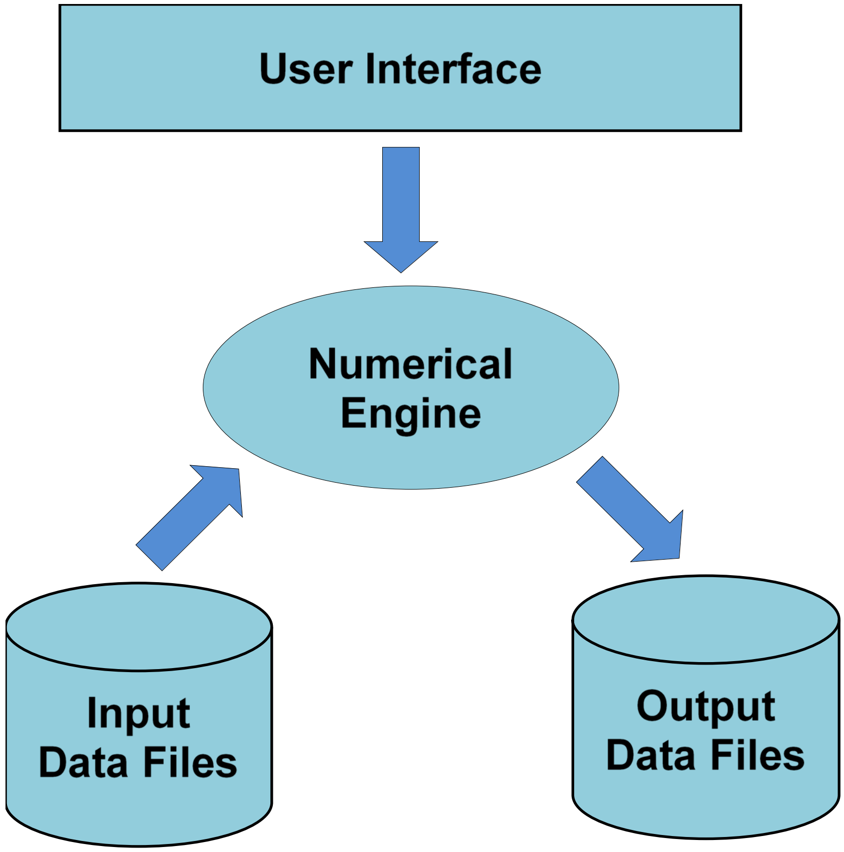
For all land-use types precipitation as well as applied water, if any, is routed through the root zone. Any surface runoff due to precipitation and irrigation generated at each cell is routed to a subregion, to another grid cell or to outside the model area, depending on the choice of the user. Any surface runoff that is routed to a subregion or grid cell becomes part of the applied water in that subregion or cell.

IDC is written in Fortran 2003 using an object-oriented programming approach. It consists of i) input data files, ii) output data files, iii) the numerical engine that reads data from input files, computes applied water demands, routes water through the root zone and prints out the results to output files, and iv) a user interface that utilizes an ASCII text file that allows the user to define input and output files and simulation control data for the numerical engine (Figure 1).

Although IDC does not use finite difference or finite element methods to solve the conservation equation in the root zone, being able to operate on a grid as well as its object-oriented design brings several advantages:

i. The computational grid allows better representation of spatially-distributed data such as potential evapotranspiration, precipitation, soil characteristics, etc.
ii. Being able to operate on computational grids allows IDC to easily couple with other numerical engines that operate on computational grids such as groundwater models.

Figure 1. *Software components of IDC*



iii. The object-oriented design allows easy re-compilation of the numerical engine into a dynamic link library (DLL) which allows easy coupling to other hydrologic, biological and environmental numerical engines such as those that comply with Open Modeling Interface (OpenMI) standards (Gregersen et al. 2007, Goodall et al. 2007).

iv. Easy coupling to numerical engines that simulate other components of the hydrologic cycle allows calibration of model parameters (e.g. soil hydraulic conductivity, soil and irrigation management parameters that play a role in the generation of surface runoff, etc.) through the use of widely available observation data (e.g. groundwater elevations and stream flows).

The methods used by IDC to compute water demand and route moisture through root zone at a regional level, and the design of the computational framework make IDC a unique tool.

Table 1. *Version numbers and simulation capabilities for the root zone component*

Version	Capabilities
4.0	• Simulation of non-ponded and ponded (rice and managed refuges) crops, urban lands, native and riparian vegetation at each element • Simulation of generic moisture (seepage from extra source of water, fog, etc.) • Ability to deliver water to an element, group of elements or a subregion to meet water demand • Ability to compute physical crop water demand dynamically based on crop, irrigation management, soil and atmospheric conditions or to pre-specify water demand to represent contractual demand
4.01	• All features listed for version 4.0 above • Optional Z-Budget output for root zone as well as land and water use budgets for zone budget generation
4.1	• All features listed for version 4.0 above • Simulation of riparian vegetation access to stream water to meet all or part of their evapotranspirative water demand • Simulation of root water uptake from groundwater that meets part or all of the plant evapotranspirative demand
4.11	• All features listed for version 4.1 above • Optional Z-Budget output for root zone as well as land and water use budgets for zone budget generation
5.0	• Simulation for agricultural water demand, root zone and land surface flow processes for an average, representative crop • Agricultural and urban water demand simulated at subregion level • Ability to compute physical crop water demand dynamically based on crop, irrigation management, soil and atmospheric conditions or to pre-specify water demand to represent contractual demand

IDC provides several different versions of root zone component with slightly different simulation features. Table 1 lists the simulation capabilities included with each version of the root zone components. It is expected that as the need for different simulation capabilities arises in the future, IDC will be extended to provide more versions of root zone components with the desired features. It should be noted that some of the features listed in Table 1 are available only when IDC is linked to an integrated hydrologic model such as IWFM (CADWR 2018).

In the following sections, flow routing and water demand calculations as well as the input and output data files in each version of root zone component will be explained.

3. Root Zone Component Version 4.0

3.1. Soil Moisture Routing

Precipitation is generally the natural source for the soil moisture in the root zone. Precipitation that falls on the ground surface infiltrates into the soil at a rate dictated by the type of ground cover, physical characteristics of the soil and the moisture that is already available in the soil. The portion of the precipitation that is in excess of the infiltration rate generates a surface flow. In IDC, this surface flow is termed as *direct runoff*. Irrigation of agricultural lands and urban outdoors such as lawns and parks can also generate surface flows. Surface flows due to irrigation are termed as *return flows* in IDC. Part of the precipitation and irrigation evaporate before infiltrating into the soil. Infiltration due to precipitation and irrigation replenish the soil moisture in the root zone which is also depleted through plant root uptake for transpiration and additional evaporation from the top layers of the soil. The transpiration through the plants and evaporation from the land surface as well as the top layers of the soil are all simulated as a single *evapotranspiration* term in IDC. In general, moisture in the root zone can move in horizontal as well as the vertical directions. In IDC, it is assumed that the horizontal movement of the moisture is negligible compared to the vertical movement. Therefore only the flow of the moisture in the vertical direction is addressed. The moisture that leaves the root zone through its bottom boundary is termed as *percolation*.

IDC uses a physically-based approach to compute the flow terms mentioned above and to route the soil moisture through the root zone. For a particular land use type at a grid cell, the conservation equation for the soil moisture discretized in time is

$$\begin{aligned}\theta^{t+1}Z^{t+1} &= \theta^{t}Z^{t}\\ &+\Delta t\left(P^{t+1}-R_P^{t+1}+A_w^{t+1}-R_f^{t+1}+G^{t+1}Z^{t+1}-D_r^{t+1}-P_C^{t+1}-ET^{t+1}\right)\\ &+\Delta\theta_a^{t+1} \qquad (1)\end{aligned}$$

and

$$\theta^{t+1} = \theta_P^{t+1} + \theta_{A_w}^{t+1} + \theta_G^{t+1} \quad (2)$$

$$\theta^{t} = \theta_P^{t} + \theta_{A_w}^{t} + \theta_G^{t} \quad (3)$$

$$R_f^{t+1} = R_{f,ini}^{t+1} - U^{t+1} \quad (4)$$

where

θ_P = soil moisture content due to precipitation (L/L),

θ_{A_w} = soil moisture content due to applied water (L/L),

θ_G = soil moisture content due to a generic, user-defined moisture inflow (L/L),

θ = total soil moisture content (L/L),

Z = rooting depth (L);

P = rate of precipitation (L/T),

R_P = direct runoff (L/T),

A_w = applied water, i.e. irrigation (L/T),

$R_{f,ini}$ = initial return flow (L/T),

U = re-used portion of the initial return flow (L/T),

R_f = net return flow after re-use takes place (L/T),

G = a generic, user-defined moisture inflow to represent any source of moisture other than precipitation or irrigation (L/L/T),

D_r = outflow due to the draining of rice and refuge ponds (L/T),

P_C = percolation (L/T),

ET = evapotranspiration (L/T),

$\Delta\theta_a$ = change in soil moisture due to change in land use area (L),

t = the time step index (dimensionless),

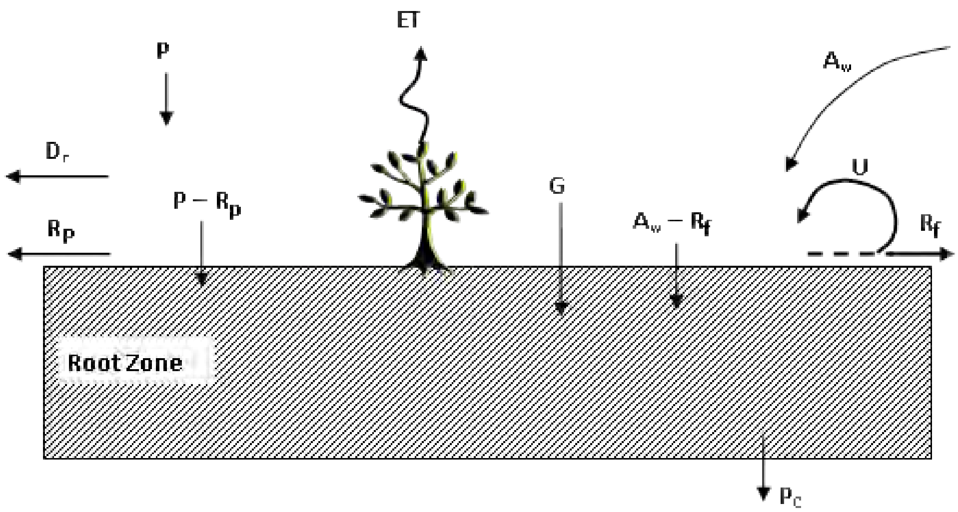
Δt = simulation time step length (T).

These flow terms are depicted in Figure 2. The soil moisture in equation (1) is represented as a summation of moisture due to precipitation and applied water in order to keep track of the contribution of applied water to crop evapotranspiration which is termed as ET of applied water (ETaw) by irrigation practitioners.

Equation (1) is solved for each land use type at each grid cell. In equation (1), θ^{t+1} and θ^t are generally less than the total porosity, θ_T, except for rice and refuge lands where ponding is possible. In these areas, it is assumed that the rooting depth is constant $(Z^{t+1} = Z^t)$, that θ can be computed to be greater than θ_T, and the difference between the θ and θ_T represents the depth of the pond. Therefore, for rice and refuge areas, θZ is not truly the stored soil moisture in the root zone; it represents the sum of the soil moisture and the depth of the ponded water.

In the following sections, the simulation of the flow processes illustrated in Figure 2 will be discussed. For simplicity, time indices t and t+1 are dropped, when appropriate, from the flow notations in the rest of this document.

Figure 2. *Schematic representation of root zone flow processes simulated by IDC*



3.1.1. Precipitation, P

Precipitation is a user-input time series data for each grid cell.

3.1.2. Direct Runoff, R_P

IDC uses a modified version of SCS curve number (SCS-CN) method (USDA 2004) described by Schroeder et al. (1994):

$$R_p = \frac{1}{\Delta t}\frac{(P\Delta t - 0.2S)^2}{P\Delta t + 0.8S} \qquad (5)$$

$$S = \begin{cases} S_{max}\left[1 - \dfrac{\theta^t - \dfrac{\theta_f}{2}}{\theta_T - \dfrac{\theta_f}{2}}\right] & \text{for } \theta^t > \dfrac{\theta_f}{2} \\ S_{max} & \text{for } \theta^t \leq \dfrac{\theta_f}{2} \end{cases} \qquad (6)$$

$$S_{max} = \frac{1000}{CN} - 10 \qquad (7)$$

where CN is the curve number specified for a combination of land use type, soil type and management practice (dimensionless), S_{max} is the soil retention parameter for dry antecedent moisture conditions (L), S is the soil retention parameter at a given moisture content (L), θ_f is the field capacity (L/L) and θ_T is the total porosity (L/L). Equations (5) - (7) state that when root zone moisture is below half of field capacity direct runoff is at a minimum as computed by the SCS-CN method. As the soil moisture increases above half of field capacity the retention capacity of the soil decreases and direct runoff increases.

Equations (5) - (7) are not used for areas such as rice and refuge ponds, and impervious urban areas (parking lots, roof tops, etc) where the infiltration of precipitation is not possible. For these areas entire precipitation becomes direct runoff. For rice lands and seasonal refuges, the ponds are temporary. Therefore, equations (5) - (7) are used during the period when ponds do not exist whereas the entire precipitation is converted into direct runoff during ponding season.

The total direct runoff that leaves a grid cell is the summation of direct runoff from all the agricultural and urban areas at the cell.

3.1.3. Applied Water, A_w

The main purpose of IDC is to compute dynamically the applied water for agricultural lands that will meet the crop evapotranspirative requirements in climatic and agricultural management settings defined by user-input parameters. The detailed discussion for the computation of applied water is given later in this document. Aside from being able to calculate it, IDC also allows the user to specify applied water. For instance, the amount of applied water may be dictated by contractual agreements rather than the crop evapotranspirative requirements. In a historical simulation, the amount of applied water may be available as historical records whereas in a projection run it will need to be computed. To be able to address such situations, IDC allows the user to specify some or all of the applied water amounts for each agricultural land use at each grid cell as time series input data. Applied water for any agricultural land use that is not assigned user specified values is computed by IDC.

In general, urban applied water to meet municipal and industrial water demand as well as demand for urban outdoors is calculated in terms of rate of water use per capita (e.g. CADWR 2005). For this reason, IDC does not attempt to compute the applied water for urban lands; instead, it is always a user-specified time series input data for urban lands at each grid cell. Urban areas are divided into pervious (lawns, parks and any unpaved outdoor areas) and impervious (roof tops, paved areas such as parking lots) areas. Applied water for urban areas is divided into two parts through user-specified time series fractions to meet the urban outdoors water demand at pervious urban lands, and municipal and industrial water demand at impervious urban lands.

Native and riparian vegetation rely on precipitation alone (the contribution of groundwater to ET of riparian vegetation is not simulated in IDC). Therefore, applied water for these areas is always taken to be zero.

Applied water is computed by IDC or specified by the user for each agricultural and urban land use at each grid cell. It consists of two components: i) surface runoff (combination of return flows due to irrigation, direct runoff due to precipitation, and drainage from rice and refuge ponds) that is generated at an upstream grid cell and used as irrigation water at the grid cell in consideration, and ii) water acquired from other sources such as streams and groundwater (stream flows and groundwater system are not simulated by IDC since IDC only considers the domain that consists of the root zone and the land surface that is separated from the rest of the hydrologic cycle). Another component that can be used to meet the crop evapotranspirative requirements as well as the urban indoors and outdoors water requirements is the re-use of captured return flow, U, in a grid cell (see Figure 2). This component is not included in the definition of the applied water to properly satisfy the statement of conservation of mass. To make a distinction between applied water with and without the re-use component, the applied water without the re-use component, U, is termed as *prime applied water* (i.e. A_w as discussed in this section), and the applied water that includes U is termed as the *total applied water*.

3.1.4. Initial Return Flow, $R_{f,ini}$

Initial return flow is specified by the user as a time series fraction of the prime applied water, A_w, for each non-ponded agricultural crop and urban land use area at each grid cell:

$$R_{f,ini} = A_w f_{R_{f,ini}} \tag{8}$$

where $f_{R_{f,ini}}$ is the initial return flow fraction (dimensionless). For urban lands, the initial return flow fraction only applies to the portion of the applied water that is allocated for the urban outdoors. The applied water that is allocated for urban indoors usage is assumed to become return flow completely.

For rice and refuge areas initial return flow is specified by the user as a time series unit flow rate. Generally, irrigation methods for rice require an additional amount of water to be applied to sustain flow-through type irrigation systems (Williams 2004) where water supplied to the top-most rice field sequentially floods each successive field as it makes its way to the lowermost basin. For refuges, additional water may be necessary to keep the water in the refuge ponds moving to control water quality and algae growth.

For areas with native and riparian vegetation, $R_{f,ini}$ is zero since applied water for these areas is zero.

3.1.5. Re-use of Return Flow, U

Re-use of return flow is specified by the user as a time series fraction of the prime applied water, A_w, for each non-ponded agricultural crop and urban land use area at each grid cell:

$$U = A_w f_U \tag{9}$$

where f_U is the re-used return flow fraction (dimensionless). Since re-used amount of return flow cannot be larger than the return flow itself, the re-use fraction must be less than or equal to the initial return flow fraction.

Similar to initial return flow, re-use is specified as time series unit flow rate for rice and refuge areas.

U simulates the re-use that occurs in a single grid cell. In an IDC application, a single grid cell can be large enough to cover multiple farms. In this case, U represents the total return flow from upstream farms that is captured and re-used by the downstream farms in the same grid cell. Another type of re-use occurs when the return flow from a grid cell crosses the cell boundary and flows into a downstream grid cell where it is captured and re-used. This type of re-use is not included in the term U. Instead, as discussed earlier, it becomes part of the prime applied water, A_w, for the downstream grid cell.

3.1.6. Net Return Flow, R_f

As shown in equation (4), the net return flow, R_f, is the difference between the initial return flow, $R_{f,ini}$ and the re-used return flow, U. Substituting equations (8) and (9) into equation (4), R_f can also be represented as

$$R_f = A_w \left(f_{R_{f,ini}} - f_U \right) \qquad (10)$$

Equation (10) is valid for non-ponded agricultural lands as well as urban areas. Equation (10) is not used for ponded crops since re-use and initial return flows are specified explicitly.

The total net return flow that leaves a grid cell is the summation of all return flows from all the agricultural and urban land areas at that cell.

3.1.7. Generic Moisture Inflow, G

Generic moisture inflow, G, is included in equation (1) to represent any moisture inflow into the root zone due to a source other than precipitation or irrigation. It is a user-defined time-series data set specified for each computational grid cell. It is given as a unit rate of inflow per unit length of the rooting depth (L/L/T) of the land use type that is being considered. IDC multiplies G by the rooting depth and the length of the simulation time step to convert it into units of length.

It is expected that G will be set to zero in most IDC applications. However, it can be used in cases where the user has estimates of moisture inflow into the root zone from sources other than precipitation and irrigation. For instance, seepage through the levees into the islands of California's Sacramento-San Joaquin Delta can be represented through G. Another possibility to utilize G is to simulate the effects of fog on meeting the evapotranspirative crop demands.

3.1.8. Drainage of Rice and Refuge Ponds, D_r

Rice ponds and seasonal refuges are drained during certain periods of the year. Rice ponds are drained for harvesting at the end of the growing season. Some rice fields may be re-flooded to decompose the rice residue as well as to create habitat for wildlife. Before the growing season begins, these fields are drained again. Similarly, seasonal refuge ponds can be periodically drained to create space for other types of land usage such as farming during growing season. IDC allows the user to simulate such land management practices by requiring time series ponding depths for rice and refuge areas. Any time the ponding depth specified for a time step is less than that specified for the previous time step, IDC computes a unit rate of pond drainage as

$$D_r^{t+1} = \frac{P_D^t - P_D^{t+1}}{\Delta t} \geq 0 \qquad (11)$$

For land use types other than rice and refuges, pond drainage is equal to zero.

3.1.9. Percolation, P_C

Percolation is the amount of vertical moisture flow that leaves the root zone through its lower boundary. IDC uses a one-dimensional physically-based routing approach to compute P_C:

$$P_C^{t+1} = K\left(\theta^{t+1}Z^{t+1}\right)\frac{dh\left(\theta^{t+1}Z^{t+1}\right)}{dz} \tag{12}$$

where K is the unsaturated hydraulic conductivity as a function of soil moisture (L/T), h is the pressure head (L), and z is the vertical distance measured from land surface (L). Assuming that the vertical head gradient is unity, using van Genuchten-Mualem equation (Mualem 1976, van Genuchten 1980) and assuming residual moisture content is negligible, equation (12) can be re-written as

$$P_C^{t+1} = P_{Crdc}^{t+1} + K_s\left(\frac{\theta^{t+1}}{\theta_T}\right)^{1/2}\left\{1-\left[1-\left(\frac{\theta^{t+1}}{\theta_T}\right)^{1/m}\right]^m\right\}^2 \tag{13}$$

and

$$m = \frac{\lambda}{\lambda+1} \tag{14}$$

$$P_{Crdc}^{t+1} = \begin{cases} \theta^t\left(Z^t - Z^{t+1}\right) & \text{if } \; Z^t > Z^{t+1} \\ 0 & \text{otherwise} \end{cases} \tag{15}$$

where K_s is the saturated hydraulic conductivity (L/T) and λ is the pore size distribution index (dimensionless).

Equation (15) shows that when the rooting depth is decreasing, generally at the harvest time, any moisture that falls outside the rooting depth is converted into percolation. However, it should be noted that setting the rooting depth, Z, to zero outside of cropping season will cause incorrect results as IDC will assume that soil has zero storage capacity and will convert all precipitation to either percolation or direct runoff. Therefore, it is important to specify a non-zero rooting depth even outside the growing season to properly represent the moisture storage capacity of the soil. Alternatively, one can assume constant rooting depth throughout the entire simulation period. Preliminary tests have shown that although changing rooting depth has an impact on the flow terms as well as the computed water demands at short time periods that are on the order of a few days, over the entire cropping season its cumulative impact is small.

As an alternative to the van Genuchten-Mualem equation, IDC can use Campbell's approach (Campbell 1974) to represent the unsaturated hydraulic conductivity:

$$P_C^{t+1} = P_{Crdc}^{t+1} + K_s \left(\frac{\theta^{t+1}}{\theta_T} \right)^{3+\frac{2}{\lambda}} \tag{16}$$

where the assumption of negligible residual moisture content is applied.

3.1.10. Evapotranspiration, ET

Calculations of ET are based on the potential ET, ET_{pot}, values specified by the user as time series data for each land use and grid cell combination. Although ET_{pot} values can be taken as the crop ET under standard conditions, ET_c, described by Allen et al. (1998), they can also be taken as the crop ET under non-standard conditions, ET_{cadj}, also described by Allen et al. (1998), to incorporate conditions such as non-uniform irrigation, low soil fertility, salt toxicity, pests, diseases, etc (except the case where the plants are water stressed because of lack of sufficient water; this situation is simulated dynamically in IDC as discussed below).

IDC computes ET as a function of the soil moisture in the root zone:

$$ET^{t+1} = \begin{cases} ET_{pot}^{t+1} & \text{if} \quad \dfrac{\theta^{t+1} - \theta_{wp}}{\left(\dfrac{\theta_f - \theta_{wp}}{2}\right)} > 1 \\[2em] \dfrac{\theta^{t+1} - \theta_{wp}}{\left(\dfrac{\theta_f - \theta_{wp}}{2}\right)} ET_{pot}^{t+1} & \text{if} \quad 0 \le \dfrac{\theta^{t+1} - \theta_{wp}}{\left(\dfrac{\theta_f - \theta_{wp}}{2}\right)} \le 1 \\[2em] 0 & \text{if} \quad \dfrac{\theta^{t+1} - \theta_{wp}}{\left(\dfrac{\theta_f - \theta_{wp}}{2}\right)} < 0 \end{cases} \qquad (17)$$

where θ_{wp} is the wilting point (L/L) and $\theta_f - \theta_{wp}$ is the total available water (TAW) (Allen et al. 1998). Equation (17) suggests that if the soil moisture at a given time step is greater than half of TAW, ET will be equal to ET_{pot}. If the soil moisture falls below half of TAW, plants will start experiencing water stress and ET will be less than ET_{pot}. Below wilting point, the ET rate will be zero. The method described by equation (17) is similar to the method described in Allen et al. (1998) to compute a non-standard crop ET under water stress conditions. In Allen et al. (1998), a water stress parameter, p, is defined for each crop which represents the soil moisture content below which the crop starts experiencing water stress. In equation (17), p is taken as 0.5 regardless of the plant type.

3.1.11. Change in Soil Moisture due to Change in Land Use Area, $\Delta\theta_a$

IDC allows the user to specify areas for each land use type at each grid cell as time series data. Equation (1) is solved and soil moisture is tracked for each land use type at each cell. Due to different crop characteristics and management practices for each land use, soil moisture will be different for different land use types. To satisfy the global conservation of mass at the modeled domain, it is necessary to keep track of the soil moisture that is exchanged between different land use types as the areas change through the simulation period. $\Delta\theta_a$ is the term that represents this exchange of soil moisture between different land use types.

As an example consider a total of n land use types defined for a grid cell with corresponding areas defined at time step t and t+1 as A_i^t and A_i^{t+1}, respectively, where i=1,…,n. For land use types whose areas decline or stay the same $\Delta\theta_a$ will be zero (volumetric soil moisture storage will be less for land use types whose areas decrease, but soil moisture depth will be the same for these land use types). On the other hand, land use types whose areas increase will adopt new soil moisture from land use types whose areas diminish. For a land use type j whose area increases by

$$A_j^e = A_j^{t+1} - A_j^t > 0 \tag{18}$$

the change in soil moisture due to area change, $\Delta\theta_{a,j}$, is computed as

$$\Delta\theta_{a,j} = \frac{A_j^t \theta_j^t Z_j^t + A_j^e \dfrac{\sum_i A_i^r \theta_i^t Z_i^t}{\sum_i A_i^r}}{A_j^{t+1}} - \theta_j^t Z_j^t \tag{19}$$

where A_i^r is the decrease in the area of land use i:

$$A_i^r = A_i^t - A_i^{t+1} > 0 \tag{20}$$

Equation (19) suggests that after adopting the soil moisture from land use types whose areas decrease, the new soil moisture computed for the land use j is uniformly distributed over the land use area.

In certain situations, the new soil moisture with the adopted moisture from reduced land use areas can be numerically greater than the total porosity. For instance such a case can occur when the area of a crop with short rooting depth extends into the area of a crop with much deeper rooting depth. In this case the new soil moisture is set to total porosity and the moisture above total porosity is converted into percolation.

3.1.12. Solution of the Root Zone Conservation Equation

Equation (1) is non-linear with respect to θ^{t+1}. IDC uses an iterative method that is a combination of bisection and Newton's methods (Gerald and Wheatley 1994) to solve equation (1). The iterative solution methodology starts and continues with Newton iterations until the estimate for the soil moisture goes above total porosity less 10% of the user-defined convergence tolerance for the iterative solver. At this point, bisection method is used as the iterative method. The reason for this switch between the two methods is that the gradient of the van Genuchten-Mualem equation near saturation becomes very large and this causes problems for Newton's method. Bisection method has slower convergence but is more robust; therefore it is preferred when soil moisture is close to or above saturation. The switch between Newton's and bisection methods occurs mostly for rice and refuge areas where soil moisture can be at or numerically above total porosity (representing the ponding conditions).

3.2. Water Demand

From a plants perspective, water demand (also referred to as the physical water demand in this document) is the amount of irrigation water to satisfy the crop's evapotranspirative requirement under a specified irrigation management setting that is not met by precipitation. From a water management perspective, it is the amount of irrigation water that needs to be delivered to farms dictated by contractual agreements. This amount may or may not be the same as the physical water demand of the crops.

IDC is designed to address both types of water demands under user-specified climatic and irrigation management settings in regional scale applications. The physical water demand is computed by utilizing the root zone conservation equation (1), whereas the contractual water demands are specified by the user. Physical water demand is calculated only for agricultural crops, refuges and urban lands; water demand is zero for native and riparian vegetation since they are not irrigated.

Below, the methods used by IDC to compute applied water demand for non-ponded and ponded (rice and refuge lands) land use areas are explained.

3.2.1. Water Demand for Non-Ponded Crops

IDC utilizes an irrigation-scheduling-type approach in computing the water demand for non-ponded crops. Each non-ponded crop at each grid cell is associated with a time series data of irrigation period flag, irrigation trigger minimum soil moisture, irrigation target soil moisture, minimum percolation requirement as a fraction of infiltrated applied water, return flow fraction and re-use fraction. IDC also requires the user to specify if the soil moisture at the beginning or at the end of a time step will be used to compute irrigation water demand. For a short simulation time step such as a day using the soil moisture at the beginning of the time step is appropriate, whereas for a long time step such as a month, it is better to use the soil moisture at the end of the time step. The real-world analogy is that a farmer may check the soil moisture conditions in the morning and decide if the crops need irrigation, while he never bases his decision of irrigating over an entire month on the moisture conditions at the beginning of that month.

The irrigation period flag tells IDC when to compute irrigation water demand for a non-ponded crop. An irrigation period flag of 0 means that it is outside the cropping season and IDC will not compute the irrigation water demand, whereas 1 means that it is growing season and the irrigation water demand will be computed.

First, the water demand calculations in the case when the soil moisture at the beginning of a time step is used will be explained.

At the beginning of a time step, if irrigation period flag is 1, IDC checks if the soil moisture, $\theta^t Z^t$, is less than the irrigation trigger minimum soil moisture, $\theta_{min}^{t+1} Z^{t+1}$, where θ_{min}^{t+1} is represented in terms of the Total Available Water (TAW):

$$\theta_{min}^{t+1} = \theta_{wp} + f_{\theta min}^{t+1} TAW \tag{21}$$

$$TAW = \theta_f - \theta_{wp} \tag{22}$$

where $f_{\theta min}^{t+1}$ is a fraction of TAW specified as time series data by the user. θ_{min}^{t+1} is the soil moisture content that corresponds to the maximum allowable depletion (Allen et al. 1998). If $\theta^t Z^t$ is less than $\theta_{min}^{t+1} Z^{t+1}$, the irrigation amount to raise the soil moisture up to irrigation target moisture, $\theta_{trg}^{t+1} Z^{t+1}$ is computed by setting θ^{t+1}

in equation (1) to θ_{trg}^{t+1} and re-writing it for A_w (in IDC irrigation water demand is equivalent to the applied water since IDC assumes that water is available to meet the irrigation water demand at all times):

$$A_w^{t+1} = \begin{cases} \dfrac{\dfrac{\theta_{trg}^{t+1} Z^{t+1} - \theta^t Z^t - \Delta\theta_a^{t+1}}{\Delta t} - P^{t+1} + R_p^{t+1} - G^{t+1} Z^{t+1} + P_{Ctrg}^{t+1} + ET_{trg}^{t+1}}{1 - \left(f_{R_{f,ini}}^{t+1} - f_U^{t+1} \right)} & \text{if} \quad \theta^t Z^t < \theta_{min}^{t+1} Z^{t+1} \\ 0 & \text{if} \quad \theta^t Z^t \geq \theta_{min}^{t+1} Z^{t+1} \end{cases} \qquad (23)$$

Several points need to be highlighted for equation (23):

1. Pond drainage flow, Dr, is set to zero since equation (23) is written for non-ponded crops.
2. ET_{trg}^{t+1} and P_{Ctrg}^{t+1} represent the ET and percolation rates, respectively, at the target soil moisture.
3. Equation (10) is substituted for return flow, Rf.

Equation (23) is the expression for the amount of applied water that will raise the soil moisture up to target soil moisture while taking into account the contribution of precipitation, irrigation efficiency measures $f_{R_{f,ini}}$ and f_U as well as the moisture depleting effects of percolation and ET.

By default, IDC uses field capacity as the target soil moisture. However, the user can optionally specify a fraction of the field capacity as the target soil moisture during irrigation to simulate the effects of deficit irrigation (Fereres and Soriano, 2007; Kirda, 2002). By setting the irrigation trigger minimum soil moisture and the irrigation target soil moisture to values that are lower than those for optimal irrigation, the user can simulate the deficit irrigation practices.

In the case where the soil moisture at the end of a time step is used for water demand calculations, IDC initially assumes that A_w^{t+1} is zero, and solves equation (1) for θ^{t+1}. If $\theta^{t+1} Z^{t+1}$ is less than $\theta_{min}^{t+1} Z^{t+1}$, there is irrigation water demand and IDC uses equation (23) to compute this demand.

It is common practice to apply additional irrigation water on the fields to flush the salts from the soil. To simulate this practice, IDC allows the user to specify an optional time-series minimum percolation factor for each non-ponded crop at each grid cell. The percolation factor is defined as a fraction of the infiltrated applied water:

$$P_{Cmin} = f_D\left(A_w - R_f\right) \tag{24}$$

where P_{Cmin} is the minimum percolation required (L/T) and f_D is the minimum percolation fraction (dimensionless). It should be noted that f_D is different than leaching fraction in that leaching fraction is defined for a set of irrigation events after which the soil salinity and water flow in the root zone reaches an equilibrium (Ayers and Westcot, 1985; Dudley et al., 2008) whereas f_D in IDC is valid only for the time step when the irrigation event takes place.

After water demand is computed using equation (23), IDC checks if percolation is greater than the minimum percolation, if f_D is supplied. If minimum percolation is not achieved, it computes a new water demand that will raise the soil moisture to the irrigation target soil moisture while generating minimum percolation. This is achieved by writing equation (24) for $A_w - R_f$, substituting it into equation (1), and solving the resulting non-linear equation for θ^{t+1}:

$$\begin{aligned}\theta^{t+1}Z^{t+1} &= \theta^t Z^t \\ &+\Delta t\left[P^{t+1} - R_p^{t+1} + G^{t+1}Z^{t+1} - P_{Cmin}^{t+1}\left(1-\frac{1}{f_D^{t+1}}\right) - ET^{t+1}\right] \\ &+\Delta\theta_a^{t+1}\end{aligned} \tag{25}$$

In writing equation (25), pond drainage, D_r, is set to zero since the equation is written for non-ponded crops only and ET^{t+1} is the ET rate at θ^{t+1}. It should also be noted that P_{Cmin} is a function of θ^{t+1} in equation (25).

Equation (25) is solved for θ^{t+1} iteratively using Newton's method. Once the solution is obtained, the water demand is computed as

$$A_w^{t+1} = \frac{P_{Cmin}^{t+1}}{f_D^{t+1}\left[1-\left(f_{R_{f,ini}}^{t+1} - f_U^{t+1}\right)\right]} \qquad (26)$$

where P_{Cmin}^{t+1} is computed at θ^{t+1} that is obtained by solving equation (25).

Percolation has an upper limit that is equal in magnitude to the saturated hydraulic conductivity, K_s, of the soil (see equation (13)). Therefore, P_{Cmin} is limited by K_s. If it is computed to be larger than K_s, it is adjusted down to K_s and the user-specified minimum percolation factor, f_D, is overridden.

Alternatively, IDC allows the user to specify water demand to address the contractual rather than the physical water demands. In this case, equations (23) and (26) are bypassed and user-specified water demands are used. However, it is likely that the specified water demands will be less than or greater than the physical water demands. In either case, IDC uses the specified values in equation (1) to route the moisture through the root zone. In the case that the specified demands are less than their physical counterparts, IDC will allow ET to fall below ET_{pot}, assuming that the target irrigation soil moisture is equal to the field capacity. If they are greater than the physical demands, IDC computes increased soil moisture, percolation and return flow, again by the use of equation (1).

The inclusion of percolation in equation (23) shows that the water demand, among other factors, depends also on the soil type where the crops are planted. The same crop under the same management factors and for the same yield will require more water if it was planted on a sandy soil than it was planted on a clayey soil.

3.2.2. Water Demand for Ponded Crops

The water demand computations for ponded crops are driven by the pond depths specified by the user except during decomposition periods for rice lands where non-flooded decomposition practices are followed. For the periods when a non-zero ponding depth is specified, IDC computes the applied water demand that will completely saturate the soil and crate a pond with the specified depth after taking into account the contribution of precipitation in a user-specified crop management setting. First an initial estimate of water demand is computed by setting drainage flow and net return flow to zero, percolation to saturated hydraulic conductivity, ET to ET_{pot}, θ^{t+1} to total porosity plus the pond depth in equation (1) and rearranging the equation for A_w:

$$A_{w,ini}^{t+1} = \frac{\theta_T Z + P_D^{t+1} - \theta^t Z - \Delta\theta_a^{t+1}}{\Delta t} - P^{t+1} + R_p^{t+1} - G^{t+1} Z + K_s + ET_{pot}^{t+1} + D_r^{t+1} > 0 \quad (27)$$

where $A_{w,ini}$ is the initial estimate of the applied water demand (L/T) and P_D is the pond depth (L). As stated previously, IDC assumes constant rooting depth for ponded crops, therefore the time index for Z in equation (27) does not appear. There is water demand only if the result of equation (27) is greater than zero. As the second step, the drainage flow is computed using equation (11). Then, the final applied water demand is computed as

$$A_w^{t+1} = A_{w,ini}^{t+1} + R_{f,ini}^{t+1} - U^{t+1} \quad > \quad 0 \qquad (28)$$

where, as mentioned earlier, $R_{f,ini}$ and U are specified as unit flow rates for rice lands and refuges.

Equations (27) and (28) are used for seasonal and permanent refuge areas as well as for rice lands where flooded decomposition practices are followed. For rice lands where non-flooded decomposition practices are followed, the same approach is used during growing season; during decomposition period user specified water application amounts are utilized.

As with non-ponded crops, if the user specifies water demand IDC bypasses its computation and substitutes the specified value into equation (1).

3.2.3. Evapotranspiration of Applied Water, ETaw

The portion of the crop evapotranspiration that is satisfied by irrigation water is referred to as the evapotranspiration of applied water (ETaw). The crop evapotranspiration can be satisfied by moisture storage already available in the soil, precipitation, applied water, and if available, other sources of moisture, G. Moisture storage is comprised of previous precipitation events and irrigation activities as well as moisture inflows from other sources. Therefore, one can view ETaw as having two components: one where the irrigation satisfies the crop ET requirement almost instantaneously (e.g. over a period of few minutes or hours), and one where a portion of the applied water is stored in the soil and satisfies the crop ET over an extended period of time (e.g. over a period of few days or weeks).

For proper prediction, IDC keeps track of the portion of soil moisture that is supplied by irrigation and effectively simulates both components of ETaw. After equation (1) is solved and all flow components are calculated, ETaw and the soil moisture storage due to irrigation are computed using the following set of expressions:

$$\alpha_{A_w} = \frac{\theta_{A_w}^t Z^t + \Delta t\left(A_w^{t+1} - R_f^{t+1}\right)}{\left(\theta_P^t + \theta_{A_w}^t + \theta_G^t\right)Z^t + \Delta t\left(P^{t+1} - R^{t+1} + A_w^{t+1} - R_f^{t+1} + G^{t+1}Z^{t+1}\right)} \tag{29}$$

$$ETaw^{t+1} = \alpha_{A_w} ET^{t+1} \tag{30}$$

$$\theta_{A_w}^{t+1} Z^{t+1} = \theta_{A_w}^t Z^t + \Delta t\left[A_w^{t+1} - R_f^{t+1} - \alpha_{A_w}\left(D_r^{t+1} + P_C^{t+1}\right) - ETaw^{t+1}\right] + \Delta\theta_{a,A_w}^{t+1} \tag{31}$$

where α_{A_w} is the ratio of stored applied water plus the infiltrated applied water to the total moisture storage plus total infiltration, and $\Delta\theta_{a,A_w}$ is the moisture storage due to irrigation that is acquired from adjacent land use areas because of change in land use area. Equations (29) - (31) suggest that all root zone flow components are proportioned between flow due to precipitation, flow due to applied water and flow due to other sources of moisture using the fraction defined in equation (29), which are used to compute the moisture storage due to irrigation.

α_{A_w} represents both the instantaneous and the long-term contributions of irrigation to ETaw and other flow terms. The part with $\Delta t\left(A_w^{t+1} - R_f^{t+1}\right)$ at the numerator represents the instantaneous contribution, whereas the part with $\theta_{A_w}^t Z^t$ represents its contribution that takes place over an extended period of time. Here, the term "instantaneous" refers to any event that takes place over a single simulation time step, Δt.

When irrigation period flag is 0 representing out-of-growing-season, ETaw is still computed to track θ_{A_w} (see equation (31)). This is because evapotranspiration continues to occur outside the irrigation period due to soil evaporation and transpiration from non-agricultural crops such as weeds.

3.2.4. Effective Precipitation, ETp

Effective precipitation, ETp, is the portion of precipitation that is available to meet crop evapotranspiration. It does not include direct runoff, percolation or evaporation before the crop can use it (USDA 1997). Similar to ETaw, ETp represents the instantaneous contribution of precipitation to satisfy the crop evapotranspiration as well as its contribution over an extended period of time. IDC uses the following expressions to compute ETp:

$$\alpha_P = \frac{\theta_P^t Z^t + \Delta t\left(P^{t+1} - R^{t+1}\right)}{\left(\theta_P^t + \theta_{A_w}^t + \theta_G^t\right)Z^t + \Delta t\left(P^{t+1} - R^{t+1} + A_w^{t+1} - R_f^{t+1} + G^{t+1}Z^{t+1}\right)} \quad (32)$$

$$ETp^{t+1} = \alpha_P ET^{t+1} \quad (33)$$

$$\theta_P^{t+1} Z^{t+1} = \theta_P^t Z^t + \Delta t\left[P^{t+1} - R^{t+1} - \alpha_P\left(D_r^{t+1} + P_C^{t+1}\right) - ETp^{t+1}\right] + \Delta\theta_{a,P}^{t+1} \quad (34)$$

where α_P is the ratio of stored precipitation plus the infiltration of precipitation to the total moisture storage plus the total infiltration, and $\Delta\theta_{a,P}$ is the moisture storage due to precipitation that is acquired from adjacent land use areas because of change in land use area.

3.2.5. Evapotranspiration due to Other Sources, ET_G

ET_G is the portion of the generic, user-defined source of moisture that is available to meet the evapotranspirative demand. Similar to ETaw and ETp, it represents the instantaneous contribution of the generic source of moisture to satisfy the crop evapotranspiration as well as its contribution over an extended period of time. IDC uses the following set of expressions to compute ET_G:

$$\alpha_G = \frac{\theta_G^t Z^t + \Delta t\left(G^{t+1} Z^{t+1}\right)}{\left(\theta_P^t + \theta_{A_w}^t + \theta_G^t\right)Z^t + \Delta t\left(P^{t+1} - R^{t+1} + A_w^{t+1} - R_f^{t+1} + G^{t+1}Z^{t+1}\right)} \quad (35)$$

$$ET_G^{t+1} = \alpha_G ET^{t+1} \tag{36}$$

$$\theta_G^{t+1} Z^{t+1} = \theta_G^t Z^t + \Delta t \left[G^{t+1} Z^{t+1} - \alpha_G \left(D_r^{t+1} + P_C^{t+1} \right) - ET_G^{t+1} \right] + \Delta\theta_{a,G}^{t+1} \tag{37}$$

where α_G is the ratio of stored moisture due to generic source plus the infiltration of the generic moisture to the total moisture storage plus the total infiltration, and $\Delta\theta_{a,G}$ is the moisture storage due to the generic moisture source that is acquired from adjacent land use areas because of change in land use area.

3.3. Example 1: Hypothetical Scenario

To test and analyze its results, IDC was run for a hypothetical case where tomatoes were the irrigated crop. Additionally, to test the irrigation scheduling logic built into IDC, it was compared, when applicable, to the CUP model developed jointly by DWR and UC Davis (Orang et al. 2004). CUP is a graphical user interface driven spreadsheet application that was developed to improve the dissemination of crop evapotranspiration (ET_c) information to California growers and water purveyors. The program uses monthly means of solar radiation, maximum and minimum temperature, dew point temperature, wind speed, and daily rainfall data to compute and apply ET_c values on a daily basis to determine crop water requirements.

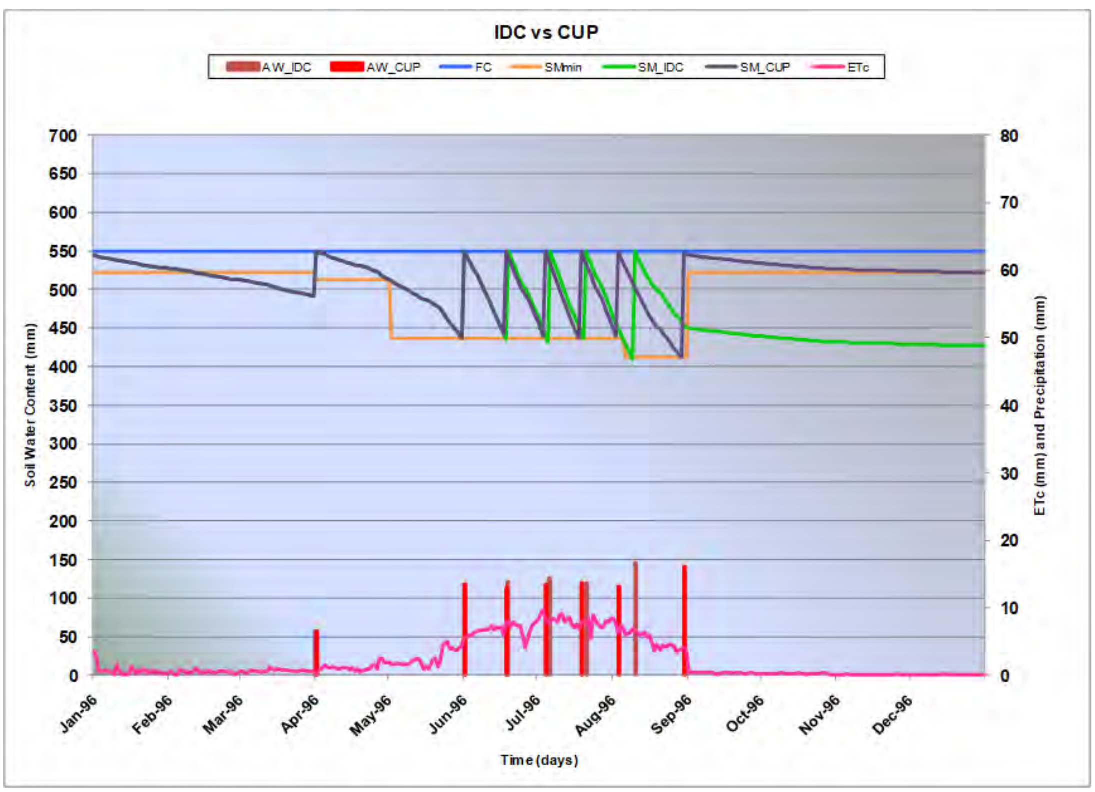
The testing and analysis of IDC results were performed in several stages. The first stage included a very simple test case with minimum amount of IDC features included. In each consecutive stage another feature of IDC was included in the test and the effects of the feature on the results were analyzed.

For this example, tomatoes were chosen as the crop for which irrigation water requirements were calculated from January 1, 1996 to December 31, 1996. The growing season for tomatoes was April 1 to August 31. The generic source of moisture was set to zero. For a specified set of weather data, CUP computed daily ET_c values that were input into IDC. Available water holding capacity (the difference between field capacity and wilting point) was 0.14 mm/mm, the rooting depth was set to 1524 mm and the maximum allowable soil moisture depletion was set to 50% of the field capacity. Using soil properties and crop specific information, CUP computed yield threshold depletion and the corresponding allowable moisture depletion (Snyder et al. 2004). The moisture content that corresponded to the allowable soil moisture depletion computed by CUP was input as the irrigation trigger moisture content into IDC. In IDC, the wilting point, field capacity, total porosity and pore size distribution index are taken to be 0.000 mm/mm, 0.270 mm/mm, 0.463 mm/mm and 0.418, respectively. These values were taken from data published by Rawls et al. (1982) for a loam soil. The initial soil moisture content was set equal to field capacity. It was also assumed in IDC that 50% of the initial soil moisture was due to precipitation.

3.3.1. Zero Precipitation, Percolation and Return Flow

CUP computes runoff due to precipitation differently than IDC. It also doesn't incorporate percolation and agricultural return flow into the computation of applied water. To simulate the similar processes, the precipitation in both programs, and saturated hydraulic conductivity and return flow factor in IDC were all set to zero. Figure 3 shows a comparison of IDC and CUP results for this case.

Figure 3. *Comparison of IDC results to CUP results for zero precipitation, percolation and return flow*



In Figure 3, FC is the field capacity, SMmin is the irrigation trigger minimum soil moisture computed by CUP and used as input to IDC, AW_IDC is the applied water computed by IDC, AW_CUP is the applied water computed by CUP, SM_IDC is the soil moisture computed by IDC, SM_CUP is the soil moisture computed by CUP, and ET_c is the crop ET that is computed by CUP and used as input to IDC.

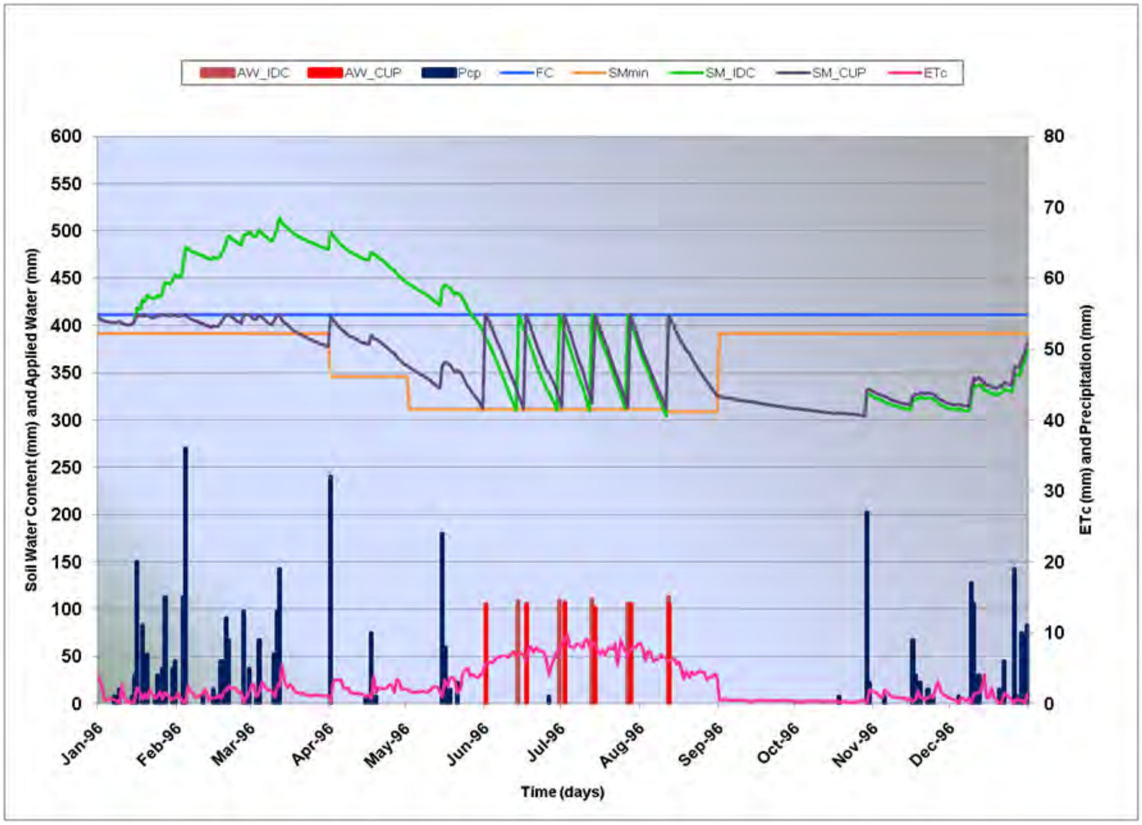
In both models, initial soil moisture is at field capacity. Until April 1, ET_c for bare soil and non-agricultural plants deplete the soil moisture below the irrigation trigger minimum soil moisture. However, since growing season does not start until April 1, irrigation is not triggered. On April 1, when the growing season starts, the first irrigation event is triggered and both models raise the soil moisture up to field capacity. Soil moisture and the magnitude of applied water are almost exactly the same until the second irrigation event towards the end of May. Here, a difference between IDC and CUP becomes apparent. The second irrigation event occurs on May 28 for CUP and on May 29 for IDC. At the beginning of May 28 both models have soil moisture that is above the irrigation trigger minimum soil moisture. CUP predicts that soil moisture at the end of the day will be less than the minimum moisture and initiates an irrigation event. IDC, on the other hand, initiates an irrigation event only based on the soil moisture at the beginning of the day. At the begging of May 29, the soil moisture is less than the minimum moisture in IDC and this is when IDC initiates an irrigation event. The effect of this difference between the two models in deciding when to irrigate accumulates throughout the growing season until the simulated soil moistures are visibly different. In fact, CUP initiates a total of 8 irrigation events that amounts to 774 mm of applied water throughout the growing season whereas IDC initiates 7 events that amounts to 712 mm.

Although there are some differences between IDC and CUP results, in general, this comparison shows that the irrigation scheduling logic built into IDC works properly. IDC allows the depletion of soil moisture until it becomes less than the irrigation trigger moisture. This is when it initiates an irrigation event to raise the moisture up to the target moisture level (field capacity, in this case).

3.3.2. Zero Percolation and Return Flow

At this stage of testing IDC, daily precipitation data for calendar year 1996 was used. With the inclusion of this data, CUP computed a new set of ET_c and irrigation trigger minimum soil moisture which were used as input to IDC. The results for this stage are shown in Figure 4.

Figure 4. *Comparison of IDC results to CUP results for zero percolation and return flow*



In this stage, another difference between IDC and CUP is shown. CUP never allows the soil moisture to go above field capacity; the infiltration of precipitation is adjusted so that soil moisture stays below or at the field capacity. IDC uses SCS curve number method (USDA 2004) to compute the direct runoff and, consequently, infiltration from precipitation (a curve number of 82 was used for this example). It also allows soil moisture to go above field capacity. This is because past CADWR experiences in coupled root zone, groundwater and stream flow modeling showed that forcing the soil moisture to be at or below field capacity at every time step required increasing direct runoff or percolation. This approach had adverse effects on the timing of recharge into groundwater and surface runoff into the streams. Furthermore, it has been observed in the field that considerable root zone drainage can occur beyond three days (Ritchie, 1981) suggesting that the soil moisture stays above field capacity for as long as the drainage continues.

Figure 4 shows that the soil moisture in IDC rises above field capacity with the winter rains whereas CUP limits it with field capacity by decreasing the infiltration of precipitation. For the entire year, IDC and CUP generate 69 mm and 141 mm of direct runoff, respectively, out of 465 mm of precipitation. Although, with different values for curve number, the direct runoff can be changed in IDC, this example shows the effect of allowing the soil moisture to rise above field capacity. With the higher moisture content at the beginning of the growing season, IDC does not initiate an irrigation until June 14, whereas CUP initiates the first irrigation on June 1. For the entire season, the application water for IDC and CUP are 547 mm and 628 mm, respectively.

3.3.3. Zero Return Flow

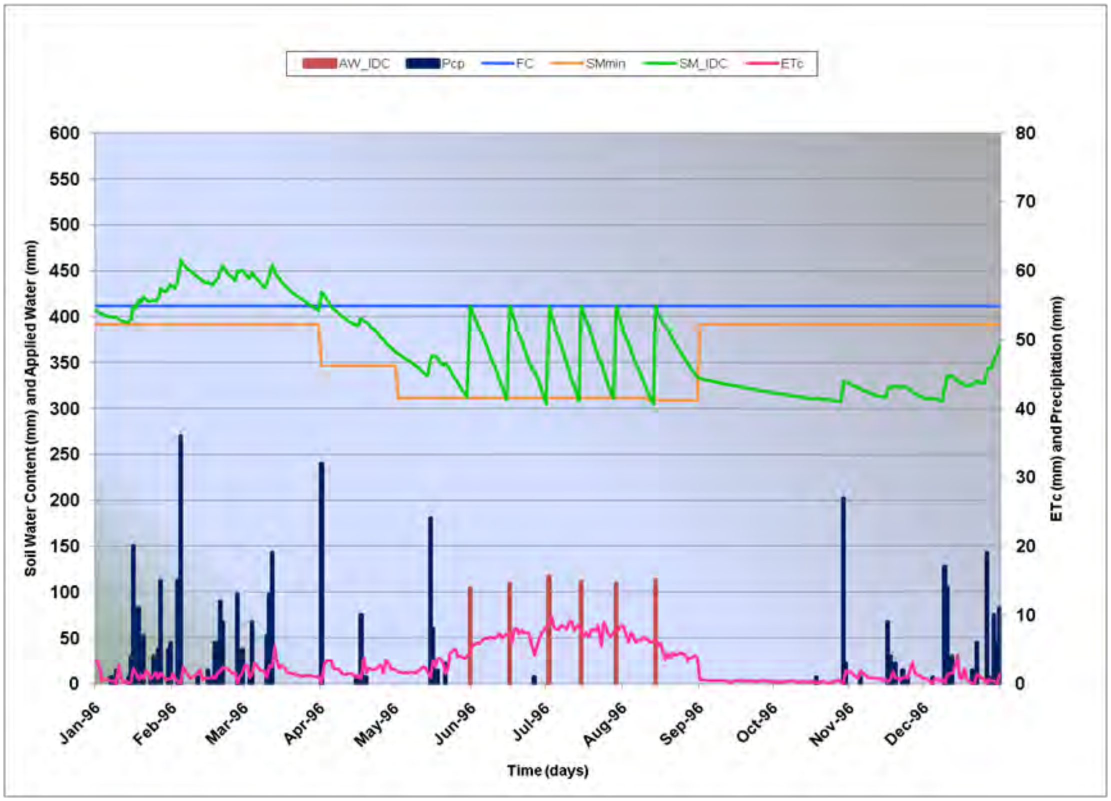
At this stage of testing, hydraulic conductivity of the loam soil was set to 1.32 cm/hour (Rawls et al. 1982) to simulate the percolation from the root zone. Since percolation is not simulated in CUP, the IDC results were compared to the IDC results from previous stage.

Figure 5 shows the results for this test case. The annual percolation is 135 mm. When compared to Figure 4, it can be seen that the soil moisture increase during the winter months is less due to the moisture depleting effects of percolation.

Inclusion of the percolation in the simulation also decreases the direct runoff from precipitation; 57 mm annually in this case versus 69 mm with zero percolation. This result is expected since depleting the soil moisture through percolation leads to increased empty storage to be filled by precipitation.

The annual applied water in this case is 666 mm compared to 547 mm with no percolation. This result is also in line with expectations that increasing the percolation should also increase the amount of applied water to achieve the same crop yield. In this case, when raising the moisture to field capacity, applied water not only counter-balances the moisture depleting effect of evapotranspiration but also that of percolation.

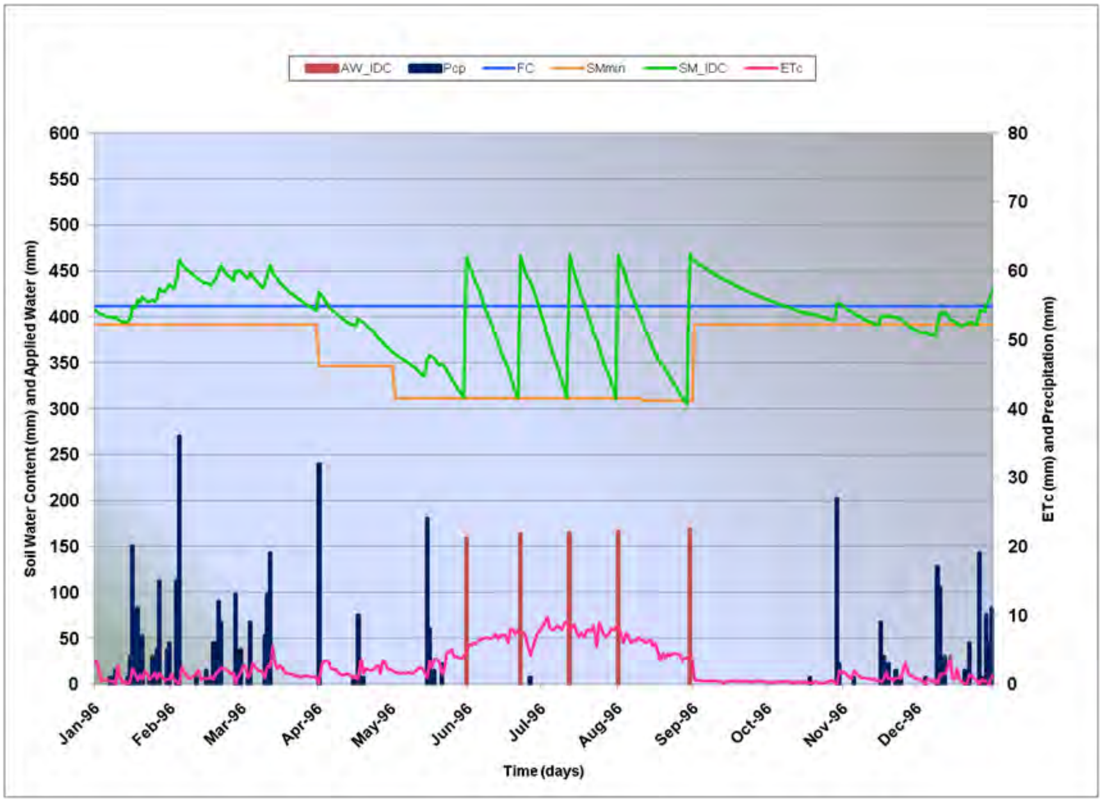
Figure 5. *IDC results for zero return flow*



3.3.4. Zero Return Flow and 1% Minimum Percolation Fraction

In this stage, a minimum percolation of 1% of infiltrated applied water is imposed. Figure 6 shows that every time an irrigation event is triggered, the soil moisture is raised above field capacity to a moisture that will create a percolation that is equal to 1% of the infiltrated applied water on that day. Since the percolation continues beyond the day of the irrigation, the total percolation from irrigation is larger than 1%. During the growing season, the total percolation amounts to 70 mm with 822 mm of applied water. Assuming that the percolation is entirely due to irrigation during the growing season, this leads to a leaching fraction of 9%.

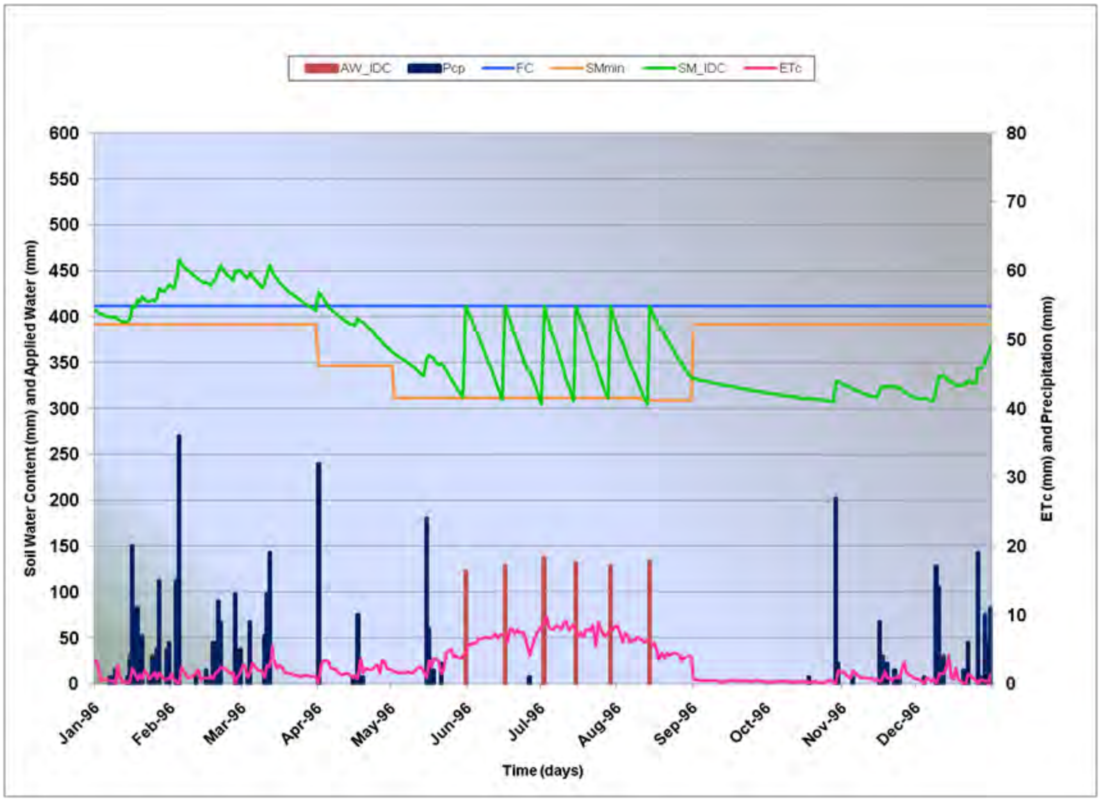
Figure 6. *IDC results for zero return flow with 1% minimum percolation requirement*



3.3.5. 15% Return Flow Fraction

In this case, the minimum percolation fraction was set to zero but the return flow fraction was set to 15% of applied water. The results for this case are shown in Figure 7. When compared to Figure 5 of section 3.3.3 (zero return flow with zero minimum percolation fraction), it can be seen that the only difference is in the amount of applied water. The total applied water in this case was 783 mm compared to 666 mm in the case with zero return flow and minimum percolation fraction (see section 3.3.3). The return flow amount was 117 mm, equal to the difference between the applied water in two test cases. The return flow is taken out of the total applied water and it does not affect the soil moisture dynamics.

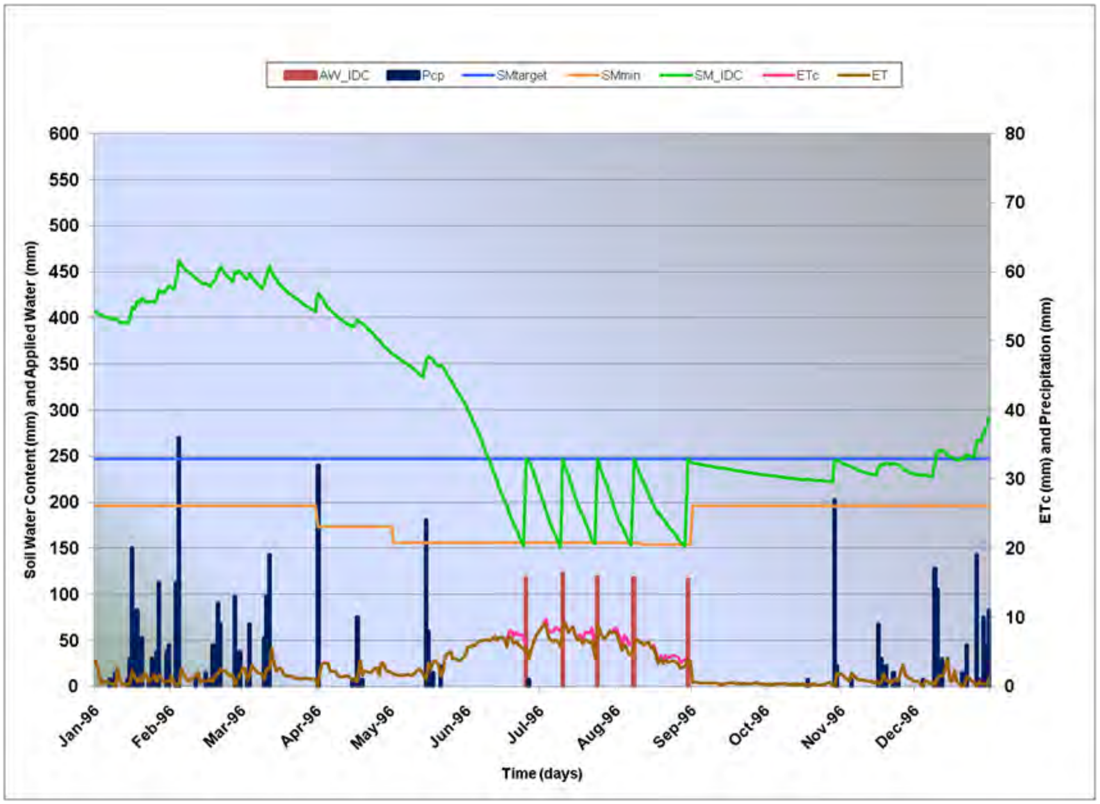
Figure 7. *IDC results for 15% return flow*



3.3.6. Deficit Irrigation

As a final test case, deficit irrigation conditions were simulated by setting the irrigation target moisture to 60% of field capacity and the irrigation trigger minimum soil moisture to 50% of those used in previous test case (see section 3.3.5). The results for this case are shown in Figure 8. SMtarget and ET in Figure 8 represent the irrigation target soil moisture and the actual ET, respectively. Deficit irrigation is generally recommended when the losses due to the decrease in the crop yield because of unmet crop ET is surpassed by the gains from conserving irrigation water (Kirda, 2002). In this test case, the total applied water and crop ET were 594 mm and 718 mm, respectively, compared to 783 mm and 764 mm, respectively, in the non-deficit irrigation scenario simulated in section 3.3.5. These results show that a 24% reduction in applied water only caused a 6% reduction in the crop ET.

Figure 8. *IDC results for deficit irrigation scenario*



3.3.7. Additional Comments on Test Cases

Some of the important seasonal (values on the left) and annual (values on the right in parentheses) flow terms from each simulated scenario are listed in Table 2. The scenario simulated in section 3.3.1 (zero precipitation, percolation and return flow) is not included in the table since the crop ET is different than the other scenarios and it would be difficult to make meaningful comparisons with other scenarios. In Table 2, AW is the applied water, ET is the actual ET, R_P is the direct runoff, R_f is the net return flow, P_C is the percolation, ETaw is the ET of applied water, ETp is the effective precipitation and IE is the irrigation efficiency expressed as ETaw divided by AW.

The following are several comments and conclusions based on the values listed in Table 2:

Table 2. *Summary of IDC results for the simulated scenarios (first values are for the growing season, second values (i.e. values in parentheses) are for the entire calendar year; all values except IE are in mm.*

Flow Term	**Scenario 1** (section 3.3.2) P_C=0 ; R_f=0	**Scenario 2** (section 3.3.3) R_f=0	**Scenario 3** (section 3.3.4) R_f=0 ; P_{Cmin}=1%	**Scenario 4** (section 3.3.5) R_f=15%	**Scenario 5** (section 3.3.6) Deficit Irrigation
AW	546 (546)	666 (666)	822 (822)	783 (783)	594 (594)
ET	764 (983)	764 (983)	764 (983)	764 (983)	718 (936)
R_P	21 (69)	16 (57)	16 (62)	16 (57)	16 (53)
R_f	0 (0)	0 (0)	0 (0)	117 (117)	89 (89)
P_C	0 (0)	43 (135)	69 (226)	43 (135)	19 (100)
ETaw	428 (428)	475 (475)	484 (484)	475 (475)	397 (397)
ETp	336 (336)	289 (289)	280 (280)	289 (289)	321 (321)
IE	78%	71%	59%	61%	67%

1. Percolation has a direct impact on the irrigation requirement, higher the percolation more applied water is needed to meet the crop ET (see AW values for scenarios simulated in sections 3.3.2, 3.3.3 and 3.3.4). However, percolation and applied water are not linearly related since a portion of the applied water is stored in the soil.
2. Direct runoff from precipitation decreases as percolation increases (see Rp values for sections 3.3.2 and 3.3.3). This is because percolation depletes the soil moisture storage allowing more precipitation to infiltrate. However, as more water is applied to increase the soil moisture above field capacity, increasing the percolation for leaching of salts, higher values of direct runoff are observed due to soil moisture being above field capacity at the end of growing season (see Figure 6 and annual Rp values for sections 3.3.3 and 3.3.4).
3. Return flow affects the irrigation requirement but not the ET, percolation, ETaw and ETp (see relevant flow terms for sections 3.3.3 and 3.3.5). As expected, increasing return flow decreases irrigation efficiency.
4. Comparing IE values for sections 3.3.3 and 3.3.4, it can be seen that applying more irrigation water for the purposes of leaching decreases the irrigation efficiency. However, an alternative definition of irrigation efficiency includes not only ETaw but also the losses if they are beneficial such as percolation for leaching (Burt et al., 1997). Although beneficial

percolation cannot immediately be quantified through IDC output values, IE would be higher for section 3.3.4 when the alternative definition of the irrigation efficiency is considered. As a rough estimate, it can be assumed that the difference between the annual percolation values from sections 3.3.3 and 3.3.4 is the beneficial percolation triggered by additional applied water. Then the IE expressed by Burt et al. (1997) can be computed as

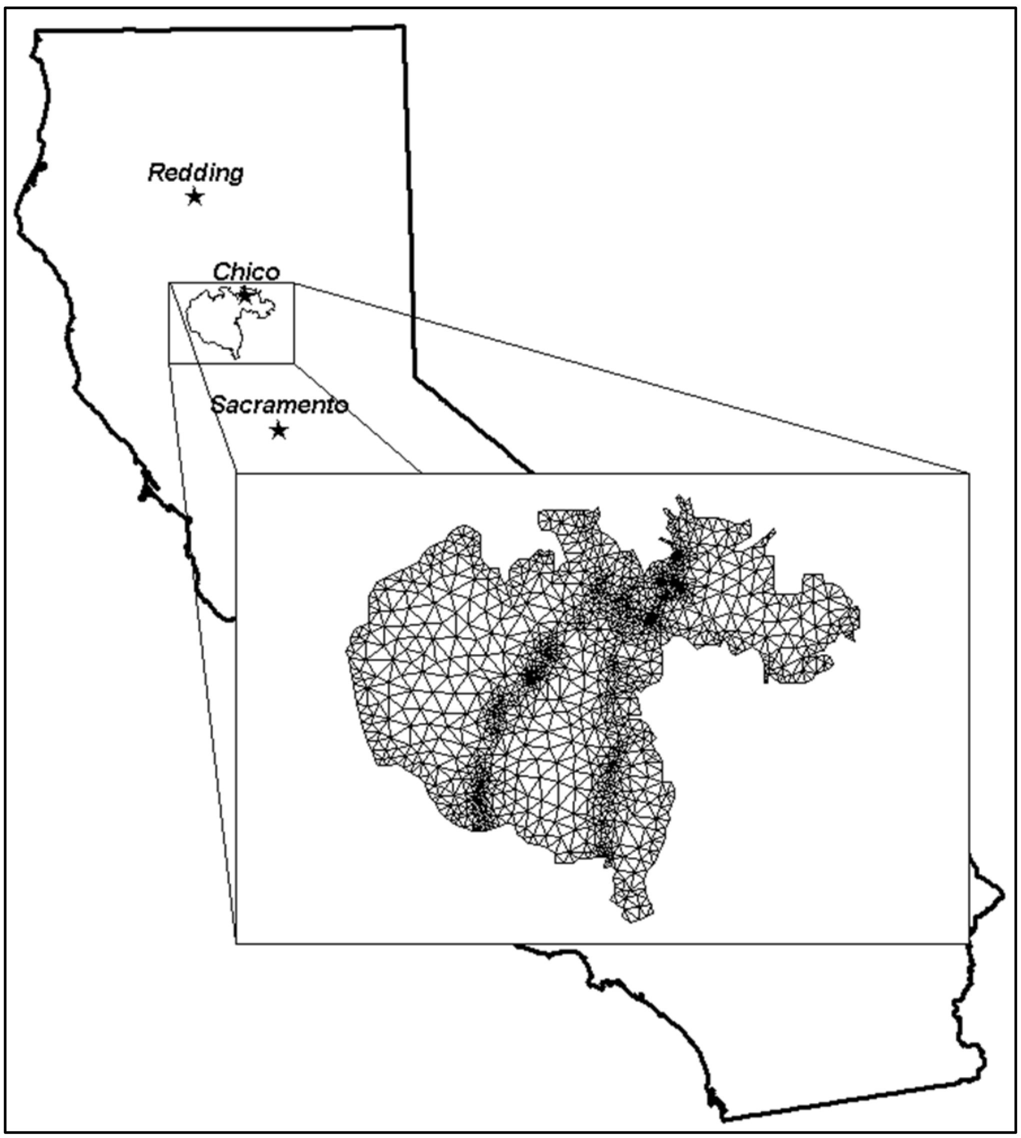
$$IE = \frac{ETaw + P_{Cbeneficial}}{AW} = \frac{484 + 226 - 135}{822} \times 100 = 70\% \qquad (38)$$

5. Deficit irrigation is one way of increasing the irrigation efficiency (Kirda, 2002). Table 2 shows a 6% increase in the IE (see IE values for scenarios 3.3.5 and 3.3.6) when a deficit irrigation scenario is simulated.
6. IDC uses the ratio of the soil moisture due to irrigation to the total soil moisture storage in computing the ETaw (see equation (30)) and hence the IE. IDC allows the user to input initial soil moisture content due to irrigation and precipitation. The ETaw values at the early stages of the simulation period are largely impacted by the user-defined initial proportioning of the moisture between precipitation and irrigation. Therefore, for a modeling study that addresses a short simulation period such as this example, IE values will be affected by the initial soil moisture estimates. Since the true portioning of the moisture between irrigation and precipitation is hard to estimate, it is advisable to include a “spin-up” period of a few years in IDC runs to achieve a more realistic mixture of stored moisture due to precipitation and applied water. This spin-up period will minimize the adverse effects of incorrect estimates of initial proportioning of the soil moisture storage on the IE calculations.

3.4. Example 2: A Real-World Application

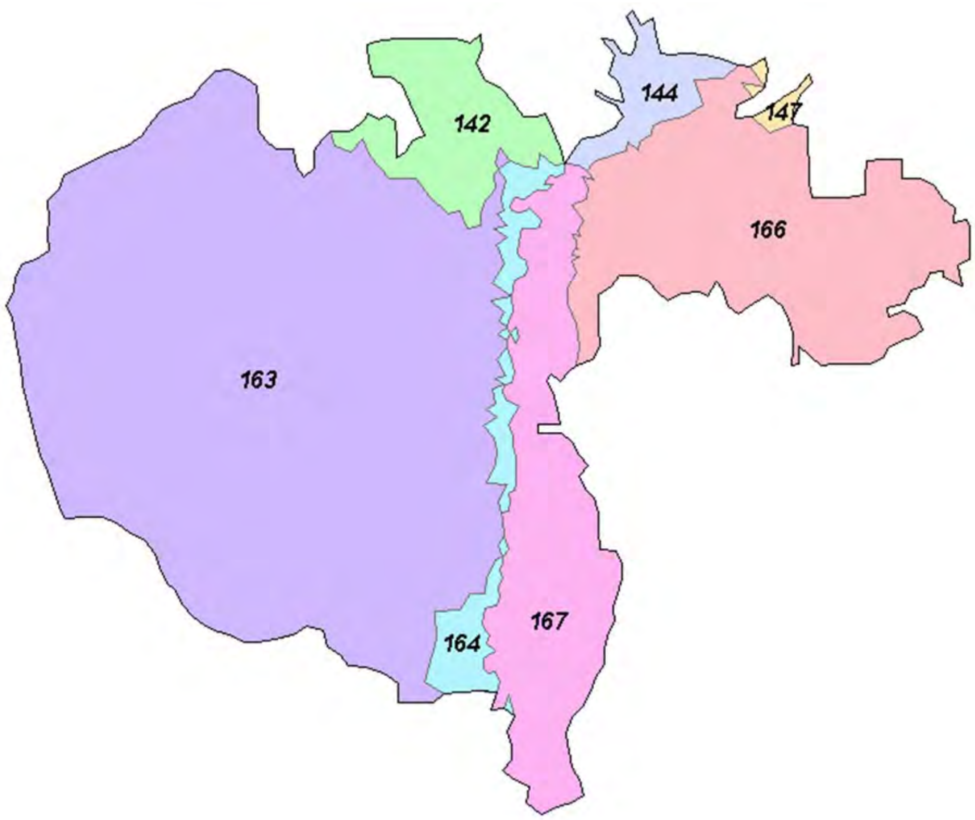
For this example IDC was used to simulate the irrigation water requirements and root zone flow terms over a period of four water years (October 1, 1997 to September 30, 2001) at a section of California's Central Valley (Figure 9) using field data as input. The reason for the selection of this area was that another project, CalSim 3.0 hydrology development, also addressed the same area.

Figure 9. *Model area and the simulation grid for Example 2*



CalSim is the CADWR's model used to simulate California State Water Project (SWP) and the Central Valley Project (CVP) operations. An earlier version of IDC was used during the CalSim 3.0 project so a large portion of the input data for this example was already developed. Furthermore, the modeled area intersected with seven Detailed Analysis Units (DAUs) (Figure 10). DAUs are the smallest study areas used by CADWR for analyses of water demand and supply, generally defined by hydrologic features or boundaries of organized water service agencies. CADWR has collected and developed extensive data sets for these regions. To test their accuracy, IDC results were compared to data developed for the seven DAUs that the model area intersects.

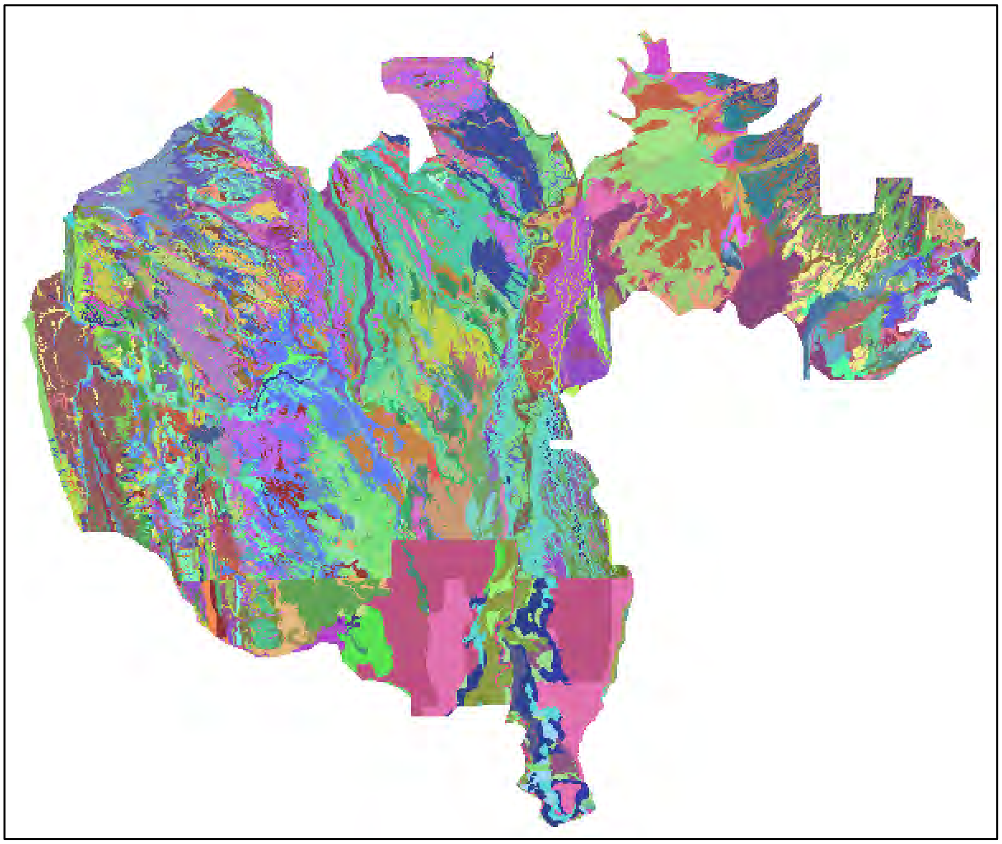
Figure 10. *DAUs in modeled area in Example 2*



The 2805 km^2 model area and the finite element grid for this example are shown in Figure 9. The simulation grid, which includes 2622 cells, was created using a mesh generator developed by CADWR as an add-on for ESRI's ArcGIS software. The part of each DAU that intersected with the model area was designated as an individual subregion (Figure 10) where subregions in IDC are used for aggregation and reporting of the simulation results.

The soil physical properties were compiled using the Natural Resources Conservation Service's (NRCS) Soil Survey Geographic Database (SSURGO). The soils map for the modeled area is shown in Figure 11 without the legend due to highly complex soil structure.

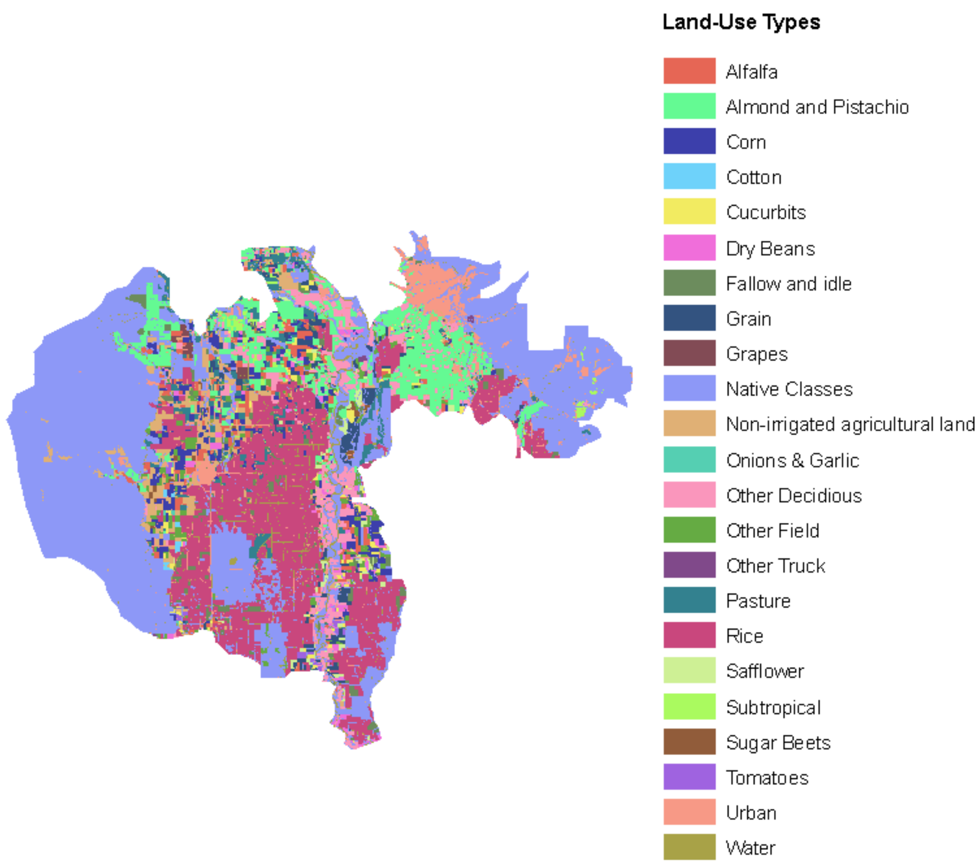
Figure 11. *Soils map for the model area*



Using the Soil Data Viewer software available from NRCS, the soil physical properties (field capacity, total porosity, saturated hydraulic conductivity and soil hydrologic group) were first averaged over soil horizons for each soil component. Properties defined for each component were then averaged for each soil map unit. Finally, properties defined for map units were intersected with simulation grid cells. Since each grid cell intersected with multiple map units, the physical soil properties were further area-averaged over grid cells to end up with a single value for each soil property for each element. The dominant surface soil texture for each grid cell was also identified and the arithmetic mean values for pore size distribution index listed in Rawls et al. (1982) were assigned to matching soil textures. Wilting point for each cell was set to zero.

The land-use map for the model area was available as a Geographic Information System (GIS) layer (Figure 12). The agricultural crops were grouped into 20 non-ponded crop types including fallow or idle areas, and rice fields. The modeled area also included urban areas, wildlife refuges and native vegetation. Total area of water and non-irrigated agricultural lands were minor, 2% and 4% of the total modeled area, respectively. Therefore these land-use types were incorporated into the lands with native vegetation (Figure 12). The land-use map was intersected with the finite element grid and the area of each land-use type over every grid cell was computed.

Figure 12. *Land-use types in the modeled area*



Precipitation data that was developed for Calsim 3.0 project using the PRISM climate data (PRISM, 2009) was utilized in this example.

ET data for each crop at each DAU obtained from DPLA changed from month to another and from year to year. However, it was zero for particular crops when they were not planted in certain years. On the other hand, the land-use areas used in this test was constant and did not change from year to year. Therefore, matching ET data from DPLA with constant land-use areas created a problem: in some years zero ET was assumed for land-use types whose area was not zero. To avoid this problem, ET data for each land use at each grid cell was obtained from the Calsim 3.0 project on a monthly basis. It changed from one month to another but the same monthly values were used for each water year.

Rice operations data such as ponding depths and return flow depths were all taken from CalSim 3.0 study whose source was the Northern District of CADWR.

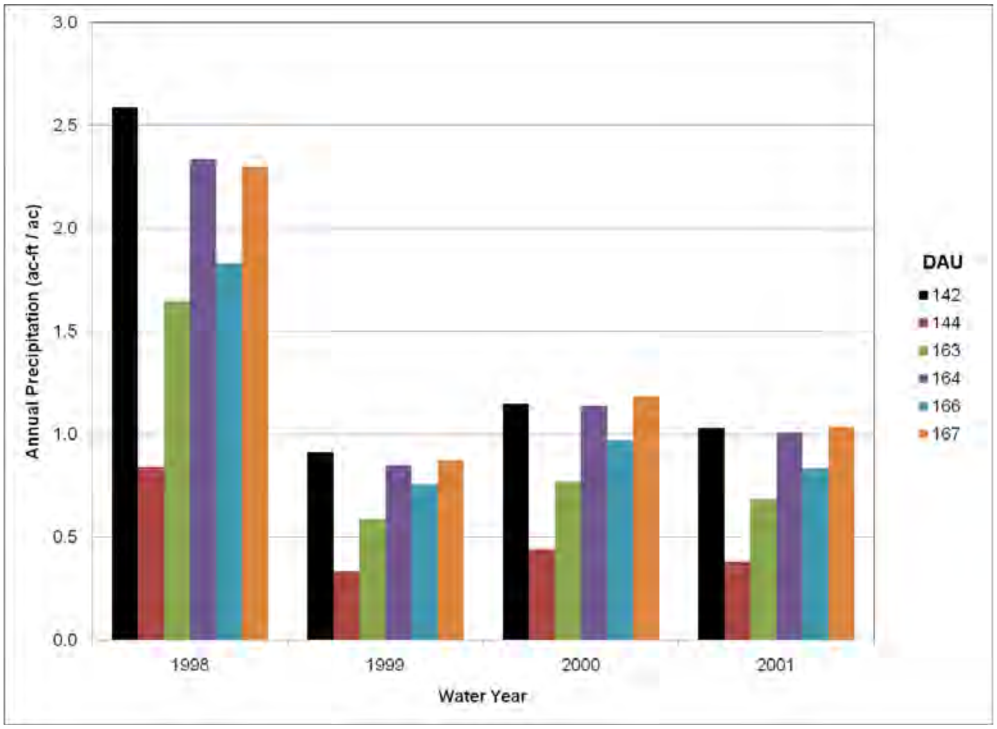
Even though the irrigation water demand data for modeled DAUs obtained from DPLA was for water years 1998 to 2001, IDC run was started from October 1, 1990; i.e. a spin-up period of eight years was used to ensure that the mixture of soil moisture storage due to irrigation and precipitation was realistic.

3.4.1. Results and Discussion

The data obtained from DPLA listed crop irrigation requirements for non-ponded agricultural crops and rice as well as ET_c for each DAU as unit rates in terms of acre-feet/acre. To be able to compare to DPLA values, IDC results were also converted to unit rates. Instead of comparing results for individual crops, the total irrigation requirements for each DAU for non-ponded crops computed by IDC were compared to total irrigation requirements for non-ponded crops obtained from DPLA. Irrigation requirement for rice from IDC and DPLA was compared individually since rice irrigation requires much more water than non-ponded crops.

Precipitation is one of the major drivers of the flow processes in IDC. Figure 13 shows the annual precipitation for each DAU.

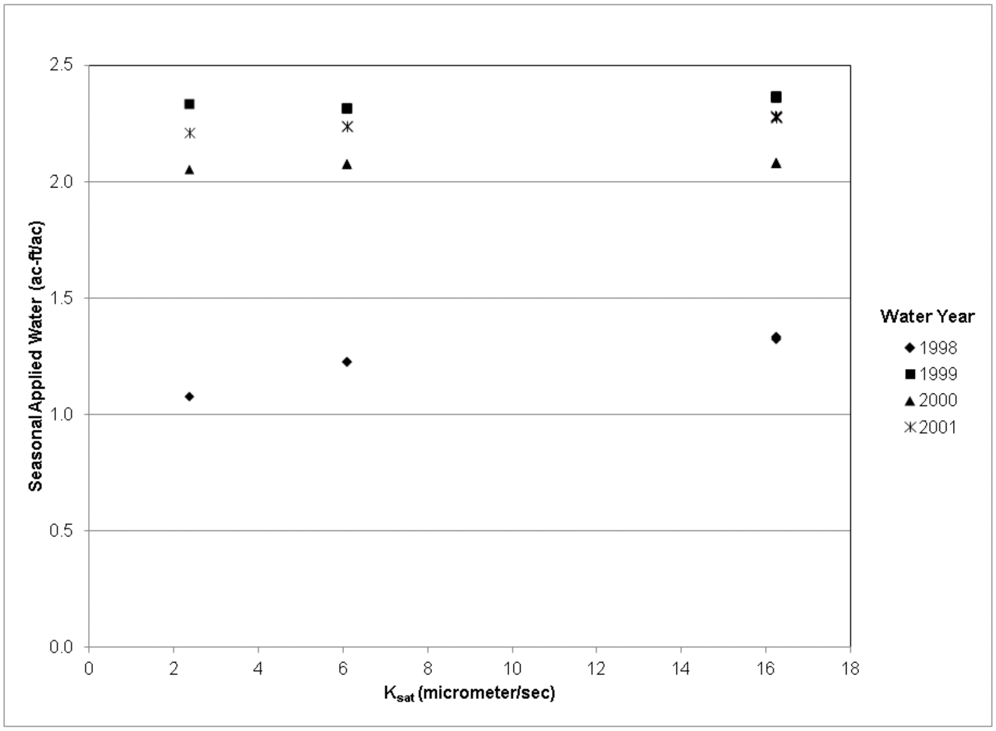
Figure 13. *Annual precipitation for each DAU*



The Soil Data Viewer from NRCS allows different ways of averaging of the soil physical properties. Also each soil physical property is assigned a lower and upper limit as well as a representative value. Combining the lower, upper and representative values with different averaging methods, one can obtain different values for each soil map unit. Figure 14 and Figure 15 show the simulated irrigation water requirements for non-ponded crops at DAU 142 and for rice in DAU 163, respectively, for varying average saturated hydraulic conductivities (K_{sat}). These DAUs were selected for analysis because DAU 142 had the largest percent non-ponded crop acreage (88% of the total modeled area of the DAU) and DAU 163 had the largest percent rice acreage (24% of the total modeled area of the DAU). Figure 14 shows results for four water years whereas Figure 15 shows those only for water year 2000 because there was no visible difference in the results from one year to another for rice irrigation requirements.

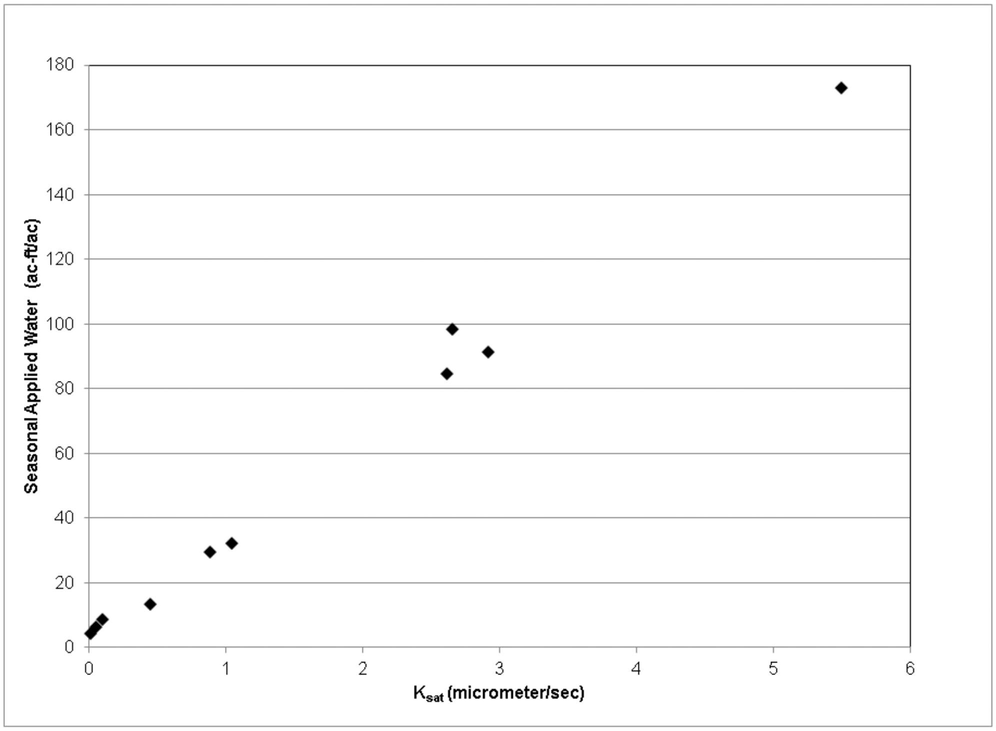
It can be seen that while irrigation water requirement for non-ponded crops is not extremely sensitive to K_{sat} (Figure 14), it is very sensitive in the case of rice (Figure 15).

Figure 14. *Seasonal irrigation water requirement versus saturated hydraulic conductivity for non-ponded crops at DAU 142*



This is expected since rice is grown under saturated conditions. However, even though K_{sat} values shown in Figure 15 were computed using the NRCS data, larger K_{sat} values lead to unreasonably high values of irrigation requirements for rice. In fact, using different averaging techniques featured in the NRCS Soil Data Viewer on upper, lower and representative K_{sat} values listed in the SSURGO database, the smallest average K_{sat} value obtained was 0.45 micrometers/sec. By contrast, DPLA assumes an average of 0.01 micrometer/sec (equivalent to 1 inch/month) percolation from rice fields in their analysis. This value is in line with other sources. For instance, Williams (2004) reports percolation at rice fields between 0.012 to 0.048 micrometers/sec (1.2 to 4.8 inches/month). Assuming that these rates represent the K_{sat} values, the smallest value obtained by averaging the data from SSURGO is one order of magnitude larger leading to large simulated irrigation requirements for rice. Although a visual inspection of SSURGO data showed that there were K_{sat} values as low as 0.001 micrometers/sec, this example shows that one needs to exercise caution when assigning K_{sat} values to grid elements where rice is grown.

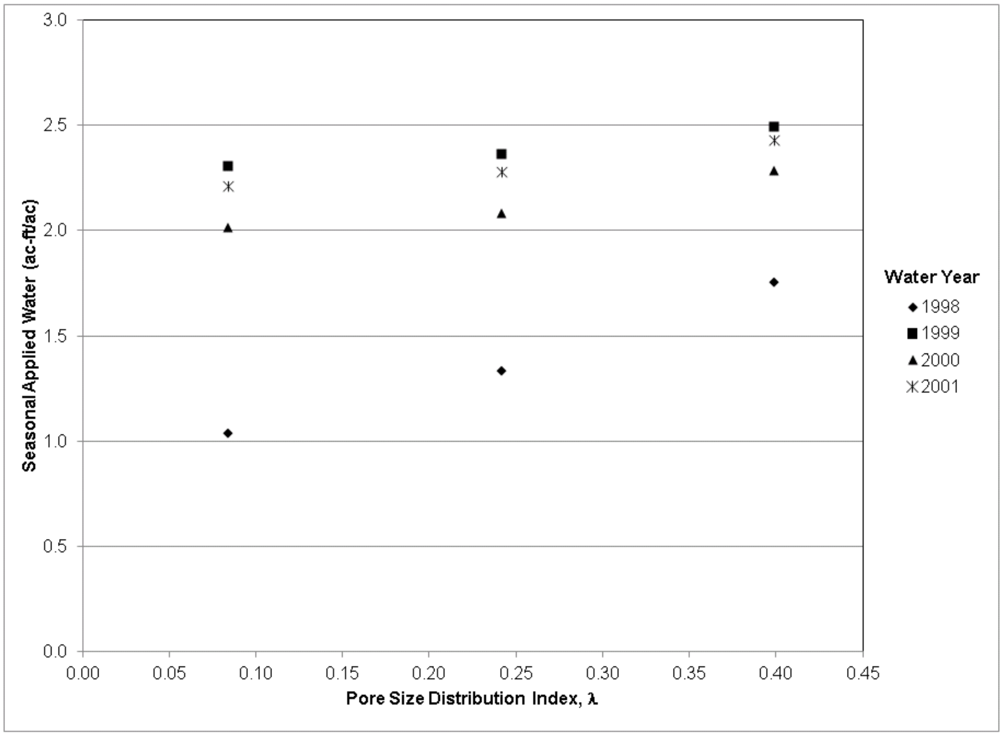
Figure 15. *Seasonal irrigation water requirement versus saturated hydraulic conductivity for rice at DAU 163 for water year 2000*



To test how IDC performs for rice fields with soil properties suggested by other sources, grid cells that had rice fields were assigned K_{sat} values of 0.01, 0.05 and 0.1 micrometers/sec. The irrigation requirement for rice computed by IDC for water year 2000 was 4.6, 6.4 and 8.7 ac-ft/ac for K_{sat} values of 0.01, 0.05 and 0.1 micrometers/sec, respectively. For comparison purposes, DPLA reports 5.8 ac-ft/ac and Williams (2004) reports an average value of 6 to 6.5 ac-ft/ac which can vary from 4 to 8 ac-ft/ac or more. This comparison suggests that IDC is capable of producing reasonable values for irrigation requirements at rice fields when grid cell K_{sat} values are set properly. In contrast, the rice irrigation requirement computed by IDC with the K_{sat} value at grid cells with rice set to the minimum values obtained by averaging the SSURGO data (0.45 micrometers/sec on average) was 13.6 ac-ft/ac.

As mentioned earlier, irrigation water requirement for non-ponded crops is not very sensitive to the changes in K_{sat} values (Figure 14). Figure 16 shows the seasonal irrigation water requirement (i.e. applied water) versus pore size distribution index, λ, for DAU 142 at different water years. For each soil texture, Rawls et al. (1982) list lower and upper limits as well as a representative value for λ.

Figure 16. *Seasonal irrigation water requirement versus pore size distribution index for non-ponded crops at DAU 142*



To generate Figure 16, IDC was run with the K_{sat} values computed by averaging representative values from SSURGO database combined with low, representative and high values of λ listed by Rawls et al. (1982). To gage the sensitivity of irrigation requirement to K_{sat} and λ values, linear best-fit curves were computed for simulation results shown in Figure 14 and Figure 16, respectively; high gradient of the best-fit curve represented high sensitivity. The gradient of the best-fit line for K_{sat} versus irrigation requirement varied from 0.0007 for year 2000 to 0.014 for year 1998, whereas for λ versus irrigation requirement it varied from 0.505 for year 2001 to 2.169 for year 1998.

As a summary, one needs to choose K_{sat} values carefully for grid cells where rice is grown. K_{sat} values will not affect the irrigation requirements for non-ponded crops in these cells because they are insensitive to changes in K_{sat} values. On the other hand, to change the irrigation requirement for non-ponded crops one can modify λ with minimal effect on the values computed for rice.

Table 3 shows a general comparison of simulation results for non-ponded crops compared to DPLA values when K_{sat} at grid cells with rice was set to 0.01

micrometers/sec. Percolation from DPLA was not available so these values are shown as n/a (not applicable). One can see in Table 3 that the annual ET rates from DPLA change from one year to another, whereas IDC values are constant. This difference is likely to cause other values to be different as well.

Table 3. *Comparison of IDC results for non-ponded crops to the values obtained from DPLA with K_{sat} values at cells with rice set to 0.01 micrometers/sec (all values are in ac-ft/ac; n/a = not applicable)*

DAU (Water Year)	ET IDC	ET DPLA	A_W IDC	A_W DPLA	ETaw IDC	ETaw DPLA	ETp IDC	ETp DPLA	P_C IDC	P_C DPLA
142 (1998)	2.65	2.18	1.74	1.66	1.16	1.24	1.49	0.94	0.63	n/a
144 (1998)	2.71	2.68	2.10	1.91	1.23	1.50	1.48	1.17	1.09	n/a
163 (1998)	2.34	2.19	1.50	2.04	1.02	1.47	1.32	0.72	0.33	n/a
164 (1998)	2.51	2.38	1.20	2.05	0.85	1.52	1.66	0.87	0.40	n/a
166 (1998)	2.80	2.54	1.91	2.11	1.13	1.56	1.67	0.98	0.91	n/a
167 (1998)	2.01	1.98	1.28	1.47	0.75	1.09	1.26	0.89	0.62	n/a
142 (1999)	2.65	2.56	2.49	2.57	1.76	1.92	0.89	0.64	0.02	n/a
144 (1999)	2.71	2.65	2.78	2.56	1.79	2.01	0.92	0.65	0.12	n/a
163 (1999)	2.33	2.49	2.26	3.28	1.55	2.04	0.78	0.45	0.02	n/a
164 (1999)	2.50	2.74	2.26	3.47	1.50	2.19	1.00	0.55	0.01	n/a
166 (1999)	2.80	2.88	2.56	3.11	1.65	2.29	1.15	0.59	0.16	n/a
167 (1999)	2.01	2.17	1.89	2.32	1.15	1.56	0.86	0.60	0.06	n/a
142 (2000)	2.65	2.60	2.28	2.49	1.64	1.87	1.00	0.74	0.07	n/a
144 (2000)	2.71	3.22	2.52	2.86	1.65	2.26	1.07	0.96	0.27	n/a
163 (2000)	2.33	2.53	2.07	2.63	1.44	1.92	0.90	0.61	0.04	n/a
164 (2000)	2.51	2.77	1.93	2.71	1.36	2.00	1.14	0.76	0.02	n/a
166 (2000)	2.80	2.97	2.30	2.96	1.57	2.24	1.23	0.74	0.29	n/a
167 (2000)	2.01	2.33	1.63	2.13	1.04	1.57	0.97	0.76	0.11	n/a
142 (2001)	2.65	2.67	2.42	2.66	1.76	2.01	0.89	0.66	0.05	n/a
144 (2001)	2.71	3.32	2.68	3.23	1.75	2.53	0.96	0.79	0.20	n/a
163 (2001)	2.33	2.60	2.17	2.88	1.55	2.10	0.78	0.50	0.03	n/a
164 (2001)	2.51	2.88	2.09	2.95	1.50	2.20	1.01	0.68	0.01	n/a
166 (2001)	2.80	3.08	2.61	3.19	1.66	2.40	1.14	0.68	0.20	n/a
167 (2001)	2.01	2.37	1.84	2.29	1.14	1.70	0.87	0.67	0.08	n/a

Furthermore, precipitation data used in DPLA analysis was not available. It was also observed that some crops that were present in some subregions in IDC had zero acreage in DPLA's data. The likelihood of precipitation data being different from IDC data along with different ET rates and different crop areas is responsible for some of the differences among other values such as applied water. Also, ETaw is constantly lower in IDC than in DPLA data, whereas ETp is higher. This means that DPLA values will lead to a higher irrigation efficiency than IDC values. This difference is likely due to different methods used for computing ETaw and ETp as well as different ET and precipitation input data. It also appears that since applied water is generally lower in IDC (see Table 3), it is likely that the infiltration of precipitation in IDC is estimated higher compared with those in DPLA. By increasing the curve numbers in IDC, the infiltration of precipitation can be decreased which will lead to increased applied water with increased ETaw and decreased ETp. Overall, however, the values from IDC and DPLA are reasonably close given the fact that there was no effort to calibrate IDC to match values from DPLA.

Similarly, Table 4 shows the comparison of IDC and DPLA values for rice. As for Table 3, IDC results were obtained by setting the K_{sat} values for grid cells that include rice fields to 0.01 micrometers/sec. It can be seen that ET values are generally lower in IDC than DPLA, with the exception of 1998. For 1998, ET values are closer to each other. It appears that due to different ET rates, applied water and ETaw are also lower in IDC for years 1999 through 2001. Since ET rates are similar for 1998, these values are also close to each other for 1998. Overall, the results match relatively well compared to the results for non-ponded crops.

***Table 4.** Comparison of IDC results for rice to the values obtained from DPLA with Ksat values at cells with rice set to 0.01 micrometers/sec (all values are in ac-ft/ac; n/a = not applicable)*

DAU (Water Year)	**ET** IDC	**ET** DPLA	**A_W** IDC	**A_W** DPLA	**ETaw** IDC	**ETaw** DPLA	**ETp** IDC	**ETp** DPLA	**P_C** IDC	**P_C** DPLA
142 (1998)	3.32	2.50	5.27	4.36	2.93	2.48	0.37	0.02	0.55	n/a
144 (1998)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	n/a
163 (1998)	2.78	2.50	4.49	4.22	2.47	2.40	0.29	0.10	0.51	n/a
164 (1998)	2.94	2.55	4.75	4.29	2.61	2.44	0.30	0.12	0.50	n/a
166 (1998)	3.49	2.53	5.87	4.25	3.16	2.42	0.30	0.12	0.66	n/a
167 (1998)	3.49	2.50	5.85	4.21	3.16	2.40	0.30	0.10	0.65	n/a
142 (1999)	3.32	3.30	5.40	7.73	3.02	3.19	0.27	0.12	0.53	n/a
144 (1999)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	n/a
163 (1999)	2.78	3.30	4.59	6.18	2.54	3.10	0.22	0.20	0.47	n/a
164 (1999)	2.94	3.26	4.85	5.98	2.68	3.06	0.23	0.20	0.49	n/a
166 (1999)	3.49	3.30	5.97	7.76	3.23	3.09	0.23	0.21	0.65	n/a
167 (1999)	3.49	3.30	5.94	6.18	3.22	3.10	0.23	0.20	0.65	n/a
142 (2000)	3.32	3.23	5.38	5.34	2.99	3.05	0.30	0.19	0.53	n/a
144 (2000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	n/a
163 (2000)	2.78	3.39	4.58	5.78	2.53	3.29	0.23	0.10	0.47	n/a
164 (2000)	2.94	3.31	4.85	5.62	2.67	3.19	0.24	0.13	0.49	n/a
166 (2000)	3.49	3.37	5.96	5.73	3.21	3.26	0.25	0.11	0.65	n/a
167 (2000)	3.48	3.40	5.95	5.79	3.21	3.30	0.24	0.10	0.65	n/a
142 (2001)	3.32	3.45	5.43	5.71	3.03	3.25	0.26	0.20	0.53	n/a
144 (2001)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	n/a
163 (2001)	2.78	3.60	4.62	5.96	2.56	3.40	0.20	0.20	0.47	n/a
164 (2001)	2.94	3.54	4.89	5.90	2.70	3.34	0.21	0.20	0.49	n/a
166 (2001)	3.49	3.59	5.97	5.96	3.22	3.39	0.24	0.20	0.65	n/a
167 (2001)	3.49	3.60	5.99	5.96	3.24	3.40	0.21	0.20	0.65	n/a

4. Root Zone Component Version 4.01

This version is exactly the same as version 4.0 except that it allows the user to print out Z-Budget data files for Land and Water Use as well as the Root Zone budgets. These files can then be post-processed using the Z-Budget tool to analyze the water demand, water supply and the root zone water budget for elements grouped into zones by the user. Land and Water Use Z-Budget and Root Zone Z-Budget outputs will be discussed later in this document. The input files to run the Z-Budget post-processing tool are described in the *User's Manual for IWFM-2015* (Dogrul 2021b).

5. Root Zone Component Version 4.1

This version is very similar to version 4.0 as described in the previous chapter. In addition to all the features of version 4.0, it includes two new capabilities, namely the riparian vegetation access to stream flow to meet the evapotranspirative demands and the root water uptake from groundwater. The root water uptake from groundwater requires depth-to-groundwater information which can be specified by the user as a time series data. However, IDC, when executed on its own, has no information about the stream flows. Therefore, riparian vegetation access to stream flow to meet the evapotranspirative demands is only effective when IDC is linked to an integrated hydrologic model such as IWFM that simulates both stream flows. When IDC is executed on its own, this feature will simply be ignored.

Since all the flow routing and demand calculations that are explained for version 4.0 are the same in version 4.1, these simulation methods will not be iterated here. Instead, only the new features will be detailed in the following sections.

5.1. Riparian Vegetation Access to Stream Flows

In version 4.0 of the root zone component, the only sources of moisture to meet the evapotranspirative demand of riparian vegetation are precipitation, any moisture that is already stored in the root zone and user-specified generic sources, if any. In the real-world, riparian vegetation grows near streams and part of the evapotranspirative demand is met by stream flow, either directly or by the moisture in the root zone that is due to stream flow seepage.

In IDC, the user specifies the stream node for each grid cell from which riparian vegetation in that cell will meet part or all of its evapotraspirative demand. Any grid cell that is away from streams with no riparian vegetation is assigned a stream node number of zero.

IDC uses the stream flow to meet the riparian water demand after considering the contribution of moisture that is already available in the root zone, precipitation, and any moisture from generic sources. First, equation (1) is solved to calculate the actual evapotranspiration at the end of the time step, ET^{t+1}, to check if it is less than the potential evapotranspiration specified by the user for riparian vegetation.

The required amount of water from the stream to meet the unmet riparian demand is calculated as

$$ET_{strm,pot}^{t+1} = ET_{pot}^{t+1} - ET^{t+1} \geq 0 \tag{39}$$

where $ET_{strm,pot}^{t+1}$ is the potential rate of evapotranspiration to be taken out of the stream (L/T). The actual amount, ET_{strm}^{t+1}, depends on the actual stream flow that is available at the stream node that the grid cell is connected to and it is found only after the entire integrated hydrologic system is simulated (as mentioned earlier, riparian evapotranspiration from streams is only simulated when IDC is linked to an integrated hydrologic model):

$$ET_{strm}^{t+1} = \frac{\min\left(ET_{strm,pot}^{t+1} A_{rip}^{t+1} \ , \ Q_{strm}^{t+1}\right)}{A_{rip}^{t+1}} \tag{40}$$

where ET_{strm}^{t+1} is the actual evapotranspiration from the stream (L/T), A_{rip}^{t+1} is the area of the riparian vegetation at the grid cell for which root zone flow processes are simulated (L^2),and Q_{strm}^{t+1} is the simulated stream flow (L^3/T). Once ET_{strm}^{t+1} is calculated, the total riparian vegetation evapotranspiration is calculated as

$$ET_{total}^{t+1} = ET_{strm}^{t+1} + ET^{t+1} \tag{41}$$

where ET_{total}^{t+1} is the total riparian vegetation evapotranspiration (L/T).

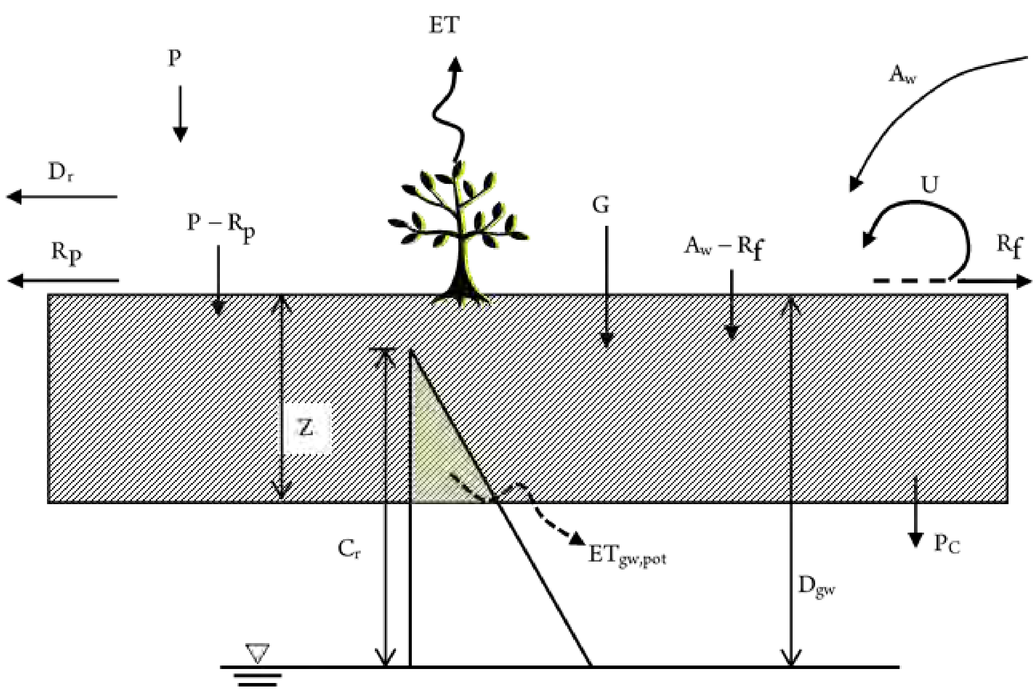
IDC assumes that all stream flow contribution to evapotranspiration of riparian vegetation is direct; i.e. the mechanism of the stream flow first seeping into the root zone before meeting the evapotranspiration is ignored. This is because of the conceptual set-up used in IDC where the flow exchange between the root zone and the stream system is not considered in order to minimize the computer run-times. On the other hand, the next section discusses the optional simulation of root water uptake from groundwater which can implicitly handle the case where the stream flow first seeps into the groundwater before potentially contributing to the riparian evapotranspiration through root water uptake.

5.2. Root Water Uptake from Groundwater

Shallow groundwater can meet part or all of the plant evapotranspirative demand. In IDC, groundwater contribution to evapotranspiration is considered as the first source of moisture that is available to the plants. As will be explained later, one of the information IDC requires to compute the root water uptake from groundwater is the depth-to-groundwater. When IDC is run as a stand-alone program the user can specify time series depth-to-groundwater data at each finite element cell. This data can be obtained either from field measurements or from separate groundwater models. If IDC is executed as a linked component of an integrated hydrologic model such as IWFM, depth-to-groundwater is calculated dynamically by the integrated hydrologic model and passed to IDC.

Figure 17 shows a schematic representation of the root zone and root water uptake from groundwater as simulated by IDC.

Figure 17. *Schematic representation of root zone and root water uptake from groundwater*



At each grid cell the user specifies a capillary rise above the saturated groundwater table. IDC assumes that the soil moisture content at the groundwater table is at total porosity (assumed equal to the specific yield of the aquifer material) and declines linearly to zero at a height equal to the capillary rise above the groundwater table. The maximum potential root water uptake from groundwater is calculated as the part of the capillary rise and the saturated groundwater that intersect with the root zone:

$$ET_{gw,pot}^{t+1} = \begin{cases} 0 & \text{if} \quad C_r + Z^{t+1} \leq D_{gw}^t \\ \dfrac{S_y\left(Z^{t+1} - D_{gw}^t + C_r\right)^2}{2\Delta t C_r} & \text{if} \quad D_{gw}^t > C_r \quad ; \quad D_{gw}^t > Z^{t+1} \\ \dfrac{S_y Z^{t+1}}{\Delta t C_r}\left(\dfrac{Z^{t+1}}{2} + C_r - D_{gw}^t\right) & \text{if} \quad D_{gw}^t \leq C_r \quad ; \quad D_{gw}^t > Z^{t+1} \\ \dfrac{S_y}{\Delta t}\left(Z^{t+1} - D_{gw}^t\right) & \text{if} \quad C_r = 0 \quad ; \quad D_{gw}^t \leq Z^{t+1} \\ \dfrac{S_y C_r}{2\Delta t} + \dfrac{S_y}{\Delta t}\left(Z^{t+1} - D_{gw}^t\right) & \text{if} \quad C_r > 0 \quad ; \quad D_{gw}^t > C_r \quad ; \quad D_{gw}^t \leq Z^{t+1} \\ \dfrac{S_y}{2\Delta t C_r}\left[2C_r Z^{t+1} - \left(D_{gw}^t\right)^2\right] & \text{if} \quad C_r > 0 \quad ; \quad D_{gw}^t \leq C_r \quad ; \quad D_{gw}^t \leq Z^{t+1} \end{cases} \quad (42)$$

where $ET_{gw,pot}^{t+1}$ is the maximum potential root water uptake from groundwater (L/T), S_y is the aquifer specific yield (dimensionless), D_{gw}^t is the depth-to-groundwater (computed as the ground surface elevation less the groundwater head) at the beginning of time step (L), C_r is the height of capillary rise above the groundwater table (L), and Δt is the simulation time step length (T). In equation (42), already known value of the depth-to-groundwater at the beginning of the time step is used to avoid additional iterations between IDC and the groundwater simulation component of the integrated hydrologic model that would arise if the unknown head at the current time step were used.

The actual root water uptake from groundwater is calculated as

$$ET_{gw}^{t+1} = \min\left(ET_{pot}^{t+1} \ , \ ET_{gw,pot}^{t+1}\right) \tag{43}$$

If IDC is linked to an integrated hydrologic model, then ET_{gw}^{t+1} in (43) becomes a sink term for the groundwater component of the model.

When simulated, root water uptake from groundwater also affects the demand for irrigation water for ponded and non-ponded crops. For non-ponded crops, IDC uses either equation (23) or equation (26) to calculate the irrigation water demand, depending on if IDC is asked to maintain a minimum percolation, whereas for ponded crops it uses equation (28). To calculate the effect of groundwater on irrigation water demand, IDC uses a modified potential ET, $ET_{pot,mod}$, in equations (23), (26) or (28) by considering the ability of groundwater to meet part or all of the potential crop ET. Therefore, the irrigation water demand when root water uptake from groundwater is considered is calculated by using the modified potential ET instead of the original potential ET:

$$A_w^{t+1} = f\left(ET_{pot,mod}^{t+1}\right) \tag{44}$$

where

$$ET_{pot,mod}^{t+1} = \max\left(0 \ , \ ET_{pot}^{t+1} - ET_{gw,pot}^{t+1}\right) \tag{45}$$

6. Root Zone Component Version 4.11

This version is exactly the same as version 4.1 except that it allows the user to print out Z-Budget data files for Land and Water Use as well as the Root Zone budgets. These files can then be post-processed using the Z-Budget tool to analyze the water demand, water supply and the root zone water budget for elements grouped into zones by the user. Land and Water Use Z-Budget and Root Zone Z-Budget outputs will be discussed later in this document. The input files to run the Z-Budget post-processing tool are described in the *User's Manual for IWFM-2015* (Dogrul 2021b).

7. Root Zone Component Version 5.0

This version of the root zone component uses similar methods as in version 4.0 to compute water demands and route the water through the root zone, but for an average agricultural crop, and for each land use and soil type combination.

The user specifies as many soil types as is necessary for the application along with their soil parameters (wilting point, field capacity, total porosity, saturated hydraulic conductivity and pore size distribution index) and each grid cell is associated with one of these soil types. The user also specifies as many agricultural cops as required by the application along with the crop and irrigation management parameters as well as the evapotranspiration. Additionally, the individual crop areas are specified at each subregion (subregions are groups of elements that represent sub-areas within the model domain) while total agricultural areas are specified for each grid cell. Based on the subregional crop areas IDC calculates area-weighted average crop characteristics that are then used in calculating average agricultural water demand and in routing water through the agricultural root zone at each soil type.

The urban and average agricultural water demands as well as the root zone flow terms for agricultural, urban, native and riparian vegetation areas are computed in unit rates at each soil type. By multiplying these values with the area of each of the four land use type in a cell leads to cell-level volumetric water demands and root zone flows.

Root zone component version 5.0 is developed mainly to provide backward compatibility to the older versions of IDC prior to version 4.0. Although it is not as accurate as versions 4.0 through 4.11, mainly because it simulates agricultural flows for an average crop, it can be used as a screening tool to quickly analyze the effects of management alternatives.

8. Running IDC

IDC can be executed as a stand-alone model or it can be linked to other simulation models that operate on finite-element or finite-difference type computational grids. Both the source code and the compiled executables are available for download from the IDC web site at https://water.ca.gov/Library/Modeling-and-Analysis/Modeling-Platforms/Integrated-Water-Flow-Model-Demand-Calculator. IDC, either executed as a stand-alone model or linked to other simulation models, requires a main control input file that lists the names of data files used for the simulation, the simulation period and length of time step, as well as the output options. Depending on the specifications listed in the input data files, one or more output files are generated. These files store simulated water budget information at each subregion or each grid cell and they are in HDF5 file format. Another program, Budget.exe, is required to process the subregional files and generate water budget tables in ASCII text format. Z-Budget.exe program is used to process cell-level water budget information and aggregate them for user-defined zones which are groups of cells. Budget.exe and Z-Budget.exe are also available for download from IWFM web site. Next, the IDC's time-tracking feature as well as input files that are used and output files that are generated by IDC are discussed.

8.1. Simulation Time Tracking

To better represent the temporal distribution of input and output data, IDC keeps track of the actual date and time of each time step in a simulation period. Each data entry in input time series data files is required to have a date and time stamp which allows IDC to retrieve time series data correctly. This, in return, allows the user to maintain a single set of time series input data files for applications where the starting and ending date and time of the simulation may change. For example, during the calibration stage of a project, the simulation is run for two periods: calibration period and the verification period. In a time tracking simulation, time series input data files can be prepared so that the data covers both the calibration and verification periods. Then the same time series data files can be used for both calibration and verification runs without the need for modification. Since a time tracking simulation keeps track of actual date and time of each of the simulation time steps, IDC can retrieve the correct data from the time series data files.

Time tracking simulations allow usage of HEC-DSS files as well as ASCII text files for time series data input and output. HEC-DSS is a database format designed by Hydrologic Engineering Center (HEC) of U.S. Army Corps of Engineers specifically for time-series data encountered in hydrologic applications. These files allow efficient storage and retrieval of hydrologic time series data, and HEC offers free utilities (HEC-DSSVue and DSS Excel add-in) for manipulation, visualization and analysis of data stored in DSS files. These utilities and instructions on how to use DSS files can be downloaded from HEC web site at www.hec.usace.army.mil.

Another advantage of time tracking simulations is that results that are printed to output files have date and time stamps associated with them. This allows easy comparison of simulation results to observed values which generally come with the date and time of observation.

8.1.1. Length of Simulation Time Step

In order to be consistent with the standards of HEC-DSS database files, IDC restricts the length of simulation time step that can be used in an application. The allowable time step lengths are listed in Table 5.

Table 5. *List of allowable time step lengths in IDC simulations*

Time Step Length	IDC Notation
1 minute	1MIN
2 minutes	2MIN
3 minutes	3MIN
4 minutes	4MIN
5 minutes	5MIN
10 minutes	10MIN
15 minutes	15MIN
20 minutes	20MIN
30 minutes	30MIN

Time Step Length	IDC Notation
1 hour	1HOUR
2 hours	2HOUR
3 hours	3HOUR
4 hours	4HOUR
6 hours	6HOUR
8 hours	8HOUR
12 hours	12HOUR

Time Step Length	IDC Notation
1 day	1DAY
1 week	1WEEK
1 month	1MON
1 year	1YEAR

8.1.2. Time Step Format

In IDC, start and end date and time of simulation period as well as the date and time of each data entry in time series data input files are required to be specified by using a time stamp. The format of the time stamp is as follows:

MM/DD/YYYY_hh:mm

where

MM	=	two digit month index;
DD	=	two digit day index;
YYYY	=	four digit year;
hh	=	two digit hour in terms of military time (e.g. 1:00pm is represented as 13:00);
mm	=	two digit minute.

The time is represented in military time and midnight is referred to as 24:00. For instance, 05/28/1973_24:00 represents the midnight on the night of May 28, 1973. Another example is the starting date and time of a simulation period: if the initial conditions for a daily simulation is given for the end of September 30, 1975, then the time stamp for the starting date and time of the simulation will be 09/30/1975_24:00. The first simulation result will be printed for October 1, 1975 at midnight with the time stamp 10/01/1975_24:00.

8.1.3. Preparation of Time Series Data Input Files

The user is allowed to use a mixture of ASCII text and DSS files for time series input data. In preparing these files, the rules listed below should be followed:

1. The data should have a regular interval. Gaps in the data are not allowed. For instance, if the data is monthly a value for every month should be entered.
2. The time stamp of the data represents the end of the interval for which the data is valid. For instance, in monthly time series evapotranspiration data, a data point time stamped with 08/31/1995_24:00 represents the evapotranspiration that occurred in August of 1995. As another example, if the starting date and time of the simulation period is 12/31/1970_24:00 (i.e. initial conditions are given at the midnight of December 31, 1970) in a daily simulation, then IDC will search for the time series data time-stamped as 01/01/1971_24:00 (data for January 1st in 1971) in the time series input files.
3. The smallest interval that can be used for time series data is 1 minute.

4. A time series input data can be constant throughout the simulation period. If an ASCII text file is used for data input, the time stamp for the constant value can be set to a date and time that is greater than the ending date and time of the simulation period. For instance, if the simulation period ends at 06/15/2003_18:00 (6:00pm on June 15, 2003), then the constant value can have a time stamp 12/31/2100_24:00 (midnight on the night of December 31, 2100). IDC reads the constant value for the midnight of December 31, 2100 and uses this value for all simulation times before this date and time. Generally, time series input files include conversion factors to convert only the "spatial" component of the input data unit. The temporal unit is deduced from the time interval of the input data. In the case of constant time series data, IDC is not able to obtain the time interval and, hence, the temporal unit. If a constant value for time series data is used, the user should make sure that appropriate conversion factors are supplied so that the temporal and spatial units of the input data are consistent with those used internally during the simulation. Time series data that is constant can also be represented in DSS files but this is not suggested.
5. For rate-type time series data (e.g. evapotranspiration data), the time unit is assumed to be the interval of data. For instance, if the evapotranspiration data is entered monthly, IDC assumes that the time unit of the evapotranspiration rates is 1 month. When time series data is a constant value for the entire simulation period IDC has no way to figure out the time unit of the input data. In this case the user should make sure that the time unit of data is the same as the consistent time unit of simulation.
6. For recycled time series data (e.g. fraction of total urban water that is used indoors given for each month but do not change from one year to the other), the year of the time stamp can be set to 4000. Year 4000 is a special flag for IDC such that it replaces year 4000 with the simulation year to retrieve the appropriate data from the input file. As an example, consider the time series data in Table 6 for the fraction of total urban water that is used indoors. This data set represents that for the initial third of each simulation year the urban water indoors usage fraction is 0.7, for the second third it is 0.5 and for the last third it is 0.35. Recycled time series data can be used in both ASCII text and DSS files.

Table 6. *Example for the representation of recycled time series data*

Time Stamp	Fraction of Urban Indoors Water
04/30/4000_24:00	0.70
08/31/4000_24:00	0.50
12/31/4000_24:00	0.35

If a monthly time series data is to be recycled the user should enter the time stamp for the last day of February as 02/29/4000_24:00 to address both the leap and non-leap years.

The interval of time series data is required to be synchronized with the simulation time step. Table 7 shows examples of accepted and unaccepted situations. It should be noted that IDC will continue to read data from the input files even if the data interval is not properly synchronized with the simulation time step. However, in such cases there is no guarantee that the correct data will be retrieved from the input file. Therefore, it is up to the user to ensure correct synchronization between the input data and the simulation time step.

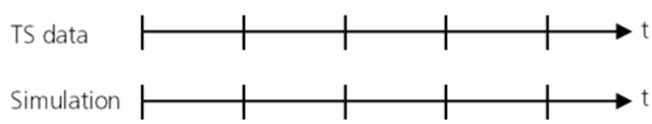
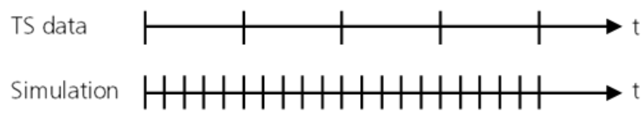
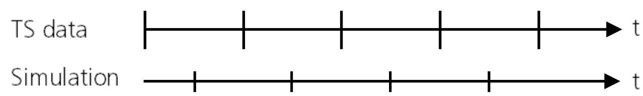
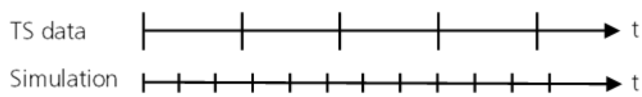
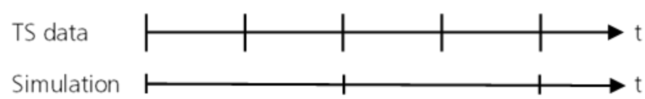
8.2. Input and Output Data File Types

IDC can access multiple file formats: (i) ASCII text, (ii) HDF5 and (iii) HEC-DSS files. The user can use several file formats in a single application. For instance, some of the input time series data can be read from HEC-DSS files whereas the rest can be read from ASCII text files. Some of the time series simulation results can be printed out to ASCII text files and the others can be printed out to HEC-DSS files.

Although IDC allows usage of several file formats in a single application, some of the input and output files are required to be in specific formats. For instance, all budget output files generated by IDC and read in by Budget post-processors are required to be in HDF5 format. Another example is the main control input file for all IDC: this file is required to be in ASCII text file format.

IDC recognizes the file formats from the file name extensions. Table 8 lists the extensions that are recognized by IDC for each of the file formats.

***Table 7.** Examples for acceptable and unacceptable cases for the synchronization of time series data interval and the simulation time step*

Situation	Graphical Representation	Accepted
Monthly time series data, monthly simulation		Yes
Monthly time series data, daily simulation		Yes
Monthly time series data, monthly simulation (TS data times don't match simulation times)		No
Monthly time series data, weekly simulation		No
Monthly time series data, yearly simulation		No

8.3. Input Files

Input files in IDC include comment lines as well as the input data itself. A line with one of "C", "c" or "*" at the first column is identified as a comment line. The inclusion of comment lines allows IDC files to be self-documenting. The purpose of each file along with the description of each input data are already included in IDC input file templates, and the user can include explanations for the data development directly in the input files using the comment lines.

A schematic representation of IDC input file structure is given in Figure 18. A Main Input File serves as the starting point for an IDC simulation.

***Table 8.** Filename extensions recognized by IDC*

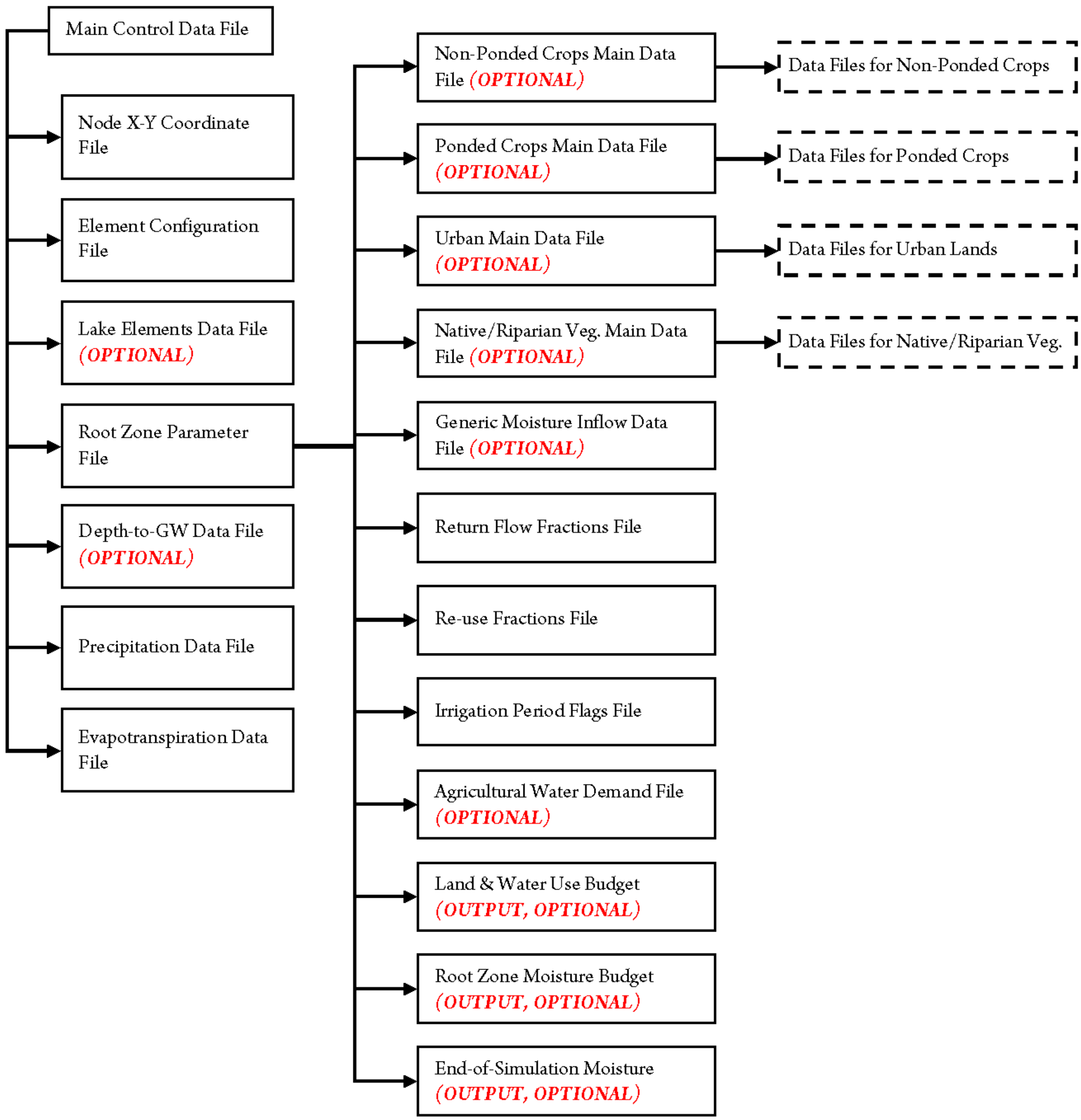
File Type	Recognized Filename Extensions
ASCII	.DAT .TXT .OUT .IN .IN1 .IN2 .BUD
HDF5	.HDF .HDF5 .H5 .HE5
HEC-DSS	.DSS

The IDC Main Input File lists the names of the data files that include grid nodal x-y coordinates, element configuration data, precipitation and evaporation data, list of elements that are covered by lakes or reservoirs where root zone flow processes are not simulated, and the root zone parameters.

The IDC Main Input File also lists the beginning and ending date and time of the simulation as well as the simulation time step length. Factors to convert IDC simulation units into desired units of output are also listed in this file.

Root Zone Parameter File that is listed in the IDC Main Input File acts as a gateway to all the parameters and data files required for the simulation of the root zone flow processes and water demand computations. The first line of data entry in this file lists the version number of the root zone component (e.g. 4.0 or 4.1). Once IDC reads this version number it knows what additional parameters it should read and what flow processes it should simulate. The Root Zone Parameter File also includes names of gateway data files required for the simulation of non-ponded crops, ponded crops, urban lands, and lands with native and riparian vegetation. Additionally, it includes file names for simulation output, soil parameters at each cell and the destination for the surface runoff generated at each cell. Gateway files for non-ponded crops, ponded-crops, urban lands and lands with native and riparian vegetation act as containers for additional data file names and parameters that are necessary to simulate the flow processes and water demands (if applicable) for these land-use types.

Figure 18. *Schematic representation of the IDC input file structure*



These gateway files provide a structure for the user to group related data files as well as turn on or off the simulation of particular land use types in an application. For instance, by leaving blank the name of the gateway file for non-ponded crops in the Root Zone Parameter File, the user can easily omit the simulation of flow processes for non-ponded crops. This feature allows easy implementation of scenario studies where a particular land-use type is assumed to be non-existent with respect to a base-case scenario.

Each land-use type (non-ponded crops, ponded-crops, urban or native and riparian vegetation) include a data file that lists the area of each land-use type at a grid cell. These areas can be entered either as absolute areas or as fractions of the total cell area. In either case, IDC normalizes all areas (given as absolute areas or crops, urban lands and lands with native and riparian vegetation should also be specified as fractions. Otherwise, the total cell area will be incorrectly divided into the land-use types.

The following sections describe in detail the variables to be populated in each of the input file and display sample files.

8.3.1. IDC Main Input File

The IDC Main Input File serves as the starting point for an IDC simulation. The names of the data files for the IDC simulation are listed in this file as well as the beginning and ending date and time of the simulation, the simulation time step length and output control options.

The following is a list of the variables used in this data file:

BDT	Beginning simulation date and time; use MM/DD/YYYY_hh:mm format
EDT	Ending simulation date and time; use MM/DD/YYYY_hh:mm format
UNITT	Time step length and unit; choose one of the options listed in the IDC Main Input File which are time steps that are recognized by HEC-DSS database system
CACHE	This is the minimum number of simulation results for each time series output data that is stored in the computer memory before saved onto the hard disk; a large value (e.g. 50000 or more) that is permissible by the memory resources may have a substantial effect on decreasing the simulation run-times
KDEB	Switch for simulation progress monitoring (1 = print detailed messages on the screen; 0 = print only simulation timesteps on the screen; −1 = do not print any messages on the screen)

```
C*******************************************************************************
C
C                          IWFM DEMAND CALCULATOR (IDC)
C                              *** Version ### ***
C
C*******************************************************************************
C
C                            MAIN INPUT FILE
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: IDC_MAIN.in
C
C*******************************************************************************
C                              File Description
C
C    This file contains the control data for IDC that includes the names and
C    descriptions of all simulation files; simulation period and output control
C    options.
C
C*****************************************************************************
C                            File Description
C
C  *Listed below are all input and output file names used when running the
C   utility.
C  *Each file name has a maximum length of 1000 characters
C  *If an optional file does not exist for a project, leave the filename blank
C
C-------------------------------------------------------------------------------
C    FILE NAME                                      DESCRIPTION
C---------------------------------------------------------------------------------------------
     Grid\Element.dat                               / 1: ELEMENT CONFIGURATION FILE (INPUT, REQUIRED)
     Grid\NodeXY.dat                                / 2: NODE X-Y COORDINATE FILE (INPUT, REQUIRED)
                                                    / 3: LAKE ELEMENTS DATA FILE (INPUT, OPTIONAL)
     RootZone\ROOTZONE_MAIN.dat                     / 4: ROOT ZONE PARAMETER DATA FILE (INPUT, REQUIRED)
     DepthToGW.dat                                  / 5: DEPTH-TO-GROUNDWATER DATA FILE (INPUT, OPTIONAL)
     Precip_ET\Precip.dat                           / 6: PRECIPITATION DATA FILE (INPUT, REQUIRED)
     Precip_ET\ET.dat                               / 7: EVAPOTRANSPIRATION DATA FILE (INPUT, REQUIRED)
C*******************************************************************************
C                         Model Simulation Period
C
C   The following lists the simulation beginning time, ending time and time step length.
C
C   BDT    ; Beginning simulation date and time. Use MM/DD/YYYY_hh:mm format.
C            * Midnight is 24:00
C   EDT   ; Ending simulation date and time.  Use MM/DD/YYYY_hh:mm format.
C           * Midnight is 24:00
C   UNITT  ; Time step length and unit. Choose one of the following:
C                  1MIN
C                  2MIN
C                  3MIN
C                  4MIN
C                  5MIN
C                  10MIN
C                  15MIN
C                  20MIN
C                  30MIN
C                  1HOUR
C                  2HOUR
C                  3HOUR
C                  4HOUR
C                  6HOUR
C                  8HOUR
C                  12HOUR
C                  1DAY
C                  1WEEK
C                  1MON
C                  1YEAR
C
C-------------------------------------------------------------------------------
C       VALUE                   DESCRIPTION
C-------------------------------------------------------------------------------
      09/30/1997_24:00          / BDT
      09/30/2001_24:00          / EDT
      1day                      / UNITT
C******************************************************************************
C                      Output Control Options
C
C    CACHE   ; Cache size in terms of number of values stored for time series data output
C    KDEB    ; Enter  1 - to print messages on the screen to monitor execution
C              Enter  0 - otherwise
C              Enter -1 - to supress printing of timesteps on the screen
C
C-----------------------------------------------------------------------------
C       VALUE                   DESCRIPTION
C-----------------------------------------------------------------------------
        5000000                 / CACHE
        0                       / KDEB
```

8.3.2. Element Configuration File

The Element Configuration File details the element configuration for each element represented in the finite element mesh, number of subregions that the model domain is divided into, the name of the subregions and the subregion number that each element belongs to. Each element is configured using three or four nodal points. All elements that represent the model domain are either triangular or quadrilateral. A zero value for IDE(4) indicates that the element is triangular. Nodes corresponding to each element are specified in a counterclockwise manner. IWFM Mesh Generator that is available for download from the IWFM web site can be used to quickly generate the finite element grid. The following variables are required as input in Element Configuration File:

NE	Number of elements within the model domain
NREGN	Number of subregions the model domain is divided into
RNAME	Name of each subregion (maximum 50 characters long)
IE	Element number
IDE	Nodes corresponding to each element number; 3 nodes are associated with each triangular element (4th node should be set to zero) and 4 nodes are associated with each quadrilateral element
IRGE	Subregion number that element IE belongs to

```
C*******************************************************************************
C
C                  INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                        ELEMENT CONFIGURATION FILE
C                         Discretization Component
C                           *** Version ### ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: Element.dat
C
C*******************************************************************************
C                            File Description
C
C   This file  contains the element configuration for each element.
C   The nodes that make a finite element are listed for each element in
C   a counter-clock wise fashion starting with any node. For triangular elements,
C   the fourth node is specified as zero.
C
C
C   For example,
C
C                    13-------------14----------17
C                     I             I         I
C                     I      2      I   3   I
C                     I             I     I
C                     I             I   I
C                    15------------- 16
C
C
C   The configuration for elements 2 and 3 will be listed as,
C
C            element   node 1    node 2    node 3   node 4
C               2        13        15        16       14
C               3        14        16        17        0
C
C*******************************************************************************
C                     Element Configuration Data
C
C    NE    ;   Number of elements within the model domain
C    NREGN ;   Number of subregions
C
C-------------------------------------------------------------------------------
C   VALUE                         DESCRIPTION
C-------------------------------------------------------------------------------
    400                           / NE
    4                             / NREGN
C*******************************************************************************
C                         Sub-region Names
C
C   The following lists the names for each sub-region in an ascending order of
C   the subregion numbers.
C
C--------------------------------------------------------------------------------
C
C   RNAME; Sub-region name (max. 50 characters)
C
C--------------------------------------------------------------------------------
C   VALUE                        DESCRIPTION
C--------------------------------------------------------------------------------
    Region1                      / RNAME1
    Region2                      / RNAME2
    Region3                      / RNAME3
    Region4                      / RNAME4
C*******************************************************************************
C
C   The data listed below represents all elements and corresponding nodes
C   within the model domain.
C
C   IE;      Element number
C   IDE;     Nodes corresponding to each element
C            *Note* IDE(4) is zero for all triangular elements
C   IRGE;    Subregion number to which element IE belongs to
C
C-------------------------------------------------------------------------------
C   Element     ------------Corresponding Nodes------------------      Subregion
C   IE          IDE(1)        IDE(2)       IDE(3)       IDE(4)          IRGE
C-------------------------------------------------------------------------------
     1           1             2            23           22               1
     2           2             3            24           23               1
     3           3             4            25           24               1
     4           4             5            26           25               1
     5           5             6            27           26               1
     .           .             .            .            .                .
     .           .             .            .            .                .
     .           .             .            .            .                ,
     397         416           417          438          437              4
     398         417           418          439          438              4
     399         418           419          440          439              4
     400         419           420          441          440              4
```

8.3.3. Nodal X-Y Coordinate File

The nodal coordinate file contains node numbers and corresponding x and y coordinates. Any coordinate units may be used as long as the appropriate conversion factor is given. This file sets up the spatial orientation of the finite element mesh nodes in the model domain. The finite element mesh is generated from the nodal coordinates, as well as relationship between elements and corresponding nodes (refer to the Element Configuration File).

ND	Number of nodes
FACT	Factor to convert nodal coordinates to simulation unit of length
ID	Node identification number
X	x-coordinate of node location
Y	y-coordinate of node location

```
C*******************************************************************************
C
C                    INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                        NODAL X-Y COORDINATE FILE
C                         Discretization Component
C                           *** Version ### ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: NodeXY.dat
C
C*******************************************************************************
C                            File Description
C
C   *This file includes all groundwater nodes that represent the model domain,
C    as well as the x and y coordinates that correspond with each node.
C
C   *The coordinates can be specified for any reference point and coordinate
C    system
C
C*******************************************************************************
C                    Groundwater Node Specifications
C
C   ND;    Number of groundwater nodes
C   FACT;  Conversion factor for nodal coordinates
C-------------------------------------------------------------------------------
C   VALUE                         DESCRIPTION
C-------------------------------------------------------------------------------
    441                           /ND
    1.0                           /FACT
C-------------------------------------------------------------------------------
C*******************************************************************************
C                      Groundwater Node Locations
C   The following lists the node number and x & y coordinate of each node
C
C   ID;   Groundwater node number
C   X,Y;  Coordinates of groundwater node location; [L]
C
C-------------------------------------------------------------------------------
C   Node     ----------Coordinates----------
C    ID           X                  Y
C-------------------------------------------------------------------------------
      1         0.0               0.0
      2         2000.0            0.0
      3         4000.0            0.0
      4         6000.0            0.0
      5         8000.0            0.0
      .         .                 .
      .         .                 .
      .         .                 .
    437         32000.0           40000.0
    438         34000.0           40000.0
    439         36000.0           40000.0
    440         38000.0           40000.0
    441         40000.0           40000.0
```

8.3.4. Lake Elements Data File

The Lake Elements Data File lists the grid cells that are lake elements and will be excluded from land surface and root zone flow computations. It should be noted that lakes in IDC are different then the ponded areas for rice and refuges. Rice and refuge ponding operations are explicitly simulated in IDC and the grid cells with such ponds should not be listed in the Lake Elements Data File.

The following variables are used in this data file:

NTELAKE Total number of lake elements

IELAKE List of lake elements

```
C*******************************************************************************
C
C                          IWFM DEMAND CALCULATOR (IDC)
C                              *** Version ### ***
C
C*******************************************************************************
C
C                     LAKE ELEMENTS DATA FILE
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: LakeElems.dat
C
C*******************************************************************************
C
C                             File Description:
C
C   This data file lists the lake elements that will be excluded from root zone
C   flow routing.
C
C*******************************************************************************
C                  Lake Elements Data
C
C   NTELAKE ;  Total number of lake elements
C   IELAKE  ;  Lake element number
C
C-------------------------------------------------------------------------------
C   VALUE                         DESCRIPTION
C-------------------------------------------------------------------------------
    7                             / NTELAKE
C-------------------------------------------------------------------------------
C   IELAKE
C-------------------------------------------------------------------------------
    12
    13
    56
    57
    58
    102
    103
```

8.3.5. Depth-to-Groundwater Data File

To simulate the contribution of groundwater to plant evapotranspiration, the Depth-to-Groundwater data file must be specified. This data file lists the specific yield for the underlying aquifer material and time series depth-to-groundwater at each finite element cell. This information can be obtained deduced from field measurements or from a groundwater model. When IDC is linked to an integrated hydrologic model such as IWFM, the depth-to-groundwater data is computed dynamically by the hydrologic model and passed to IDC. It should be noted that if the contribution of groundwater to evapotranspiration is to be simulated, then Root Zone Component Version 4.1 must be used.

The following variables are used in this file:

NDGW	Number of depth-to-groundwater time series data columns
FACTDGW	Conversion factor for depth-to-groundwater
NSPDGW	Number of time steps to update the depth-to-groundwater data; if time tracking simulation, enter any number
NFQDGW	Repetition frequency of the depth-to-groundwater data (enter zero if full time series data is supplied); if time tracking simulation, enter any number
DSSFL	If the time series data is stored in a DSS file, name of the file; leave blank if the data is listed in the Depth-to-Groundwater Data File

Aquifer Specific Yield and Cell-Data Connections

In this section, specific yield of the underlying aquifer material and the depth-to-groundwater data column pointer are listed for each finite element cell:

IE	Finite element identification number
SY	Specific yield of the underlying aquifer material at element IE; [L/L]
IDGW	Column number for the depth-to-groundwater time series data to be used at element IE

Data Input from Depth-to-Groundwater Data File

If the time series data is listed in the Depth-to-Groundwater Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using "C", "c" or "*", and the variables in the "Data Input from DSS File" section below should be populated.

ITDGW	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
DGW	Depth-to-groundwater time series data, [L]

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

REC	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*******************************************************************************
C
C                          IWFM DEMAND CALCULATOR (IDC)
C                              *** Version ### ***
C
C*******************************************************************************
C
C                     DEPTH-TO-GROUNDWATER DATA FILE
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: DepthToGW.dat
C
C*******************************************************************************
C
C                             File Description:
C
C   This data file lists the specific yield of underlying aquifer material and
C   time-series depth-to-groundwater data at each element to be used in water
C   demand calculations and root zone flow routing.
C
C*******************************************************************************
C              Depth-to-Groundwater Time Series Data Specifications
C
C   NDGW   ;  Number of data columns (or pathnames if DSS files are used)
C   FACTDGW;  Conversion factor for depth-to-groundwater data
C   NSPDGW ;  Number of time steps to update the depth-to-groundwater data
C              * Enter any number if time-tracking option is on
C   NFQDGW ;  Repetition frequency of the depth-to-groundwater data
C              * Enter 0 if full time series data is supplied
C              * Enter any number if time-tracking option is on
C   DSSFL  ;  The name of the DSS file for data input (maximum 50 characters);
C              * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------
C         VALUE                                      DESCRIPTION
C-------------------------------------------------------------------------------
          1                                          / NDGW
          1.0                                        / FACTDGW
          1                                          / NSPDGW
          0                                          / NFQDGW
                                                     / DSSFL
C*******************************************************************************
C             Specific Yield and Element-Data-Column Connections
C
C   IE     ;  Element ID
C   SY     ;  Specific yield of the underlying aquifer material to be used in computing root
C               water uptake from groundwater; [L/L]
C   IDGW   ;  Depth-to-groundwater data column to be used for element IE
C
C-------------------------------------------------------------------------------
C   IE      SY     IDGW
C-------------------------------------------------------------------------------
   1        0.2     1
   2        0.2     1
   3        0.2     1
   .        .       .
   .        .       .
   .        .       .
   397      0.2     1
   398      0.2     1
   399      0.2     1
   400      0.2     1
C*******************************************************************************
C                           Depth-to-Groundwater Data
C                             (READ FROM THIS FILE)
C
C   List depth-to-groundwater data below, if it will
C   not be read from a DSS file (i.e. DSSFL is left blank above).
C
C   ITDGW ;   Time
C   DGW   ;   Depth-to-groundwater; [L]
C
C-------------------------------------------------------------------------------
C ITDGW               DGW[1]  DGW[2]  DGW[3] ... DGW[NDGW]
C-------------------------------------------------------------------------------
   12/31/2500_24:00   10.0
*
C-------------------------------------------------------------------------------
C                    Pathnames for Depth-to-Groundwater Data
C                           (READ FROM DSS FILE)
C
C   List the pathnames for the depth-to-groundwater data below, if it will be read
C   from a DSS file (i.e. DSSFL is specified above).
C
C   REC    ;  Time series record number
C   PATH   ;  Pathname for the time series record
C
C-------------------------------------------------------------------------------
C   REC        PATH
C-------------------------------------------------------------------------------
*
*
```

8.3.6. Precipitation File

The Precipitation File contains the time series rainfall values for each of the rainfall stations used in the simulation. Each element is associated with a rainfall station in the Root Zone Component Main File as described later in this document. The factors that convert the precipitation at rainfall stations to the precipitation over the elements are also listed in the Root Zone Component Main File. The rainfall data for a station associated with an element is multiplied by the corresponding factor to obtain the rainfall rate over an element.

In non-time tracking simulations a time-series precipitation data set of any frequency can be used as the precipitation data in IDC. NSPRN and NFQRN must be specified according to the frequency of the data entered. If the precipitation data is specified for the entire simulation period, NFQRN should be set to zero. In time tracking simulations the time series precipitation data can be either listed in this file or in a DSS file. If a DSS file is used for data input, then the name of the DSS file and the pathnames corresponding to each of the time series data are required.

The following variables are used:

NRAIN	Number of rainfall stations used in the model
FACTRN	Conversion factor for the spatial component of the unit for the rainfall rate
NSPRN	Number of time steps to update the precipitation data; if time tracking simulation, enter any number
NFQRN	Repetition frequency of the precipitation data (enter zero if full time series data is supplied); if time tracking simulation, enter any number
DSSFL	If the time series data is stored in a DSS file, name of the file; leave blank if the data is listed in the Precipitation File

Data Input from Precipitation File

If the time series data is listed in the Precipitation File, then the following variables need to be populated. Otherwise, these variables should be commented out using "C", "c" or "*", and the variables in the "Data Input from DSS File" section below should be populated.

ITRN	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
ARAIN	Rainfall rate at the corresponding rainfall station, [L/T]

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

REC	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*******************************************************************************
C
C                   INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                          PRECIPITATION DATA FILE
C               Precipitation and Evapotranspiration Component
C                            *** Version ### ***
C
C
C             Project : IDC Version ### Release
C                       California Department of Water Resources
C             Filename: Precip.dat
C
C*******************************************************************************
C                              File Description:
C
C   This data file contains the time-series rainfall at each rainfall station used
C   in the model.
C
C*******************************************************************************
C                          Rainfall Data Specifications
C
C   NRAIN ;  Number of rainfall stations (or pathnames if DSS files are used)
C             used in the model
C   FACTRN;  Conversion factor for rainfall rate
C             It is used to convert only the spatial component of the unit;
C             DO NOT include the conversion factor for time component of the unit.
C             * e.g. Unit of rainfall rate listed in this file = INCHES/MONTH
C                    Consistent unit used in simulation        = FEET/DAY
C                    Enter FACTRN (INCHES/MONTH -> FEET/MONTH) = 8.33333E-02
C                     (conversion of MONTH -> DAY is performed automatically)
C   NSPRN ;  Number of time steps to update the precipitation data
C             * Enter any number if time-tracking option is on
C   NFQRN ;  Repetition frequency of the precipitation data
C             * Enter 0 if full time series data is supplied
C             * Enter any number if time-tracking option is on
C   DSSFL ;  The name of the DSS file for data input (maximum 50 characters);
C             * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------
C         VALUE                                       DESCRIPTION
C-------------------------------------------------------------------------------
          2                                           / NRAIN
          8.33333E-2                                  / FACTRN   (in -> ft)
          1                                           / NSPRN
          0                                           / NFQRN
          TSDATA_IN.DSS                               / DSSFL
C-------------------------------------------------------------------------------
C                              Rainfall Data
C                          (READ FROM THIS FILE)
C
C   List the rainfall rates for each of the rainfall station below, if it will
C   not be read from a DSS file (i.e. DSSFL is left blank above).
C
C   ITRN ;   Time
C   ARAIN;   Rainfall rate at the corresponding rainfall station; [L/T]
C
C-------------------------------------------------------------------------------
C ITRN    ARAIN(1)  ARAIN(2)  ARAIN(3) ...
C-------------------------------------------------------------------------------
*
*
C-------------------------------------------------------------------------------
C                        Pathnames for Rainfall Data
C                          (READ FROM DSS FILE)
C
C   List the pathnames for the rainfall data below, if it will be read
C   from a DSS file (i.e. DSSFL is specified above).
C
C   REC    ;  Time series record number
C   PATH   ;  Pathname for the time series record
C
C---------------------------------------------------------------------------------
C   REC        PATH
C---------------------------------------------------------------------------------
     1         /SAMPLE_PROBLEM/GAGE1/PRECIP//1MON/PRECIPITATION/
     2         /SAMPLE_PROBLEM/GAGE2/PRECIP//1MON/PRECIPITATION/
```

8.3.7. Evapotranspiration File

The Evapotranspiration File contains time series ET data for all crop types and non-agricultural land use types. The ET rates listed in this file are associated with individual land-use types in each element using the related Root Zone Component files as described later in this document. The conversion factor for the ET rates is a required input, as well as the number of time steps to update the data and the repetition frequency of the data. In time tracking simulations the time series evapotranspiration data can be either listed in this file or in a DSS file. If a DSS file is used for data input, then the name of the DSS file and the pathnames corresponding to each of the time series data are required. The ET rates listed in this file are associated with individual land-use types in each element using the related root zone component files as described later in this document.

The example file given below shows how recycled time series data in a time tracking simulation can be specified using the special year 4000 flag. The following is a list of the variables that need to be specified:

NCOLET	Number of evapotranspiration data columns
FACTET	Conversion factor for the spatial component of the unit for the evapotranspiration rate
NSPET	Number of time steps to update the ET data; if time tracking simulation, enter any number
NFQET	Repetition frequency of the ET data (enter zero if full time series data is supplied); if time tracking simulation, enter any number
DSSFL	If the time series data is stored in a DSS file, name of the file; leave blank if the data is listed in the Evapotranspiration File

Data Input from Evapotranspiration File

If the time series data is listed in the Evapotranspiration File, then the following variables need to be populated. Otherwise, these variables should be commented out using “C”, “c” or “*”, and the variables in the “Data Input from DSS File” section below should be populated.

ITEV	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.

AEVAP	Evapotranspiration rate, [L/T]

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

REC	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*******************************************************************************
C
C                   INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                        EVAPOTRANSPIRATION DATA FILE
C                Precipitation and Evapotranspiration Component
C                            *** Version ### ***
C
C
C
C              Project : IDC Version ### Release
C                        California Department of Water Resources
C              Filename: ET.dat
C
C*******************************************************************************
C                          File Description:
C
C   This data file contains sets of evapotranspiration values that are used in
C   root zone, lake and small watershed components of Simulation.
C
C*******************************************************************************
C                      Evapotranspiration Data Specifications
C
C   NCOLET;  Number of ET columns (or pathnames if DSS files are used)
C   FACTET:  Conversion factor for evapotranspiration rate
C             It is used to convert only the spatial component of the unit;
C             DO NOT include the conversion factor for time component of the unit.
C             * e.g. Unit of ET rate listed in this file       = INCHES/MONTH
C                    Consistent unit used in simulation        = FEET/DAY
C                    Enter FACTET (INCHES/MONTH -> FEET/MONTH) = 8.33333E-02
C                     (conversion of MONTH -> DAY is performed automatically)
C   NSPET ;  Number of time steps to update the ET data
C             * Enter any number if time-tracking option is on
C   NFQET ;  Repetition frequency of the ET data
C             * Enter 0 if full time series data is supplied
C             * Enter any number if time-tracking option is on
C   DSSFL ;  The name of the DSS file for data input (maximum 50 characters);
C             * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------
C         VALUE                                    DESCRIPTION
C-------------------------------------------------------------------------------
          5                                        / NCOLET
          0.083333                                 / FACTET  (in/month -> ft/month)
          1                                        / NSPET
          0                                        / NFQET
                                                   / DSSFL
C-------------------------------------------------------------------------------
C                             Evapotranspiration Data
C                              (READ FROM THIS FILE)
C
C   ITEV ;   Time
C   AEVAP;   Evapotranspiration rate; [L/T]
C
C-------------------------------------------------------------------------------
C ITEV   AEVAP[1]  AEVAP[2]  AEVAP[3] ...  AEVAP[NCOLET]
C-------------------------------------------------------------------------------
C                     Tomatoes  Alfalfa     Rice    Urban    Native
  10/31/4000_24:00      3.4       3.5        2.2      3.4       3.4
  11/30/4000_24:00      1.6       1.6        1.6      1.6       1.6
  12/31/4000_24:00      1.0       1.0        1.0      0.5       1.0
  01/31/4000_24:00      1.0       1.0        1.0      0.5       1.0
  02/29/4000_24:00      1.8       1.8        1.8      1.8       1.8
  03/31/4000_24:00      3.0       3.0        3.0      3.0       3.0
  04/30/4000_24:00      4.5       4.1        8.0      4.5       4.5
  05/31/4000_24:00      5.9       5.4        9.1      5.9       5.9
  06/30/4000_24:00      7.3       6.8       10.4      7.3       7.3
  07/31/4000_24:00      7.9       7.7        9.7      7.9       7.9
  08/31/4000_24:00      6.6       6.8        7.0      6.6       6.6
  09/30/4000_24:00      5.2       5.4        1.9      5.2       5.2
C-------------------------------------------------------------------------------
C                        Pathnames for Evapotranspiration Data
C                               (READ FROM DSS FILE)
C
C   List the pathnames for evapotranspiration  data below, if it will
C   be read from a DSS file (i.e. DSSFL is specified above).
C
C   REC   ;  Time series record number
C   PATH ;  Pathname for the time series record
C
C-------------------------------------------------------------------------------------
C   REC       PATH
C-------------------------------------------------------------------------------------
*
*
```

8.3.8. Input Files for Root Zone Component Version 4.0

The root zone component is the main simulation part of IDC. Root Zone Component Main File is the gateway to additional data files that are used in simulating land surface and root zone flow processes at agricultural, urban, native vegetation and riparian vegetation lands. Agricultural and urban water demands are also computed in the root zone component. Root zone component version 4.0 files are described in detail in the following sections.

8.3.8.1. Root Zone Component Main File

The Root Zone Component Main File includes the convergence criteria for the iterative solution of the non-linear soil moisture mass balance equation, names of additional input files that are used to simulate land surface and root zone flow processes for agricultural, urban and natural lands, and agricultural and urban water demands. Subregional Land and Water Use as well as Subregional Root Zone Moisture Budget output filenames are also listed in this file. Soil properties at each grid cell and the destination for the surface flow generated at each cell are listed in the last section of the Root Zone Component Main File.

First data line of the Root Zone Component Main File lists the version number (i.e. 4.0) of the root zone component that will be used in simulating the land surface and root zone flow processes. IDC first reads this data line to figure out what other parameters will be read and what flow processes are to be simulated. This first line of data entry must not be modified.

The following sections and variables are defined in the rest of this file:

Root Zone Simulation Scheme Control and Filenames

In this section convergence criteria for the iterative solution methodology and names of additional input and output files are listed.

RZCONV	Convergence criteria for iterative soil moisture accounting as a fraction of total porosity; [L/L]
RZITERMX	Maximum number of iterations for iterative soil moisture accounting
FACTCN	Conversion factor to convert inches to the simulation unit of length

AGNPFL	Filename for the Non-Ponded Crops Main File (maximum 1000 characters); leave blank if non-ponded crops are not simulated
PFL	Filename for the Ponded Crops Main File (maximum 1000 characters); leave blank if rice and/or refuge lands are not simulated
URBFL	Filename for the Urban Lands Main File (maximum 1000 characters); leave blank if urban lands are not simulated
NVRVFL	Filename for the Natural Lands Main File (maximum 1000 characters); leave blank if native and/or riparian vegetation lands are not simulated
RFFL	File that lists the return flow fractions (maximum 1000 characters); leave blank if only native and/or riparian vegetation lands are simulated
RUFL	File that lists the irrigation water re-use factors (maximum 1000 characters); leave blank if only native and/or riparian vegetation lands are simulated
IPFL	File that lists the irrigation periods for each ponded and non-ponded crop (maximum 1000 characters); this is a required file even if ponded and non-ponded crops are not simulated
MSRCFL	File that lists generic source of moisture rates other than precipitation and irrigation (maximum 1000 characters); leave blank if there are no generic sources of moisture simulated
AGWDFL	File that lists agricultural water supply requirement (maximum 1000 characters); leave blank if agricultural water supply requirement for all crops will be computed dynamically
LWUBUDFL	HDF5 output file for subregional land and water use budget (maximum 1000 characters); leave blank if this output is not required
RZBUDFL	HDF5 output file for subregional root zone moisture (maximum 1000 characters); leave blank if this output is not required

FNSMFL	Output file for end-of-simulation soil moisture (maximum 1000 characters); leave blank if this output is not required

Soil Parameters and Surface Flow Destinations

In this section, soil parameters, precipitation rates, generic soil moisture sources (if any) and surface runoff destinations are listed for each finite element.

FACTK	Conversion factor for the spatial component of the root zone hydraulic conductivity
TUNITK	Time unit of root zone hydraulic conductivity this should be one of the units recognized by HEC-DSS that are listed in the IDC Main Input File
IE	Element identification number
WP	Wilting point; [L/L]
FC	Field capacity; [L/L]
TN	Total porosity; [L/L]
LAMBDA	Pore size distribution index
K	Saturated hydraulic conductivity; [L/T]
RHC	Method to represent hydraulic conductivity versus moisture content curve (1 = Campbell's equation, 2 = van Genucten-Mualem equation)
IRNE	Precipitation rate; this number corresponds to the appropriate data column in the Precipitation File
FRNE	Factor to convert rainfall at the precipitation data column IRNE to rainfall at element IE
IMSRC	Generic source of moisture; this number corresponds to the appropriate data column in the Generic Moisture Source File that applies to element IE (enter any number if the Generic Moisture Source File, MSRCFL, is not defined)
TYPDEST	Destination type for the surface flow from element IE (0 = surface flow goes outside of model area, 1 = surface flow goes to a stream node, 3 = surface flow goes to a lake, 5 = surface flow recharges the groundwater)
DEST	Destination identification number for the surface flow from element IE; enter any number if surface flow from the element

	goes outside the model area (TYPDEST = 0) or recharges the groundwater (TYPDEST = 5)
KPonded	Saturated hydraulic conductivity to be used for ponded crops in the element (enter −1.0 if KPonded is the same as K); [L/T]

```
#4.0
C***  DO NOT DELETE ABOVE LINE ***
C
C*******************************************************************************
C
C                   INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                     ROOT ZONE PARAMETERS DATA FILE
C                          Root Zone Component
C                          *** Version 4.0 ***
C
C
C              Project:  IDC Version ### Release
C                        California Department of Water Resources
C              Filename: ROOTZONE_MAIN.dat
C
C*******************************************************************************
C                             File Description
C
C   This data file contains the parameters and data file names for the simulation
C   of root zone processes.
C
C*******************************************************************************
C                  Root Zone Simulation Scheme Control and File Names
C
C   RZCONV   ;  Convergence criteria for iterative soil moisture accounting as a
C                fraction of total porosity; [L/L]
C   RZITERMX ;  Maximum number of iterations for iterative soil moisture accounting
C   FACTCN   ;  Conversion factor to convert inches to the simulation unit of length
C   AGNPFL   ;  Non-ponded agricultural crop data file (max. 1000 characters)
C                * Leave blank if non-ponded crops are not simulated
C   PFL      ;  Rice/refuge data file (max. 1000 characters)
C                * Leave blank if rice and/or refuge lands are not simulated
C   URBFL    ;  Urban lands data file (max. 1000 characters)
C                * Leave blank if urban lands are not simulated
C   NVRVFL   ;  Native/riparian vegetation lands data file (max. 1000 characters)
C                * Leave blank if native and/or riparion veg. lands are not simulated
C   RFFL     ;  File that lists the return flow fractions (max. 1000 characters)
C                * Leave blank if only native/riparian vegetation lands are simulated
C   RUFL     ;  File that lists the irrigation water re-use factors (max. 1000 characters)
C                * Leave blank if only native/riparian vegetation lands are simulated
C   IPFL     ;  File that lists the irrigation periods for each ponded and
C                non-ponded crop (max. 1000 characters)
C                * Leave blank if both ponded and non-ponded crops are not simulated
C   MSRCFL   ;  File that lists generic source of moisture rates other than precipitation
C                and irrigation (max. 1000 characters)
C                * Leave blank if there are no generic sources of moisture simulated
C   AGWDFL   ;  File that lists agricultural water supply requirement (max. 1000 characters)
C                * Leave blank if agricultural water supply requirement will be computed
C                  dynamically
C   LWUBUDFL ;  HDF5 output file for land and water use budget at each
C                  subregion (max. 1000 characters)
C                * Leave blank if this output is not required
C   RZBUDFL  ;  HDF5 output file for root zone moisture budget at each
C                  subregion (max. 1000 characters)
C                * Leave blank if this output is not required
C   FNSMFL   ;  Output file for end-of-simulation soil moisture (max. 1000 characters)
C                * Leave blank if this output is not required
C
C-----------------------------------------------------------------------------------------
C         VALUE                                      DESCRIPTION
C-----------------------------------------------------------------------------------------
          0.0001                                     / RZCONV
          200                                        / RZITERMX
          0.08333                                    / FACTCN  (in -> ft)
          RootZone\NonPondedAg\NonPondedAg.dat       / AGNPFL
          RootZone\PondedAg\PondedAg.dat             / PFL
          RootZone\Urban\Urban.dat                   / URBFL
          RootZone\NVRV\NVRV.dat                     / NVRVFL
          RootZone\ReturnFlowFrac.dat                / RFFL
          RootZone\ReuseFrac.dat                     / RUFL
          RootZone\IrrigPeriod.dat                   / IPFL
                                                     / MSRCFL
          RootZone\AgWaterDemand.dat                 / AGWDFL
          Budget\LWU.hdf                             / LWUBUDFL
          Budget\RZ.hdf                              / RZBUDFL
                                                     / FNSMFL
C*******************************************************************************
C              Parameters for Soil, Precipitation and Runoff Destination
C
C   Enter conversion factors.
C
C   FACTK  ;  Conversion factor for root zone hydraulic conductivity
C              It is used to convert only the spatial component of the unit;
C              DO NOT include the conversion factor for time component of the unit.
C              * e.g. Unit of hydraulic conductivity listed in this file = IN/DAY
C                     Consistent unit used in simulation                 = FT/MONTH
C                     Enter FACT (IN/MONTH -> FT/MONTH)                  = 8.33333E-02
C                     (conversion of DAY -> MONTH is performed automatically)
C   TUNITK ;  Time unit of root zone hydraulic conductivity.  This should be one of the
C             units recognized by HEC-DSS that are listed in the Main Control File.
C
C-----------------------------------------------------------------------------------------
C         VALUE                                      DESCRIPTION
C-----------------------------------------------------------------------------------------
          0.283464                                   / FACTK (micrometers/sec -> ft/day)
          1day                                       / TUNITK
C-----------------------------------------------------------------------------------------
C
C   Enter soil parameters, precipitaion and surface flow destination data below for each
C   grid element.
C
C   IE     ;  Element ID
C   WP     ;  Wilting point; [L/L]
C   FC     ;  Field capacity; [L/L]
C   TN     ;  Total porosity; [L/L]
C   LAMBDA ;  Pore size distribution index; [dimensionless]
C   K      ;  Saturated hydraulic conductivity; [L/T]
C   RHC    ;  Method to represent hydraulic conductivity vs. moisture content curve
C               1 = Campbell's equation
```

```
C              2 = van Genucten-Mualem equation
C   IRNE   ;  Precipitation data column in the Precipitation file that applies to element IE
C   FRNE   ;  Factor to convert rainfall at the precipitation data column to
C              rainfall at element IE
C   IMSRC  ;  Generic source of moisture data column in the Generic Moisture Source file (MSRCFL
C              file listed above) that applies to element IE
C                * Note: Enter any number if MSRCFL above is left blank
C   TYPDEST;  Destination type for the surface flow from element IE
C              0 = Surface flow goes outside of model area
C              1 =   "       "    "  to a stream node
C              3 =   "       "    "   " a lake
C              5 =   "       "    "   " groundwater
C   DEST   ;  Destination for the surface flow from element IE
C                * Note: Enter any number if TYPDEST is set to 0 or 5
C   KPonded;  Saturated hydraulic conductivity to be used for ponded crops in the element; [L/T]
C                * Note: Enter -1.0 if KPonded is the same as K
C
C-------------------------------------------------------------------------------------------------------
C  IE      WP        FC        TN        LAMBDA    K        RHC    IRNE  FRNE   IMSRC   TYPDEST  DEST   KPonded
C-------------------------------------------------------------------------------------------------------
   1       0.0000    0.1370    0.4530    0.378     5.0E-02   2      1    1.0      0       0       3      -1.0
   2       0.0000    0.1571    0.4640    0.242     5.1E+01   2      1    1.0      0       0       3      -1.0
   3       0.0000    0.1053    0.4630    0.252     5.0E-02   2      1    1.0      0       0       3      -1.0
   .         .         .         .         .         .       .      .     .       .       .       .        .
   .         .         .         .         .         .       .      .     .       .       .       .        .
   .         .         .         .         .         .       .      .     .       .       .       .        .
   220     0.0000    0.1210    0.4300    0.223     5.0E-02   2      3    1.0      0       0       3      1.0E-03
   221     0.0000    0.0485    0.4530    0.378     5.0E-02   2      3    1.0      0       0       0      1.0E-03
   222     0.0000    0.2322    0.5010    0.234     1.9E+01   2      3    1.0      0       0       0      1.0E-03
   223     0.0000    0.1210    0.4300    0.223     5.0E-02   2      3    1.0      0       0       3      1.0E-03
```

8.3.8.2. Return Flow Fractions Data File

The Return Flow Fractions Data File lists return flows specified as time series fractions of applied water. Non-ponded crops, ponded crops and urban lands at each element are associated with data columns in this file through pointers specified in the Non-Ponded Crops Main File, Ponded Crops Main File and Urban Lands Main File, respectively.

The following variables are used in this file:

NCOLRT	Number of return flow fractions data columns
NSPRT	Number of time steps to update the return flow fractions; enter any number if time-tracking simulation
NFQRT	Repetition frequency of the return flow fractions data; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Return Flow Fractions Data File

If the time series data is listed in the Return Flow Fractions Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using "C", "c" or "*", and the variables in the "Data Input from DSS File" section below should be populated.

TIME	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
RTRNF	Return flows as a fraction of applied water

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

REC	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*******************************************************************************
C
C                   INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                  RETURN FLOW FRACTIONS DATA FILE
C                        Root Zone Component
C                        *** Version 4.0 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: ReturnFlowFrac.dat
C
C*******************************************************************************
C                            File Description
C
C   This data file contains a set of return flows given as fractions of irrigation
C   water.
C
C*******************************************************************************
C                Return Flow Fractions Data Specifications
C
C   NCOLRT ; Number of return flow fractions data columns
C   NSPRT  ; Number of time steps to update the return flow fractions
C              * Enter any number if time-tracking option is on
C   NFQRT  ; Repetition frequency of the return flow fractions data
C              * Enter 0 if full time series data is supplied
C              * Enter any number if time-tracking option is on
C   DSSFL  ; The name of the DSS file for data input
C              * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------
C         VALUE                                      DESCRIPTION
C-------------------------------------------------------------------------------
          2                                          / NCOLRT
          1                                          / NSPRT
          0                                          / NFQRT
                                                     / DSSFL
C------------------------------------------------------------------------------------
C                            Return Flow Fractions
C                            (READ FROM THIS FILE)
C
C   List the return flow fractions data below, if it will not be read from
C   a DSS file (i.e. DSSFL is left blank above).
C
C   TIME ;  Time
C   RTRNF;  Return flows as a fraction of applied water; [dimensionless]
C
C------------------------------------------------------------------------------------
C  TIME              RTRNF_AG    RTRNF_URB  RTRNF[3] ... RTRNF[NCOLRT]
C------------------------------------------------------------------------------------
   12/31/2500_24:00    0.2         0.2
*
C-------------------------------------------------------------------------------
C                   Pathnames for Return Flow Fractions Data
C                             (READ FROM DSS FILE)
C
C   List the pathnames for return flow fractions data below, if it
C   will be read from a DSS file (i.e. DSSFL is specified above).
C
C   REC  ;  Time series record number
C   PATH ;  Pathname for the time series record
C
C------------------------------------------------------------------------------------
C   REC     PATH
C------------------------------------------------------------------------------------
*
*
```

8.3.8.3. Re-use Fractions Data File

The Re-use Fractions Data File lists re-used portion of the captured return flow from agricultural and urban lands. It is specified as time series fractions of applied water. The difference between the return flow and re-use is the net return flow from agricultural and urban lands. Non-ponded crops, ponded crops and urban lands at each element are associated with data columns in this file through pointers specified in the Non-Ponded Crops Main File, Ponded Crops Main File and Urban Lands Main File, respectively.

The following variables are used in this file:

NCOLRUF	Number of re-use fractions data columns
NSPRUF	Number of time steps to update the re-use fractions; enter any number if time-tracking simulation
NFQRUF	Repetition frequency of the re-use fractions data; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Re-use Fractions Data File

If the time series data is listed in the Re-use Fractions Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using “C”, “c” or “*”, and the variables in the “Data Input from DSS File” section below should be populated.

TIME	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
RUF	Re-use as a fraction of applied water

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

REC	Record number that coincides with the data column number for the time series data

PATH	Pathname for the time series record that will be used for data retrieval

```
C*******************************************************************************
C
C                 INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                   RE-USE FRACTIONS DATA FILE
C                      Root Zone Component
C                      *** Version 4.0 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: ReuseFrac.dat
C
C*******************************************************************************
C                            File Description
C
C   This data file contains a set of re-use data given as fractions of irrigation
C   water.
C
C*******************************************************************************
C                 Re-Use Fractions Data Specifications
C
C   NCOLRUF ; Number of re-use fractions data columns
C   NSPRUF  ; Number of time steps to update the re-use fractions
C              * Enter any number if time-tracking option is on
C   NFQRUF  ; Repetition frequency of the re-use fractions data
C              * Enter 0 if full time series data is supplied
C              * Enter any number if time-tracking option is on
C   DSSFL   ; The name of the DSS file for data input
C              * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------
C         VALUE                                     DESCRIPTION
C-------------------------------------------------------------------------------
           2                                        / NCOLRUF
           1                                        / NSPRUF
           0                                        / NFQRUF
                                                    / DSSFL
C--------------------------------------------------------------------------------
C                             Re-Use Fractions
C                           (READ FROM THIS FILE)
C
C   List the re-use fractions data below, if it will not be read from
C   a DSS file (i.e. DSSFL is left blank above).
C
C   TIME ;  Time
C   RUF  ;  Re-use as a fraction of applied water; [dimensionless]
C
C--------------------------------------------------------------------------------
C  TIME                RUF_AG  RUF_URB  RUF[3] ... RUF[NCOLRUF]
C--------------------------------------------------------------------------------
   12/31/2500_24:00    0.05     0.0
*
C-------------------------------------------------------------------------------
C                        Pathnames for Re-Use Fractions Data
C                              (READ FROM DSS FILE)
C
C   List the pathnames for re-use fractions data below, if it
C   will be read from a DSS file (i.e. DSSFL is specified above).
C
C   REC  ;  Time series record number
C   PATH ;  Pathname for the time series record
C
C--------------------------------------------------------------------------------
C   REC     PATH
C--------------------------------------------------------------------------------
*
*
```

8.3.8.4. Irrigation Period Data File

The Irrigation Period Data File includes time series flags that represent cropping seasons for ponded and non-ponded crops. A value of 0 represents a non-cropping period so IDC does not compute agricultural water demand for that period; a value of 1 represents cropping period and IDC calculates water demand for that period. The ponded and non-ponded crops in each element are associated with data columns in this file through pointers specified in the Ponded Crops Main File and the Non-Ponded Crops Main File.

The following variables are used in this file:

NCOLIP	Number of data columns for irrigation period
NSPIP	Number of time steps to update the irrigation period data; enter any number if time-tracking option is on
NFQIP	Repetition frequency of the irrigation period data; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Irrigation Period Data File

If the time series data is listed in the Irrigation Period Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using "C", "c" or "*", and the variables in the "Data Input from DSS File" section below should be populated.

TIME	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
IP	Irrigation period indicator (0 = it is out of cropping season and IDC will not compute a water demand; 1 = cropping season and IDC will compute a water demand)

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

REC	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*******************************************************************************
C
C                 INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                  IRRIGATION PERIOD DATA FILE
C                      Root Zone Component
C                      *** Version 4.0 ***
C
C
C            Project:  IDC Version ### Release
C                      California Department of Water Resources
C            Filename: IrrigPeriod.dat
C
C*******************************************************************************
C                          File Description
C
C   This data file contains a set of irrigation period indicators (1 for irrigation
C   season and 0 for non-irrigation season).  These values are correlated to
C   individual ponded and non-ponded crops through the Ponded Crops Main File and
C   the Non-Ponded Crops Main File.
C
C*******************************************************************************
C                Irrigation Period Data Specifications
C
C   NCOLIP  ; Number of irrigation period data columns
C   NSPIP   ; Number of time steps to update the irrigation period data
C              * Enter any number if time-tracking option is on
C   NFQIP   ; Repetition frequency of the irrigation period data
C              * Enter 0 if full time series data is supplied
C              * Enter any number if time-tracking option is on
C   DSSFL   ; The name of the DSS file for data input
C              * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------
C         VALUE                                     DESCRIPTION
C-------------------------------------------------------------------------------
          22                                        / NCOLIP
          1                                         / NSPIP
          0                                         / NFQIP
          Example_Data.dss                          / DSSFL
C-----------------------------------------------------------------------------------------------
C                          Irrigation Period Indicators
C                             (READ FROM THIS FILE)
C
C   List the irrigtaion period data below, if it will not be read from
C   a DSS file (i.e. DSSFL is left blank above).
C
C   TIME ;  Time
C   IP   ;  Irrigation period indicator;
C             0 = non-irrigation period (i.e. agricultural water demand will not be computed)
C             1 = irrigation period (i.e. agricultural water demand will be computed)
C
C-----------------------------------------------------------------------------------------------
C  TIME  IP[1]  IP[2]  IP[3] ... IP[NCOLIP]
C-----------------------------------------------------------------------------------------------
*
*
C-------------------------------------------------------------------------------
C                      Pathnames for Irrigation Period Data
C                             (READ FROM DSS FILE)
C
C   List the pathnames for irrigation period indicators below, if it
C   will be read from a DSS file (i.e. DSSFL is specified above).
C
C   REC  ;  Time series record number
C   PATH ;  Pathname for the time series record
C
C------------------------------------------------------------------------------------------------
C   REC     PATH
C------------------------------------------------------------------------------------------------
    1        /IWFM/GR_IP/FLAG//1MON/IRRIG_PERIOD/
    2        /IWFM/CO_IP/FLAG//1MON/IRRIG_PERIOD/
    3        /IWFM/SB_IP/FLAG//1MON/IRRIG_PERIOD/
    4        /IWFM/CR_IP/FLAG//1MON/IRRIG_PERIOD/
    5        /IWFM/DB_IP/FLAG//1MON/IRRIG_PERIOD/
    6        /IWFM/SF_IP/FLAG//1MON/IRRIG_PERIOD/
    7        /IWFM/FI_IP/FLAG//1MON/IRRIG_PERIOD/
    8        /IWFM/AL_IP/FLAG//1MON/IRRIG_PERIOD/
    9        /IWFM/PA_IP/FLAG//1MON/IRRIG_PERIOD/
    10       /IWFM/TM_IP/FLAG//1MON/IRRIG_PERIOD/
    11       /IWFM/CU_IP/FLAG//1MON/IRRIG_PERIOD/
    12       /IWFM/OG_IP/FLAG//1MON/IRRIG_PERIOD/
    13       /IWFM/TR_IP/FLAG//1MON/IRRIG_PERIOD/
    14       /IWFM/AP_IP/FLAG//1MON/IRRIG_PERIOD/
    15       /IWFM/OR_IP/FLAG//1MON/IRRIG_PERIOD/
    16       /IWFM/SO_IP/FLAG//1MON/IRRIG_PERIOD/
    17       /IWFM/FL_IP/FLAG//1MON/IRRIG_PERIOD/
    18       /IWFM/RICE_FL_IP/FLAG//1MON/IRRIG_PERIOD/
    19       /IWFM/RICE_NFL_IP/FLAG//1MON/IRRIG_PERIOD/
    20       /IWFM/RICE_NDC_IP/FLAG//1MON/IRRIG_PERIOD/
    21       /IWFM/RFG_SL_IP/FLAG//1MON/IRRIG_PERIOD/
    22       /IWFM/RFS_PR_IP/FLAG//1MON/IRRIG_PERIOD/
```

8.3.8.5. Generic Moisture Source File

The Generic Moisture Source File lists time series moisture inflow into the root zone from sources other than irrigation and precipitation. Possible sources of moisture are fog and lateral seepage through levees in places such as California's Sacramento-San Joaquin River Delta. The inflow rate is given in terms of unit rate per rooting depth of a land-use type. All land-use types can have access to generic sources of moisture. Each land-use type at each element is associated to a data column in this file through pointers in the respective main input file of a particular land-use.

The following variables are used in this file:

NCOLSRC	Number of generic moisture data columns
FACTSRC	Conversion factor for the spatial component of the generic moisture data
NSPSRC	Number of time steps to update the generic moisture data; enter any number if time-tracking simulation
NFQSRC	Repetition frequency of the generic moisture data; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Generic Moisture Source File

If the time series data is listed in the Generic Moisture Source File, then the following variables need to be populated. Otherwise, these variables should be commented out using "C", "c" or "*", and the variables in the "Data Input from DSS File" section below should be populated.

TIME	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
MSRC	Generic moisture inflow rate; [(L/L)/T]

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

REC	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*******************************************************************************
C
C                   INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C              GENERIC MOISTURE SOURCE DATA FILE
C                     Root Zone Component
C                     *** Version 4.0 ***
C
C
C              Project:  IDC Version ### Release
C                        California Department of Water Resources
C              Filename: GenericMoist.dat
C
C*******************************************************************************
C                              File Description:
C
C    This file contains a set of moisture time-series data to be used as generic
C    source of water for the root zone. This additional source of moisture can be
C    used to represent any source of water other then precipitation and irrigation.
C    The unit of the generic moisture is specified as [(L/L)/T], for instance
C    inches per foot per month. These values will be converted to unit rate of inflow
C    by the Root Zone Component by multiplying them with the rooting depth for each
C    land use. The generic moisture data are correlated to individual grid cells
C    through the Root Zone Parameter file.
C
C*******************************************************************************
C                    Generic Moisture Source Data Specifications
C
C    NCOLSRC; Number of generic moisture data columns (or pathnames if DSS files are used)
C    FACTSRC; Conversion factor for generic moisture data
C              It is used to convert only the spatial component of the unit;
C              DO NOT include the conversion factor for time component of the unit.
C              * e.g. Unit of generic moisture listed in this file         = INCHES/FOOT/MONTH
C                     Consistent unit used in simulation                   = FOOT/FOOT/DAY
C                     Enter FACTSRC (INCHES/FOOT//MONTH -> FOOT/FOOT/MONTH) = 8.33333E-02
C                      (conversion of MONTH -> DAY is performed automatically)
C    NSPSRC ; Number of time steps to update the generic moisture data
C              * Enter any number if time-tracking option is on
C    NFQSRC ; Repetition frequency of the generic moisture data
C              * Enter 0 if full time series data is supplied
C              * Enter any number if time-tracking option is on
C    DSSFL ;  The name of the DSS file for data input (maximum 50 characters);
C              * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------
C         VALUE                                      DESCRIPTION
C-------------------------------------------------------------------------------
          3                                          / NCOLSRC
          0.083333                                   / FACTSRC   (in -> ft)
          1                                          / NSPSRC
          0                                          / NFQSRC
          INPUT_DATA.DSS                             / DSSFL
C-------------------------------------------------------------------------------
C                         Generic Moisture Data
C                         (READ FROM THIS FILE)
C
C    List the generic moisture rates below in units of L/L/T, if it will
C    not be read from a DSS file (i.e. DSSFL is left blank above).
C
C    TIME ;   Time
C    MSRC ;   Generic moisture rate; [L/L/T]
C
C-------------------------------------------------------------------------------
C   TIME      MSRC[1]  MSRC[2]  MSRC[3]  ...  MSRC[NCOLSRC] ...
C-------------------------------------------------------------------------------
*
*
C-------------------------------------------------------------------------------
C                    Pathnames for Generic Moisture Data
C                         (READ FROM DSS FILE)
C
C    List the pathnames for the generic moisture data below, if it will be read
C    from a DSS file (i.e. DSSFL is specified above).
C
C    REC    ;  Time series record number
C    PATH   ;  Pathname for the time series record
C
C-----------------------------------------------------------------------------------------------
C    REC        PATH
C-----------------------------------------------------------------------------------------------
    1          /DELTA/SOUTH_LEVEE/SEEP//1DAY/SEEPAGE/
    2          /DELTA/NORTH_LEVEE/SEEP//1DAY/SEEPAGE/
    3          /DELTA/EAST_LEVEE/SEEP//1DAY/SEEPAGE/
```

8.3.8.6. Agricultural Supply Requirement Data File

IDC allows time-series agricultural water demands to be specified for some or all of the crops rather than dynamically computing them. This feature is useful in planning studies when the water demand is dictated by the contractual limits rather than crop evapotranspirative requirements. This feature can also be used when the historical surface water deliveries are known and the part or all of the deliveries are used for artificial recharge of the groundwater. The non-ponded and ponded crops in each element can optionally be associated with a data column in this file through the pointers in the Non-Ponded Crops Main File and the Ponded Crops Main File, respectively.

The following variables are used in this file:

NDMAG	Number of agricultural supply requirement data columns
FACTDMAG	Conversion factor for the spatial component of the agricultural supply requirement data
NSPDMAG	Number of time steps to update the agricultural supply requirement data; enter any number if time-tracking simulation
NFQDMAG	Repetition frequency of the agricultural supply requirement data; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Agricultural Supply Requirement Data File

If the time series data is listed in the Agricultural Supply Requirement Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using “C”, “c” or “*”, and the variables in the “Data Input from DSS File” section below should be populated.

ITDA	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
RDMAG	Agricultural water supply requirement; $[L^3/T]$

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

I	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*******************************************************************************
C
C                  INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C          AGRICULTURAL WATER SUPPLY REQUIREMENT DATA FILE
C                         Root Zone Component
C                         *** Version 4.0 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: AgWaterDemand.dat
C
C*******************************************************************************
C                             File Description
C
C   This data file contains a set of agricultural water supply requirement data.
C   These data are correlated to individual crops through Non-Ponded and Ponded
C   Crop Data Files.
C
C*******************************************************************************
C             Agricultural Water Supply Requirement Data Specifications
C
C   NDMAG   ;  Number of agricultural water supply requirement data columns
C   FACTDMAG;  Conversion factor for the agricultural supply requirement
C               It is used to convert only the spatial component of the unit;
C               DO NOT include the conversion factor for time component of the unit.
C               * e.g. Unit of flow listed in this file           = AC-FT/MONTH
C                      Consistent unit used in simulation         = CU.FT/DAY
C                      Enter FACTDMAG (AC-FT/MONTH -> CU.FT/MONTH) = 43560.0
C                     (conversion of MONTH -> DAY is performed automatically)
C   NSPDMAG ;  Number of time steps to update the agricultural supply requirement data
C               * Enter any number if time-tracking option is on
C   NFQDMAG ;  Repetition frequency of the agricultural supply requirement data
C               * Enter 0 if full time series data is supplied
C               * Enter any number if time-tracking option is on
C   DSSFL   ;  The name of the DSS file for data input
C               * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------
C        VALUE                                      DESCRIPTION
C-------------------------------------------------------------------------------
           31                                       / NDMAG
           43560.0                                  / FACTDMAG (ac.ft -> cu.ft)
           1                                        / NSPDMAG
           0                                        / NFQDMAG
                                                    / DSSFL
C-------------------------------------------------------------------------------
C               Agricultural Water Supply Requirement Data
C                          (READ FROM THIS FILE)
C
C   List the agricultural water supply requirement data below, if it will not
C   be read from a DSS file (i.e. DSSFL is left blank above).
C
C   ITDA;    Time
C   RDMAG;   Agricultural water supply requirement; [L^3/T]
C
C-------------------------------------------------------------------------------
C ITDA                     RDMAG(1)  RDMAG(2)
C-------------------------------------------------------------------------------
C                              1        2        3       ...     29      30      31
  10/31/4000_24:00          26.02     8.88     0.34     ...    4.06    6.71  213.58
  11/30/4000_24:00          18.24     6.22     0.24     ...    2.85    4.70  149.75
  12/31/4000_24:00          17.34     5.92     0.23     ...    2.71    4.47  142.39
  01/31/4000_24:00           9.87     3.37     0.13     ...    1.54    2.54   81.01
  02/29/4000_24:00           7.77     2.65     0.10     ...    1.21    2.00   63.83
  03/31/4000_24:00           2.69     0.92     0.04     ...    0.42    0.69   22.09
  04/30/4000_24:00           0.60     0.20     0.01     ...    0.09    0.15    4.91
  05/31/4000_24:00           2.69     0.92     0.04     ...    0.42    0.69   22.09
  06/30/4000_24:00           5.38     1.84     0.07     ...    0.84    1.39   44.19
  07/31/4000_24:00           9.27     3.16     0.12     ...    1.45    2.39   76.10
  08/31/4000_24:00          13.16     4.49     0.17     ...    2.05    3.39  108.02
  09/30/4000_24:00          18.24     6.22     0.24     ...    2.85    4.70  149.75
C-------------------------------------------------------------------------------
C                  Pathnames for Agricultural Water Supply Requirement Data
C                                 (READ FROM DSS FILE)
C
C   List the pathnames for the agricultural water supply requirement data below,
C   if it will be read from a DSS file (i.e. DSSFL is specified above).
C
C   I    ;  Pathname number
C   PATH ;  Pathname for the time series record
C
C---------------------------------------------------------------------------------------
C   I       PATH
C---------------------------------------------------------------------------------------
*
*
```

8.3.8.7. Non-Ponded-Crops Component Files

8.3.8.7.a Non-Ponded Crops Main File

The Non-Ponded Crops Main File is the gateway file for all data that is necessary to simulate non-ponded crops and generate non-ponded-crop related budget files.

The file is divided into several sections and uses the following variables:

General Data

Number of non-ponded crops simulated, crop codes and filename for the non-ponded crop acreage data are defined in this section:

NCROP	Number of agricultural crops excluding ponded crops (i.e. rice and refuge)
FLDMD	Flag for the root zone moisture to be used for the computation of agricultural water demand and the timing of irrigation (0 = use the soil moisture at the beginning of time step, 1 = use the soil moisture at the end of time step); setting FLDMD to 0 works well when the simulation time step is small (e.g. 1 day) while it should be set to 1 when the simulation time step is longer (e.g. 1 month)
CCODE	Crop codes; enter 2-character crop codes for each of the non-ponded crops modeled (following codes are reserved and should not be used: UR = Urban, RI = Rice, RF = Refuge, NV = Native vegetation, RV = Riparian vegetation)
LUFLNP	File that lists the crop areas (maximum 1000 characters)

Budget Output Files

To generate crop-specific land and water use and root zone budgets, the following variables must be specified:

NBCROP	Number of non-ponded crops for water budget output; enter 0 if crop specific budget output is not required
BCCODE	Crop codes (from above) for which water budget output is required
CLWUBUDFL	HDF5 output file for crop-specific land and water use budget at each subregion for selected crops (maximum 1000 characters); leave blank if this output is not required

CRZBUDFL	HDF5 output file for root zone moisture budget at each subregion for selected crops (maximum 1000 characters); leave blank if this output is not required

Rooting Depths

RZFRACFL	File that lists fraction of maximum root depths to represent root growth (maximum 1000 characters)
FACT	Conversion factor for maximum crop root zone depths
IC	Crop identification number; enter 1 through NCROP, sequentailly
ROOT	Maximum crop root zone depth; [L]
ICROOT	Root depth as a fraction of maximum root depth; this number corresponds to the appropriate data column in the Root Depth Fractions Data File

Curve Numbers for Rainfall Runoff Simulation

Curve numbers for each element and crop combination are entered in this section.

IE	Element identification number entered sequentially; enter 0 if curve numbers defined for each crop are to be used for all elements
CN	Curve number for each non-ponded agricultural crop

Crop Evapotranspiration

Crop evapotranspiration for each element and crop combination is listed here by specifying a column number in the Evapotranspiration File:

IE	Element identification number entered sequentially; enter 0 if following values are to be used for all elements
ICET	Crop ET; this number corresponds to the appropriate data column the Evapotranspiration File

Agricultural Water Supply Requirement

If, for any crop at an element, the agricultural water supply requirement is pre-specified instead of being computed dynamically, they are specified in this section:

IE	Element identification number; enter 0 if following values are to be used for all elements

ICAW	Agricultural water supply requirement; this number corresponds to the appropriate data column in the Agricultural Supply Requirement Data File (AGWDFL) listed in the Root Zone Component Main File (enter 0 if agricultural water supply requirement will be computed dynamically

Irrigation Periods

Time series irrigation period data is listed in this section for each crop and element combination:

IE	Element identification number; enter 0 if following values are to be used for all elements
ICIP	Irrigation period; this number corresponds to the appropriate data column in the Irrigation Period Data File (IPFL) listed in the Root Zone Parameters Data File.

Minimum Soil Moisture

The minimum soil moisture that is used to trigger an irrigation event for each crop and element combination is listed in this section:

MINSMFL	File that lists the minimum soil moisture for each crop (maximum 1000 characters)
IE	Element identification number; enter 0 if following values are to be used for all elements
ICMSM	Minimum soil moisture as a fraction of field capacity; this corresponds to the appropriate data column in the Minimum Soil Moisture Data File (MINSMFL)

Target Soil Moisture for Irrigation

The moisture level which is targeted to be achieved by the irrigation event is listed for each crop and element combination in this section:

TRGSMFL	File that lists the target soil moisture for each crop during irrigation (maximum 1000 characters); leave blank if target soil moisture is the field capacity
IE	Element identification number; enter 0 if following values are to be used for all elements

ICTRGSM	Target soil moisture as a fraction of total available water (i.e. field capacity less wilting point); this number corresponds to the appropriate data column in the Target Soil Moisture Data File (TRGSMFL)

Return Flow Fractions

The return flow fractions for each crop and element combination are listed in this section:

IE	Element identification number; enter 0 if following values are to be used for all elements
ICRTRNF	Fraction of the applied water that becomes return flow; this number corresponds to the appropriate data column in the Return Flow Fractions Data File given in the Root Zone Component Main File

Re-use Fractions

The re-use fractions for each crop and element combination are listed in this section:

IE	Element identification number; enter 0 if following values are to be used for all elements
ICRUF	Fraction of the applied water that becomes re-used water; this number corresponds to the appropriate data column in the Re-use Fractions Data File given in the Root Zone Component Main File

Minimum Percolation Fractions

If a minimum percolation amount needs to be specified, it is listed in this section for each crop and element combination:

DPFL	File that lists the minimum percolation fractions (maximum 1000 characters); leave blank if minimum percolation is not imposed
IE	Element identification number; enter 0 if following values are to be used for all elements
ICDPF	Fraction of the "infiltrated" applied water that is going to be percolation; this number corresponds to the appropriate data

	column in the Minimum Percolation Fractions Data File (DPFL)

Initial Soil Moisture Conditions

IE	Element identification number; enter 0 if following values are to be used for all elements
FSOILMP	Fraction of initial soil moisture at element IE that is due to precipitation
SOILM	Initial root zone moisture content; [L/L]

```
C*******************************************************************************
C
C                 INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C               NON-PONDED AGRICULTURAL CROPS DATA FILE
C                        Root Zone Component
C                        *** Version 4.0 ***
C
C
C            Project:  IDC Version ### Release
C                      California Department of Water Resources
C            Filename: NonPondedAg_MAIN.dat
C
C*******************************************************************************
C                         File Description
C
C   This data file contains the parameters and data file names for the simulation
C   of root zone processes and managament of non-ponded agricultural crops.
C
C*******************************************************************************
C            Number of Non-Ponded Agricultural Crops and Crop Codes
C
C   NCROP    ;  Number of agricultural crops excluding ponded crops (i.e. rice and refuge)
C   FLDMD    ;  Flag for the root zone moisture to be used for the computation of
C                agricultural water demand and the timing of irrigation
C                * 0: Use the soil moisture at the beginning of time step
C                * 1: Use the soil moisture at the end of time step
C   CCODE    ;  Crop codes (max. 2 characters)
C               (1 to NCROP)
C              * Note: The following codes are reserved and should not be used:
C                UR : Urban
C                RI : Rice
C                RF : Refuge
C                NV : Native vegetation
C                RV : Riparian vegetation
C   LUFLNP   ;  File that lists the crop areas (max. 1000 characters)
C
C-------------------------------------------------------------------------------
C   VALUE                DESCRIPTION
C-------------------------------------------------------------------------------
    17                                                       / NCROP
    0                                                        / FLDMD
    GR                                                       / CCODE1    GRAIN
    CO                                                       / CCODE2    COTTON
    SB                                                       / CCODE3    SUGAR BEETS
    CR                                                       / CCODE4    CORN
    DB                                                       / CCODE5    DRY BEANS
    SF                                                       / CCODE6    SAFFLOWER
    FI                                                       / CCODE7    OTHER FIELD
    AL                                                       / CCODE8    ALFALFA
    PA                                                       / CCODE9    PASTURE
    TM                                                       / CCODE10   TOMATOES
    CU                                                       / CCODE11   CUCURBITS
    OG                                                       / CCODE12   ONIONS AND GARLIC
    TR                                                       / CCODE13   OTHER TRUCK
    AP                                                       / CCODE14   ALMONDS AND PISTACHIO
    OR                                                       / CCODE15   OTHER DECID.
    SO                                                       / CCODE16   SUBTROPICAL
    FL                                                       / CCODE17   FALLOW AND IDLE
    RootZone\NonPondedAg\NonPondedAgArea.dat                 / LUFLNP
C*******************************************************************************
C                      Water Budget Output Files
C
C   NBCROP   ;  Number of non-ponded crops for water budget output
C                * Enter 0 if crop specific budget output is not required
C   BCCODE   ;  Crop codes (from above) for which water budget output is required
C                (1 to NBCROP)
C   CLWUBUDFL;  HDF5 output file for land and water use budget at each
C                  subregion for selected crops (max. 1000 characters)
C                * Leave blank if this output is not required
C   CRZBUDFL ;  HDF5 output file for root zone moisture budget at each
C                  subregion for selected crops (max. 1000 characters)
C                * Leave blank if this output is not required
C
C-------------------------------------------------------------------------------
C   VALUE                DESCRIPTION
C-------------------------------------------------------------------------------
    17                                          / NBCROP
    GR                                          / BCCODE1    GRAIN
    CO                                          / BCCODE2    COTTON
    SB                                          / BCCODE3    SUGAR BEETS
    CR                                          / BCCODE4    CORN
    DB                                          / BCCODE5    DRY BEANS
    SF                                          / BCCODE6    SAFFLOWER
    FI                                          / BCCODE7    OTHER FIELD
    AL                                          / BCCODE8    ALFALFA
    PA                                          / BCCODE9    PASTURE
    TM                                          / BCCODE10   TOMATOES
    CU                                          / BCCODE11   CUCURBITS
    OG                                          / BCCODE12   ONIONS AND GARLIC
    TR                                          / BCCODE13   OTHER TRUCK
    AP                                          / BCCODE14   ALMONDS AND PISTACHIO
    OR                                          / BCCODE15   OTHER DECID.
    SO                                          / BCCODE16   SUBTROPICAL
    FL                                          / BCCODE17   FALLOW AND IDLE
    Budget\NonPondedAgLWU.hdf                   / CLWUBUDFL
    Budget\NonPondedAgRZ.hdf                    / CRZBUDFL
C*******************************************************************************
C                               Rooting Depths
C
C   RZFRACFL ;  File that lists fraction of maximum root depths to represent
C                root growth (max. 1000 characters)
C   FACT     ;  Conversion factor for maximum crop root zone depths
C   IC       ;  Crop type number (1 to NCROP);
C   ROOT     ;  Maximum crop root zone depth; [L]
C   ICROOT   ;  Root depth as a fraction of maximum root depth - this number
C                corresponds to the appropriate data column in the root depth
C                fractions data file (RZFRACFL).
C
*   Crop/Land Use No.           Name
```

```
*    ----------------           ------
*       1                         GR  grain
*       2                         CO  cotton
*       3                         SB  sugar beets
*       4                         CR  corn
*       5                         DB  dry beans
*       6                         SF  safflower
*       7                         FI  other field
*       8                         AL  alfalfa
*       9                         PA  pasture
*       10                        TM  processed tomatoes
*       11                        CU  cucurbits
*       12                        OG  onions & garlic
*       13                        TR  other truck
*       14                        AP  almonds & pistachios
*       15                        OR  other deciduous
*       16                        SO  subtropical
*       17                        FL  fallow and idle
*
C-------------------------------------------------------------------------------
C   VALUE                                   DESCRIPTION
C-------------------------------------------------------------------------------
    RootZone\NonPondedAg\RootDepthFrac.dat    / RZFRACFL
    1.0                                       / FACT
C-------------------------------------------------------------------------------
C   IC    ROOT      ICROOT
C-------------------------------------------------------------------------------
    1     4.0       1
    2     6.0       2
    3     5.0       3
    4     4.0       4
    5     4.0       5
    6     4.0       6
    7     4.0       7
    8     6.0       8
    9     2.0       9
    10    5.0       10
    11    3.0       11
    12    3.0       12
    13    3.0       13
    14    6.0       14
    15    6.0       15
    16    4.0       16
    17    1.0       17
C*******************************************************************************
C                    Curve Numbers for Rainfall Runoff Simulation
C
C   Enter curve numbers for each grid element and crop combination.
C
C   IE      ;  Element ID (Enter 0 if following values are to be used for all element
C                and non-ponded agricultural crop combinations)
C   CN      ;  Curve number for each non-ponded agricultural crop (1 to NCROP)
C
C-------------------------------------------------------------------------------
C                                                          CN BY CROP
C IE    ---------------------------------------------------------------------------------------------
C         GR    CO    SB    CR    DB    SF    FI    AL    PA    TM    CU    OG    TR    AP    OR    SO    FL
C----------------------------------------------------------------------------------------------------
    1     81    82    82    85    81    81    81    81    74    82    85    85    85    82    72    72    91
    2     81    82    82    85    81    81    81    81    74    82    85    85    85    82    72    72    91
    3     73    75    75    78    72    72    72    72    61    75    78    78    78    75    58    58    86
    .     .     .     .     .     .     .     .     .     .     .     .     .     .     .     .     .     .
    .     .     .     .     .     .     .     .     .     .     .     .     .     .     .     .     .     .
    .     .     .     .     .     .     .     .     .     .     .     .     .     .     .     .     .     .
    221   81    82    82    85    81    81    81    81    74    82    85    85    85    82    72    72    91
    222   73    75    75    78    72    72    72    72    61    75    78    78    78    75    58    58    86
    223   73    75    75    78    72    72    72    72    61    75    78    78    78    75    58    58    86
C*******************************************************************************
C                         Crop Evapotranspiration (ETc)
C
C   The following lists the ETc column pointers for each finite element and non-ponded
C   agricultural crop combination.
C
C   IE        ;  Element ID (Enter 0 if following values are to be used for all element
C                  and non-ponded agricultural crop combinations)
C   ICET      ;  Crop ET (ETc) - this number corresponds to the appropriate data column
C                  in the ET data file listed in the Main Input File.  List for each
C                  non-ponded agricultural crop (1 to NCROP).
C
C-------------------------------------------------------------------------------
C                                                               ICET BY CROP
C   IE   -------------------------------------------------------------------------------------------
C         GR    CO    SB    CR    DB    SF    FI    AL    PA    TM    CU    OG    TR    AP    OR    SO    FL
C----------------------------------------------------------------------------------------------------
    0     1     2     3     4     5     6     7     8     9     10    11    12    13    14    15    16    17
C*******************************************************************************
C                         Agricultural Water Supply Requirement
C
C   The following lists the agricultural water supply requirement column pointers
C   for each finite element and non-ponded agricultural crop combination.
C
C   IE        ;  Element ID (Enter 0 if following values are to be used for all element
C                  and non-ponded agricultural crop combinations)
C   ICAW      ;  Agricultural water supply requirement - this number corresponds to the
C                  appropriate data column in the agricultural water supply requirement data
C                  file (AGWDFL) listed in the Root Zone Parameters Data File.  List for each
C                  non-ponded agricultural crop (1 to NCROP).
C                  *** Note: Enter 0 if agricultural water supply requirement will be computed
C                            internally.
C
C-------------------------------------------------------------------------------
C                                                               ICAW BY CROP
C   IE   -------------------------------------------------------------------------------------------
C         GR    CO    SB    CR    DB    SF    FI    AL    PA    TM    CU    OG    TR    AP    OR    SO    FL
C----------------------------------------------------------------------------------------------------
    0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
C*******************************************************************************
C                         Irrigation Periods
C
C   The following lists the irrigation period column pointers for each
C   finite element and non-ponded agricultural crop combinations.
C
```

```
C   IE       ;  Element ID (Enter 0 if following values are to be used for all element
C                 and non-ponded agricultural crop combinations)
C   ICIP     ;  Irrigation period - this number corresponds to the appropriate data
C                 column in the irrigation period data file (IPFL) listed in the Root
C                 Zone Parameters Data File.  List for each non-ponded crop (1 to NCROP).
C
C-----------------------------------------------------------------------------
C                                                              ICIP BY CROP
C   IE  ---------------------------------------------------------------------------------------------------
C         GR    CO    SB    CR    DB    SF    FI    AL    PA    TM    CU    OG    TR    AP    OR    SO    FL
C------------------------------------------------------------------------------------------------------------
    0     1     2     3     4     5     6     7     8     9     10    11    12    13    14    15    16    17
C****************************************************************************
C                       Minimum Soil Moisture
C
C   The following lists the minimum soil moisture column pointers for
C   each finite element and non-ponded agricultural crop combinations.
C
C   MINSMFL  ;  File that lists the minimum soil moisture for each crop
C                 (max. 1000 characters)
C   IE       ;  Element ID (Enter 0 if following values are to be used for all element
C                 and non-ponded agricultural crop combinations)
C   ICMSM    ;  Minimum soil moisture as a fraction of Total Available Water
C                 (TAW = field capacity - wilting point) - this number corresponds to
C                 the appropriate data column in the minimum soil moisture
C                 data file (MINSMFL).  List for each non-ponded crop (1 to NCROP).
C
C-----------------------------------------------------------------------------
C        VALUE                                     DESCRIPTION
C-----------------------------------------------------------------------------
         RootZone\NonPondedAg\MinMoist.dat         / MINSMFL
C-----------------------------------------------------------------------------
C                                                              ICMSM BY CROP
C IE  -----------------------------------------------------------------------------------------------------
C         GR    CO    SB    CR    DB    SF    FI    AL    PA    TM    CU    OG    TR    AP    OR    SO    FL
C------------------------------------------------------------------------------------------------------------
   0      1     2     3     4     5     6     7     8     9     10    11    12    13    14    15    16    17
C****************************************************************************
C                       Target Soil Moisture for Irrigation
C
C   The following lists the target soil moisture column pointers for
C   each finite element and non-ponded agricultural crop combinations.
C
C   TRGSMFL  ;  File that lists the target soil moisture for each crop during irrigation
C                 (max. 1000 characters)
C                 * Leave blank if target soil moisture is field capacity
C   IE       ;  Element ID (Enter 0 if following values are to be used for all element
C                 and non-ponded agricultural crop combinations)
C   ICTRGSM  ;  Target soil moisture as a fraction of field capacity - this number
C                 corresponds to the appropriate data column in the target soil moisture
C                 data file (TRGSMFL).  List for each non-ponded crop (1 to NCROP).
C
C-----------------------------------------------------------------------------
C        VALUE                                     DESCRIPTION
C-----------------------------------------------------------------------------
                                                   / TRGSMFL
C-----------------------------------------------------------------------------
C   IE    ICTRGSM[1]  ICTRGSM[2] ... ICTRGSM[NCROP]
C-----------------------------------------------------------------------------
*
*
C****************************************************************************
C                        Irrigation Water Return Flow Fractions
C
C   The following lists the irrigation water return flow fraction column pointers
C   for each finite element and non-ponded agricultural crop combinations.
C
C   IE       ;  Element ID (Enter 0 if following values are to be used for all element
C                  and non-ponded agricultural crop combinations)
C   ICRTRNF  ;  Fraction of the applied water that becomes return flow - this number
C                  corresponds to the appropriate data column in irrigation water
C                  return flow factor data file (RFFL) given in the Root Zone
C                  Parameters Data File.  List for each non-ponded crop (1 to NCROP)
C
C-----------------------------------------------------------------------------
C                                                              ICRTRNF BY CROP
C IE  -----------------------------------------------------------------------------------------------------
C         GR    CO    SB    CR    DB    SF    FI    AL    PA    TM    CU    OG    TR    AP    OR    SO    FL
C------------------------------------------------------------------------------------------------------------
  0       1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1
C****************************************************************************
C                        Irrigation Water Re-Use Fractions
C
C   The following lists the irrigation water re-use fraction column pointers
C   for each finite element and non-ponded agricultural crop combinations.
C
C   IE       ;  Element ID (Enter 0 if following values are to be used for all element
C                  and non-ponded agricultural crop combinations)
C   ICRUF    ;  Fraction of the applied water that is re-used - this number
C                  corresponds to the appropriate data column in irrigation water
C                  re-use factor data file (RUFL) given in the Root Zone
C                  Parameters Data File.  List for each non-ponded crop (1 to NCROP)
C
C-----------------------------------------------------------------------------
C                                                              ICRUF BY CROP
C IE  -----------------------------------------------------------------------------------------------------
C         GR    CO    SB    CR    DB    SF    FI    AL    PA    TM    CU    OG    TR    AP    OR    SO    FL
C------------------------------------------------------------------------------------------------------------
    0     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1     1
C****************************************************************************
C                           Minimum Deep Percolation Fractions
C
C   The following lists the fractions for minimum deep percolation at each finite element.
C
C   DPFL     ;  File that lists the minimum deep percolation fractions (max. 1000 characters)
C                  * Leave blank if minimum deep percolation is not imposed
C   IE       ;  Element ID (Enter 0 if following values are to be used for all element
C                and non-ponded agricultural crop combinations)
C   ICDPF    ;  Fraction of the "infiltrated" applied water that is going to be deep
C                percolation - this number corresponds to the appropriate data column in
C                minimum deep percolation factor data file (DPFL).  List for each non-ponded
C                crop (1 to NCROP).
```

```
C-------------------------------------------------------------------------------
C        VALUE                                           DESCRIPTION
C-------------------------------------------------------------------------------
                                                         / DPFL
C-------------------------------------------------------------------------------
C   IE    ICDPF[1]  ICDPF[2] ... ICDPF[NCROP]
C-------------------------------------------------------------------------------
*
*
C*******************************************************************************
C                          Initial Soil Moisture Condition
C                         For Non-Ponded Agricultural Lands
C
C   IE     ; Element ID (Enter 0 if following values are to be used for all element
C              and non-ponded agricultural crop combinations)
C   FSOILMP; Fraction of initial soil moisture at element IE that is due to precipitation
C   SOILM  ; Initial root zone moisture content; [L/L]
C              (1 to NCROP)
C
C-------------------------------------------------------------------------------------------------------------------
C IE   FSOILMP  GR    CO    SB    CR    DB    SF    FI    AL    PA    TM    CU    OG    TR    AP    OR    SO    FL
C-------------------------------------------------------------------------------------------------------------------
  1      0.5    0.13  0.13  0.13  0.13  0.13  0.13  0.13  0.13  0.13  0.13  0.13  0.13  0.13  0.13  0.13  0.13  0.13
  2      0.5    0.15  0.15  0.15  0.15  0.15  0.15  0.15  0.15  0.15  0.15  0.15  0.15  0.15  0.15  0.15  0.15  0.15
  3      0.5    0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10  0.10
  .       .      .     .     .     .     .     .     .     .     .     .     .     .     .     .     .     .     .
  .       .      .     .     .     .     .     .     .     .     .     .     .     .     .     .     .     .     .
  .       .      .     .     .     .     .     .     .     .     .     .     .     .     .     .     .     .     .
  221    0.5    0.04  0.04  0.04  0.04  0.04  0.04  0.04  0.04  0.04  0.04  0.04  0.04  0.04  0.04  0.04  0.04  0.04
  222    0.5    0.23  0.23  0.23  0.23  0.23  0.23  0.23  0.23  0.23  0.23  0.23  0.23  0.23  0.23  0.23  0.23  0.23
  223    0.5    0.12  0.12  0.12  0.12  0.12  0.12  0.12  0.12  0.12  0.12  0.12  0.12  0.12  0.12  0.12  0.12  0.12
```

8.3.8.7.b Non-Ponded Crops Area Data File

Areas of each non-ponded crop at every element are listed in this file:

FACTLNNP	Conversion factor for land use areas; enter 0.0 if land use distribution is given as a fraction of element area
NSPLNNP	Number of time steps to update the land use data; enter any number if time-tracking option is on
NFQLNNP	Repetition frequency of the crop area data; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Non-Ponded Crops Area Data File

If the time series data is listed in the Non-Ponded Crops Area Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using “C”, “c” or “*”, and the variables in the “Data Input from DSS File” section below should be populated.

ITLN	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
IE	Element identification number
ALAND	Area (or fraction of area) corresponding to non-ponded crops over an element; $[L^2]$ or $[L^2/L^2]$ based on FACTLNNP above.

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

IE	Element identification number
LUTYPE	Crop identification number entered sequentially
PATH	Pathname corresponding to element and non-ponded crop type combination

```
C*******************************************************************************
C
C                  INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                       NON-PONDED CROP AREA FILE
C                          Root Zone Component
C                          *** Version 4.0 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: NonPondedCropArea.dat
C
C*******************************************************************************
C                          File Description
C
C   This data file contains the land use distribution of non-ponded crops for
C   each element for the simulation period.
C
C*******************************************************************************
C                           Land Use Data Specifications
C
C   FACTLNNP;   Conversion factor for land use area
C                * Enter 0.0 if land use distribution is given as a fraction of element area
C   NSPLNNP ;   Number of time steps to update the land use data
C                * Enter any number if time-tracking option is on
C   NFQLNNP ;   Repetition frequency of the land use data
C                * Enter 0 if full time series data is supplied
C                * Enter any number if time-tracking option is on
C   DSSFL   ;   The name of the DSS file for data input
C                * Leave blank if DSS file is not used for data input
C
C-----------------------------------------------------------------------------------------
C         VALUE                                    DESCRIPTION
C-----------------------------------------------------------------------------------------
          10.763910417                             / FACTLNNP  (sq.m. -> sq.ft.)
          1                                        / NSPLNNP
          0                                        / NFQLNNP
                                                   / DSSFL
C-----------------------------------------------------------------------------------------
C                             Land Use Data
C                         (READ FROM THIS FILE)
C
C   List the land use data below, if it will not be read from a DSS file
C   (i.e. DSSFL is left blank above).
C
C   ITLN ;   Time
C   IE   ;   Element number
C   ALAND;   Area (or fraction of area) corresponding to non-ponded crops over an
C             element; [L^2] or [L^2/L^2] (based on FACTLNNP above)
C             (1 to NCROP)
C               1      : Non-ponded crop 1
C               2      : Non-ponded crop 2
C                                .
C                                .
C               NCROP  : Non-ponded crop NCROP
C            * Note: Crop areas over elements that are designated as lake elements
C                    will be ignored
C
C-----------------------------------------------------------------------------------------------------------
C                                                                    ALAND
C                            ----------------------------------------------------------------------------
C   ITLN             IE            GR            CO            SB    ...   OR            SO            FL
C-----------------------------------------------------------------------------------------------------------
 12/31/2500_24:00    1           0.00          0.00          0.00   ...  0.00          0.00      52162.85
                     2           0.00          0.00          0.00   ...  0.00          0.00          0.00
                     3           0.00          0.00          0.00   ...  0.00          0.00          0.00
                     .             .             .             .    ...   .             .             .
                     .             .             .             .    ...   .             .             .
                     221         0.00     705478.12          0.00   ...  0.00          0.00        452.45
                     222         0.00          0.00          0.00   ...  0.00          0.00          0.00
                     223         0.00          0.00          0.00   ...  0.00          0.00          0.00
C-----------------------------------------------------------------------------------------
C                              Pathnames for Land Use Data
C                                (READ FROM DSS FILE)
C
C   List the pathnames for the land use data below, if it will be read from a DSS file
C   (i.e. DSSFL is specified above).
C
C   The pathnames should be listed for each element and non-ponded crop combination.
C   They should be listed in an order such that, the crop type changes first.
C
C   * Example with 3 non-ponded agricultural crops (i.e. NCROP=3):
C
C       IE     LUTYPE      PATH
C        1        1       (pathname[1])
C        1        2       (pathname[2])
C        1        3       (pathname[3])
C        2        1       (pathname[4])
C        2        2       (pathname[5])
C        2        3       (pathname[6])
C        .        .            .
C        .        .            .
C       NE        1       (pathname[(NCROP)*NE - 2])
C       NE        2       (pathname[(NCROP)*NE - 1])
C       NE        3       (pathname[(NCROP)*NE])
C
C   IE     ;  Element number
C   LUTYPE ;  Land use type
C               1       = Non-ponded agricultural crop 1
C               2       = Non-ponded agricultural crop 2
C                            .
C                            .
C               NCROP   = Non-ponded agricultural crop NCROP
C   PATH   ;  Pathname corresponding to element and non-ponded crop type combination
C
C-----------------------------------------------------------------------------------------
C   IE        LUTYPE        PATH
C-----------------------------------------------------------------------------------------
*
```

8.3.8.7.c Root Depth Fractions Data File

This file includes the time series rooting depths as a fraction of the maximum rooting depths listed in the Non-Ponded Crops Main File. The non-ponded crops are associated with data columns in this file through pointers specified in the Non-Ponded Crops Main File.

The following variables are listed in this file:

NCOLRDF	Number of data columns for the rooting depth fractions
NSPRDF	Number of time steps to update the rooting depth fractions; enter any number if time-tracking option is on
NFQRDF	Repetition frequency of the rooting depth fractions; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Root Depth Fractions Data File

If the time series data is listed in the Root Depth Fractions Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using "C", "c" or "*", and the variables in the "Data Input from DSS File" section below should be populated.

TIME	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
RDFRC	Root depths as a fraction of the maximum rooting depth

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

REC	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*******************************************************************************
C
C                  INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                   ROOT DEPTH FRACTIONS DATA FILE
C                        Root Zone Component
C                        *** Version 4.0 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: RootDepthFrac.dat
C
C*******************************************************************************
C                           File Description
C
C   This data file contains a set of rooting depths given as a fraction of the
C   maximum rooting depth to represent the root growth for non-ponded and ponded
C   crops.
C
C*******************************************************************************
C               Root Depth Fractions Data Specifications
C
C   NCOLRDF ; Number of root depth fractions data columns
C   NSPRDF  ; Number of time steps to update the root depth fractions
C              * Enter any number if time-tracking option is on
C   NFQRDF  ; Repetition frequency of the root depth fractions data
C              * Enter 0 if full time series data is supplied
C              * Enter any number if time-tracking option is on
C   DSSFL   ; The name of the DSS file for data input
C              * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------
C         VALUE                                      DESCRIPTION
C-------------------------------------------------------------------------------
          17                                         / NCOLRDF
          1                                          / NSPRDF
          0                                          / NFQRDF
                                                     / DSSFL
C-----------------------------------------------------------------------------------------------
C                            Root Depth Fractions
C                            (READ FROM THIS FILE)
C
C   List the root depth fractions (between 0.0 and 1.0) data below, if it will not be read from
C   a DSS file (i.e. DSSFL is left blank above).
C
C   TIME ;  Time
C   RDFRC;  Root depths as a fraction of the maximum rooting depth; [dimensionless]
C
C-----------------------------------------------------------------------------------------------
C  TIME              RDFRC[1]  RDFRC[2]  RDFRC[3] ... RTRNF[NCOLRDF]
C--------------------------------------------------------------------------------------------------------------------------
C                    GR    CO    SB    CR    DB    SF    FI    AL    PA    TM    CU    OG    TR    AP    OR    SO    FL
C                    1     2     3     4     5     6     7     8     9     10    11    12    13    14    15    16    17
C--------------------------------------------------------------------------------------------------------------------------
   12/31/2500_24:00  1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0
*
C-------------------------------------------------------------------------------
C                    Pathnames for Root Depth Fractions Data
C                            (READ FROM DSS FILE)
C
C   List the pathnames for root depth fractions data below, if it
C   will be read from a DSS file (i.e. DSSFL is specified above).
C
C   REC  ;  Time series record number
C   PATH ;  Pathname for the time series record
C
C---------------------------------------------------------------------------------------------------------
C   REC     PATH
C---------------------------------------------------------------------------------------------------------
*
*
```

8.3.8.7.d Minimum Soil Moisture Data File

This file includes the time series minimum soil moisture data that is used by IDC as an irrigation event trigger. The data is specified as a fraction of the total available water which is defined as the field capacity less the wilting point. In a given time step, if the root zone moisture falls below the minimum soil moisture IDC computes the agricultural supply requirement that is going to raise the moisture up to irrigation target moisture (field capacity, by default) after the losses due to percolation and return flow are taken into account. Each non-ponded crop at each grid cell is associated with a data column in this file through pointers listed in the Non-Ponded Crops Main File.

The following variables must be specified in this data file:

NCOLSM	Number of minimum soil moisture data columns
NSPSM	Number of time steps to update the minimum soil moisture data; enter any number if time-tracking option is on
NFQSM	Repetition frequency of the minimum soil moisture data; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Minimum Soil Moisture Data File

If the time series data is listed in the Minimum Soil Moisture Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using "C", "c" or "*", and the variables in the "Data Input from DSS File" section below should be populated.

TIME	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
SMMIN	Minimum soil moisture as a fraction of the total available water (i.e. field capacity less wilting point)

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

REC	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*******************************************************************************
C
C                  INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                  MINIMUM SOIL MOISTURE DATA FILE
C                       Root Zone Component
C                       *** Version 4.0 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: MinMoist.dat
C
C*******************************************************************************
C                            File Description
C
C   This data file contains a set of minimum soil moistures as a fraction of the
C   Total Available Water (TAW = field capacity - wilting point) that are used
C   as triggers for irrigation events. These values are correlated to individual
C   crops through the Agricultural Lands Main Data File.
C
C*******************************************************************************
C                 Minimum Soil Moisture Data Specifications
C
C   NCOLSM ; Number of minimum soil moisture data columns
C   NSPSM  ; Number of time steps to update the minimum soil moisture data
C             * Enter any number if time-tracking option is on
C   NFQSM  ; Repetition frequency of the minimum soil moisture data
C             * Enter 0 if full time series data is supplied
C             * Enter any number if time-tracking option is on
C   DSSFL  ; The name of the DSS file for data input
C             * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------
C         VALUE                                      DESCRIPTION
C-------------------------------------------------------------------------------
          17                                       / NCOLSM
          1                                        / NSPSM
          0                                        / NFQSM
                                                   / DSSFL
C-----------------------------------------------------------------------------------------------
C                          Minimum Soil Moisture Data
C                              (READ FROM THIS FILE)
C
C   List the minimum soil moisture data below, if it will not be read from
C   a DSS file (i.e. DSSFL is left blank above).
C
C   TIME ;  Time
C   SMMIN;  Minimum soil moisture as a fraction of the Total Available Water
C             (TAW = field capacity - wilting point)
C
*   Crop/Land Use No.            Name
*   ----------------             ------
*       1                          GR  grain
*       2                          CO  cotton
*       3                          SB  sugar beets
*       4                          CR  corn
*       5                          DB  dry beans
*       6                          SF  safflower
*       7                          FI  other field
*       8                          AL  alfalfa
*       9                          PA  pasture
*       10                         TM  tomatoes
*       11                         CU  cucurbits
*       12                         OG  onions & garlic
*       13                         TR  other truck
*       14                         AP  almonds & pistachios
*       15                         OR  other deciduous
*       16                         SO  subtropical
*       17                         FL  fallow and bare soil
*
C-------------------------------------------------------------------------------------------------------------------------
C TIME                 GR     CO     SB     CR     DB     SF     FI     AL     PA     TM     CU     OG     TR     AP     OR     SO     FL
C-------------------------------------------------------------------------------------------------------------------------
  12/31/2500_24:00  0.55    0.5    0.45  0.5    0.5    0.4    0.7    0.4    0.5    0.6    0.5    0.7    0.5    0.6    0.5    0.5    0.5
*
C-------------------------------------------------------------------------------
C                      Pathnames for Minimum Soil Moisture Data
C                              (READ FROM DSS FILE)
C
C   List the pathnames for minimum soil moisture data below, if it
C   will be read from a DSS file (i.e. DSSFL is specified above).
C
C   REC  ;  Time series record number
C   PATH ;  Pathname for the time series record
C
C---------------------------------------------------------------------------------------------------------
C   REC     PATH
C---------------------------------------------------------------------------------------------------------
*
*
```

8.3.8.7.e Irrigation Target Moisture Data File

The Irrigation Target Moisture Data File is optional and lists the target moisture that IDC uses to compute the agricultural water supply requirement. This is the moisture level that will be achieved when the irrigation amount is equal to the IDC-computed water demand. The irrigation target moisture is specified as a fraction of the field capacity. A value that is less than 1.0 may represent deficit irrigation conditions (along with proper values of evapotranspiration rate and minimum soil moisture data) while a value that is larger than 1.0 may represent additional irrigation for leaching salts. If this file is omitted, then IDC uses field capacity as the irrigation target moisture. Each non-ponded crop at each element is associated with a data column in this file through pointers specified in the Non-Ponded Crops Data File.

The following variables are used in this file:

NCOLTSM	Number of irrigation target soil moisture data columns
NSPTSM	Number of time steps to update the irrigation target soil moisture data; enter any number if time-tracking option is on
NFQTSM	Repetition frequency of the irrigation target soil moisture data; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Irrigation Target Moisture Data File

If the time series data is listed in the Irrigation Target Moisture Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using "C", "c" or "*", and the variables in the "Data Input from DSS File" section below should be populated.

TIME	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
SMTRG	Irrigation target soil moisture as a fraction of field capacity

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

REC	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*******************************************************************************
C
C                  INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C               IRRIGATION TARGET SOIL MOISTURE DATA FILE
C                         Root Zone Component
C                         *** Version 4.0 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: TargetMoist.dat
C
C*******************************************************************************
C                           File Description
C
C   This data file contains a set of irrigation target soil moistures as a fraction of
C   field capacity that are used in computing irrigation water demand. During an
C   irrigation event the soil moisture is raised to the target soil moisture.  Target
C   soil mositure cannot be less than minimum soil moisture specified in the Minimum
C   Soil Moisture data file. These values are correlated to individual crops through
C   the Non-Ponded Crop Data File.
C
C*******************************************************************************
C               Irrigation Target Soil Moisture Data Specifications
C
C   NCOLTSM ; Number of irrigation target soil moisture data columns
C   NSPTSM  ; Number of time steps to update the irrigation target soil moisture data
C              * Enter any number if time-tracking option is on
C   NFQTSM  ; Repetition frequency of the irrigation target soil moisture data
C              * Enter 0 if full time series data is supplied
C              * Enter any number if time-tracking option is on
C   DSSFL   ; The name of the DSS file for data input
C              * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------
C         VALUE                                   DESCRIPTION
C-------------------------------------------------------------------------------
          17                                      / NCOLTSM
          1                                       / NSPTSM
          0                                       / NFQTSM
                                                  / DSSFL
C---------------------------------------------------------------------------------------------
C                      Irrigation Target Soil Moisture Data
C                            (READ FROM THIS FILE)
C
C   List the irrigation target soil moisture data below, if it will not be read from
C   a DSS file (i.e. DSSFL is left blank above).
C
C   TIME ;  Time
C   SMTRG;  Irrigation target soil moisture as a fraction of field capacity; [L/L]
C
*   Crop/Land Use No.           Name
*   ----------------            ------
*       1                         GR  grain
*       2                         CO  cotton
*       3                         SB  sugar beets
*       4                         CR  corn
*       5                         DB  dry beans
*       6                         SF  safflower
*       7                         FI  other field
*       8                         AL  alfalfa
*       9                         PA  pasture
*       10                        TM  tomatoes
*       11                        CU  cucurbits
*       12                        OG  onions & garlic
*       13                        TR  other truck
*       14                        AP  almonds & pistachios
*       15                        OR  other deciduous
*       16                        SO  subtropical
*       17                        FL  fallow and bare soil
*
C-----------------------------------------------------------------------------------------------------------------------
C                                                        SMTRG
C                   ----------------------------------------------------------------------------------------------------
C TIME               GR    CO    SB    CR    DB    SF    FI    AL    PA    TM    CU    OG    TR    AP    OR    SO    FL
C-----------------------------------------------------------------------------------------------------------------------
  12/31/2500_24:00  1.0   1.0   0.7   1.1   1.0   1.0   1.1   1.0   1.0   1.0   1.0   0.7   1.0   1.0   1.0   1.0   0.0
*
C-------------------------------------------------------------------------------
C                Pathnames for Irrigation Target Soil Moisture Data
C                             (READ FROM DSS FILE)
C
C   List the pathnames for irrigation target soil moisture data below, if it
C   will be read from a DSS file (i.e. DSSFL is specified above).
C
C   REC  ;  Time series record number
C   PATH ;  Pathname for the time series record
C
C--------------------------------------------------------------------------------------------------------
C   REC     PATH
C--------------------------------------------------------------------------------------------------------
*
*
```

8.3.8.7.f Minimum Percolation Fractions Data File

The Minimum Percolation Fractions Data File is optional and lists the minimum percolation values that IDC uses to compute the agricultural water supply requirement. This is the percolation level that IDC will try to achieve with the applied water during an irrigation event. However, the percolation is limited with the saturated hydraulic conductivity of the root zone and IDC may not be able to achieve the user-specified minimum percolation if it is greater than the saturated hydraulic conductivity. The minimum percolation is specified as a fraction of the infiltrated applied water (i.e. total applied water less the net return flow). This minimum percolation data can be used to simulate the irrigation practices to facilitate the leaching of salts. If this file is omitted, then IDC will not try to increase the applied water to achieve a minimum percolation. Each non-ponded crop at each element is associated with a data column in this file through pointers specified in the Non-Ponded Crops Data File.

The following variables are used in this file:

NCOLDPF	Number of minimum percolation data columns
NSPDPF	Number of time steps to update the minimum percolation data; enter any number if time-tracking option is on
NFQDPF	Repetition frequency of the minimum percolation data; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Minimum Percolation Fractions Data File

If the time series data is listed in the Minimum Percolation Fractions Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using "C", "c" or "*", and the variables in the "Data Input from DSS File" section below should be populated.

TIME	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
LF	Minimum percolation as a fraction of the infiltrated applied water

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

REC	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*******************************************************************************
C
C                 INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                MINIMUM PERCOLATION FACTORS DATA FILE
C                        Root Zone Component
C                        *** Version 4.0 ***
C
C
C            Project:  IDC Version ### Release
C                      California Department of Water Resources
C            Filename: MinPerc.dat
C
C*******************************************************************************
C                          File Description
C
C   This data file contains a set of minimum percolation factors given as
C   fractions of infiltrated irrigation water.  These values are correlated to
C   individual crops through the Non-Ponded Crop Data File.
C
C*******************************************************************************
C            Minimum Percolation Factors Data Specifications
C
C   NCOLDPF ; Number of minimum percolation factors data columns
C   NSPDPF  ; Number of time steps to update the minimum percolation
C              * Enter any number if time-tracking option is on
C   NFQDPF  ; Repetition frequency of the minimum percolation factors data
C              * Enter 0 if full time series data is supplied
C              * Enter any number if time-tracking option is on
C   DSSFL   ; The name of the DSS file for data input
C              * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------
C         VALUE                                       DESCRIPTION
C-------------------------------------------------------------------------------
          2                                           / NCOLDPF
          1                                           / NSPDPF
          0                                           / NFQDPF
                                                      / DSSFL
C----------------------------------------------------------------------------------------------
C                         Minimum Percolation Factors
C                             (READ FROM THIS FILE)
C
C   List the minimum percolation factors data below, if it will not be read from
C   a DSS file (i.e. DSSFL is left blank above).
C
C   TIME ;  Time
C   LF   ;  Minimum percolation factors as a fraction of infiltrated irrigation water; [dimensionless]
C
C----------------------------------------------------------------------------------------------
C  TIME                DPF[1]  DPF[2]  DPF[3] ... DPF[NCOLLF]
C----------------------------------------------------------------------------------------------
   12/31/2500_24:00   0.10    0.15
*
C-------------------------------------------------------------------------------
C                 Pathnames for Minimum Percolation Factors Data
C                             (READ FROM DSS FILE)
C
C   List the pathnames for minimum percolation factors data below, if it
C   will be read from a DSS file (i.e. DSSFL is specified above).
C
C   REC  ;  Time series record number
C   PATH ;  Pathname for the time series record
C
C------------------------------------------------------------------------------------------------------
C   REC     PATH
C------------------------------------------------------------------------------------------------------
*
*
```

8.3.8.8. Ponded-Crops Component Files

There are 5 pre-specified ponded crops simulated by IDC: i) rice with flooded decomposition, ii) rice with non-flooded decomposition, iii) rice with no decomposition, iv) seasonal refuges, and v) permanent refuges. Even though refuges are not agricultural lands, their ponding operations are very similar to those of rice fields. Therefore, they are grouped and simulated as ponded crops in IDC.

The following sections describe in detail the input data files that are used to simulated ponded crops.

8.3.8.8.a Ponded Crops Main File

The Ponded Crops Main File is the gateway file for all data that is necessary to simulate ponded crops and generate ponded-crop related budget files.

The file is divided into several sections and uses the following variables:

Land-Use Areas

The filename for the ponded crop areas data file is listed in this section:

LUFLP	File that lists the ponded crop areas (maximum 1000 characters)

Budget Output Files

To generate crop-specific land and water use and root zone budgets, the following variables must be specified:

NBCROP	Number of ponded crops for water budget output; enter 0 if crop specific budget output is not required
BCCODE	Crop codes for which water budget output is required (RICE_FL = rice with flooded decomposition, RICE_NFL = rice with non-flooded decomposition, RICE_NDC = rice with no decomposition, REFUGE_SL = seasonal refuges, REFUGE_PR = permanent refuges)
CLWUBUDFL	HDF5 output file for crop-specific land and water use budget at each subregion for selected crops (maximum 1000 characters); leave blank if this output is not required

CRZBUDFL	HDF5 output file for root zone moisture budget at each subregion for selected crops (maximum 1000 characters); leave blank if this output is not required

Rooting Depths

FACT	Conversion factor for rice and refuge root zone depths
ROOTRI_FL	Root zone depth for rice with flooded decomposition; [L]
ROOTRI_NFL	Root zone depth for rice with non-flooded decomposition; [L]
ROOTRI_NDC	Root zone depth for rice with no decomposition; [L]
ROOTRF_SL	Root zone depth for seasonal refuges; [L]
ROOTRF_PR	Root zone depth for permanent refuges; [L]

Curve Numbers for Rainfall Runoff Simulation

Curve numbers for each element and ponded-crop combination are entered in this section. The curve numbers listed in this section are used only outside the ponding season; during ponding season a value of 100 is used.

IE	Element identification number entered sequentially; enter 0 if curve numbers defined for each ponded-crop are to be used for all elements
CNRI_FL	Curve number for rice lands with flooded decomposition
CNRI_NFL	Curve number for rice lands with non-flooded decomposition
CNRI_NDC	Curve number for rice lands with no decomposition
CNRF_SL	Curve number for seasonal refuge lands
CNRF_PR	Curve number for permanent refuge lands

Crop Evapotranspiration

Crop evapotranspiration for each element and ponded-crop combination is listed here by specifying a column number in the Evapotranspiration File:

IE	Element identification number entered sequentially; enter 0 if following values are to be used for all elements
ICETRI_FL	Evapotranspiration rate for rice with flooded decomposition; this number corresponds to the appropriate data column in the Evapotranspiration File listed in the Root Zone Component Main File

ICETRI_NFL	Evapotranspiration rate for rice with non-flooded decomposition; this number corresponds to the appropriate data column in the Evapotranspiration File listed in the Root Zone Component Main File
ICETRI_NDC	Evapotranspiration rate for rice with no decomposition; this number corresponds to the appropriate data column in the Evapotranspiration File listed in the Root Zone Component Main File
ICETRI_SL	Evapotranspiration rate for seasonal refuges; this number corresponds to the appropriate data column in the Evapotranspiration File listed in the Root Zone Component Main File
ICETRI_PR	Evapotranspiration rate for permanent refuges; this number corresponds to the appropriate data column in the Evapotranspiration File listed in the Root Zone Component Main File

Agricultural Water Supply Requirement

If, for any ponded-crop at an element, the agricultural water supply requirement is pre-specified instead of being computed dynamically, they are specified in this section:

IE	Element identification number; enter 0 if following values are to be used for all elements
ICAWRI_FL	Agricultural water supply requirement for rice with flooded decomposition; this number corresponds to the appropriate data column in the Agricultural Supply Requirement Data File (AGWDFL) listed in the Root Zone Component Main File (enter 0 if agricultural water supply requirement will be computed dynamically
ICAWRI_NFL	Agricultural water supply requirement for rice with non-flooded decomposition; this number corresponds to the appropriate data column in the Agricultural Supply Requirement Data File (AGWDFL) listed in the Root Zone Component Main File (enter 0 if agricultural water supply requirement will be computed dynamically

ICAWRI_NDC	Agricultural water supply requirement for rice with no decomposition; this number corresponds to the appropriate data column in the Agricultural Supply Requirement Data File (AGWDFL) listed in the Root Zone Component Main File (enter 0 if agricultural water supply requirement will be computed dynamically
ICAWRF_SL	Water supply requirement for seasonal refuges; this number corresponds to the appropriate data column in the Agricultural Supply Requirement Data File (AGWDFL) listed in the Root Zone Component Main File (enter 0 if agricultural water supply requirement will be computed dynamically
ICAWRF_PR	Water supply requirement for permanent refuges; this number corresponds to the appropriate data column in the Agricultural Supply Requirement Data File (AGWDFL) listed in the Root Zone Component Main File (enter 0 if agricultural water supply requirement will be computed dynamically

Irrigation Periods

Time series irrigation period data is listed in this section for each ponded crop and element combination:

IE	Element identification number; enter 0 if following values are to be used for all elements
ICIP_FL	Irrigation period for rice with flooded decomposition; this number corresponds to the appropriate data column in the Irrigation Period Data File (IPFL) listed in the Root Zone Parameters Data File.
ICIP_NFL	Irrigation period for rice with non-flooded decomposition; this number corresponds to the appropriate data column in the Irrigation Period Data File (IPFL) listed in the Root Zone Parameters Data File.
ICIP_NDC	Irrigation period for rice with no decomposition; this number corresponds to the appropriate data column in the Irrigation

	Period Data File (IPFL) listed in the Root Zone Parameters Data File.
ICIP_SL	Irrigation period for seasonal refuges; this number corresponds to the appropriate data column in the Irrigation Period Data File (IPFL) listed in the Root Zone Parameters Data File.
ICIP_PR	Irrigation period for permanent refuges; this number corresponds to the appropriate data column in the Irrigation Period Data File (IPFL) listed in the Root Zone Parameters Data File.

Rice and Refuge Operations Input Files

In this section filenames for input data files that list time series ponding depths and pond operation flows are listed:

PNDTHFL	File that lists the ponding depths for rice and refuge operations (maximum 1000 characters)
FLOWFL	File that lists rice and refuge pond operation flows that include water application depths for non-flooded decomposition of rice, re-use and return flow depths (maximum 1000 characters)

Ponding Depths

Time series ponding depths for each element and ponded-crop combination are listed in this section.

IE	Element identification number; enter 0 if following values are to be used for all element and ponded-crop combinations
ICPDRI_FL	Ponding depth for rice with flooded decomposition including depths for decomposition operations; this number corresponds to the appropriate data column in the Ponding Depth Data File (PNDTHFL)
ICPDRI_NFL	Ponding depth for rice with non-flooded decomposition; this number corresponds to the appropriate data column in the Ponding Depth Data File (PNDTHFL)

ICPDRI_NDC	Ponding depth for rice with no decomposition; this number corresponds to the appropriate data column in the Ponding Depth Data File (PNDTHFL)
ICPDRF_SL	Ponding depth for seasonal refuge ponds; this number corresponds to the appropriate data column in the Ponding Depth Data File (PNDTHFL)
ICPDRF_PR	Ponding depth for permanent refuge ponds; this number corresponds to the appropriate data column in the Ponding Depth Data File (PNDTHFL)

Application Depths for Non-Flooded Decomposition of Rice

For rice with non-flooded decomposition, the water application rates for the decomposition of rice are listed here.

IE	Element identification number; enter 0 if following values are to be used for all element and ponded-crop combinations
ICDWRI_NFL	Water application depth for non-flooded decomposition of rice; this number corresponds to the appropriate data column in the Pond Operation Flows Data File (FLOWFL).

Return Flow Depths

The return flow depths for each crop and element combination are listed in this section. The return flows for rice and refuges include circulation depths as well as lateral subsurface flows (i.e. seepage) into the return flow collection ditches.

IE	Element identification number; enter 0 if following values are to be used for all elements
ICRTRI_FL	Depth of return flow for rice with flooded decomposition; this number corresponds to the appropriate data column in the Pond Operation Flows Data File (FLOWFL)
ICRTRI_NFL	Depth of return flow for rice with non-flooded decomposition; this number corresponds to the appropriate data column in the Pond Operation Flows Data File (FLOWFL)
ICRTRI_NDC	Depth of return flow for rice with no decomposition; this number corresponds to the appropriate data column in the Pond Operation Flows Data File (FLOWFL)

ICRTRF_SL	Depth of return flow for seasonal refuges; this number corresponds to the appropriate data column in the Pond Operation Flows Data File (FLOWFL)
ICRTRF_PR	Depth of return flow for permanent refuges; this number corresponds to the appropriate data column in the Pond Operation Flows Data File (FLOWFL)

Re-use Flow Depth

The re-use flow depths for each crop and element combination are listed in this section:

IE	Element identification number; enter 0 if following values are to be used for all elements
ICRUFRI_FL	Depth of re-used water for rice with flooded decomposition; this number corresponds to the appropriate data column in the Pond Operation Flows Data File (FLOWFL)
ICRUFRI_NFL	Depth of re-used water for rice with non-flooded decomposition; this number corresponds to the appropriate data column in the Pond Operation Flows Data File (FLOWFL)
ICRUFRI_NDC	Depth of re-used water for rice with no decomposition; this number corresponds to the appropriate data column in the Pond Operation Flows Data File (FLOWFL)
ICRUFRF_SL	Depth of re-used water at seasonal refuges; this number corresponds to the appropriate data column in the Pond Operation Flows Data File (FLOWFL)
ICRUFRF_PR	Depth of re-used water at permanent refuges; this number corresponds to the appropriate data column in the Pond Operation Flows Data File (FLOWFL)

Initial Soil Moisture Conditions

The initial soil moisture content for each ponded crop and element combination is listed in this section. For ponded crops, soil moisture content can be greater 1.0; in this case the portion of the soil moisture above 1.0 represents the ponding depth.

IE	Element identification number; enter 0 if following values are to be used for all elements

FSOILMP	Fraction of initial soil moisture at element IE that is due to precipitation
SOILM_RI_FL	Initial root zone moisture content for rice with flooded decomposition; [L/L]
SOILM_RI_NFL	Initial root zone moisture content for rice with non-flooded decomposition; [L/L]
SOILM_RI_NDC	Initial root zone moisture content for rice with no decomposition; [L/L]
SOILM_RF_SL	Initial root zone moisture content for seasonal refuges; [L/L]
SOILM_RF_PR	Initial root zone moisture content for permanent refuges; [L/L]

```
C*******************************************************************************
C
C                    INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                      RICE AND REFUGE LANDS DATA FILE
C                           Root Zone Component
C                           *** Version 4.0 ***
C
C
C
C              Project:  IDC Version ### Release
C                        California Department of Water Resources
C              Filename: PondedAg_MAIN.dat
C
C*******************************************************************************
C                            File Description
C
C    This data file contains the parameters and data file names for the simulation
C    of root zone processes and managament of lands with rice and refuge.
C
C*******************************************************************************
C                           Land Use Areas
C
C    LUFLP   ;  File that lists the crop areas (max. 1000 characters)
C
C-------------------------------------------------------------------------------
     RootZone\PondedAg\PondedAgArea.dat                        / LUFLP
C*******************************************************************************
C                        Water Budget Output Files
C
C    NBCROP   ;  Number of ponded crops for water budget output
C                 * Enter 0 if crop specific budget output is not required
C    BCCODE   ;  Crop codes for which water budget output is required
C                 (1 to NBCROP)
C                 * Use the following crop codes:
C                   RICE_FL  : Rice with flooded decomposition
C                   RICE_NFL : Rice with non-flooded decomposition
C                   RICE_NDC : Rice with no decomposition
C                   REFUGE_SL: Seasonal refuges
C                   REFUGE_PR: Permanent refuges
C    CLWUBUDFL;  HDF5 output file for land and water use budget at each
C                   subregion for selected crops (max. 1000 characters)
C                 * Leave blank if this output is not required
C    CRZBUDFL ;  HDF5 output file for root zone moisture budget at each
C                   subregion for selected crops (max. 1000 characters)
C                 * Leave blank if this output is not required
C
C-------------------------------------------------------------------------------
C    VALUE                  DESCRIPTION
C-------------------------------------------------------------------------------
       2                              / NBCROP
       RICE_FL                        / BCCODE[1]
       REFUGE_PR                      / BCCODE[2]
       Budget\PondedAgLWU.hdf         / CLWUBUDFL
       Budget\PondedAgRZ.hdf          / CRZBUDFL
C*******************************************************************************
C                             Rooting Depths
C
C    FACT       ;    Conversion factor for rice and refuge root zone depths
C    ROOTRI_FL ;     Root zone depth for rice with flooded decomposition; [L]
C    ROOTRI_NFL;     Root zone depth for rice with non-flooded decomposition; [L]
C    ROOTRI_NDC;     Root zone depth for rice with no decomposition; [L]
C    ROOTRF_SL ;     Root zone depth for seasonal refuges; [L]
C    ROOTRF_PR ;     Root zone depth for permanent refuges; [L]
C
C-------------------------------------------------------------------------------
C    VALUE                  DESCRIPTION
C-------------------------------------------------------------------------------
     1.0                    / FACT
     2.0                    / ROOTRI_FL
     2.0                    / ROOTRI_NFL
     2.0                    / ROOTRI_NDC
     2.0                    / ROOTRF_SL
     2.0                    / ROOTRF_PR
C*******************************************************************************
C                    Curve Numbers for Rainfall Runoff Simulation
C
C    Enter curve numbers for each grid element and rice/refuge combination.
C
C    IE        ;  Element ID (Enter 0 if following values are to be used for all
C                 element and ponded agricultural crop combinations)
C    CNRI_FL   ;  Curve number for rice lands with flooded decomposition
C    CNRI_NFL ;   Curve number for rice lands with non-flooded decomposition
C    CNRI_NDC ;   Curve number for rice lands with no decomposition
C    CNRF_SL   ;  Curve number for seasonal refuge lands
C    CNRF_PR   ;  Curve number for permanent refuge lands
C               * Note: CN for rice and refuge should be entered for the type of
C                       soil and land cover during non-ponding season. During the
C                       ponding season CN=100 will be used.
C
C-------------------------------------------------------------------------------
C   IE      CNRI_FL    CNRI_NFL     CNRI_NDC    CNRF_SL    CNRF_PR
C-------------------------------------------------------------------------------
     1           78          78           78         65         65
     2           78          78           78         65         65
     3           71          71           71         48         48
     .           .           .            .          .          .
     .           .           .            .          .          .
     .           .           .            .          .          .
     221         78          78           78         65         65
     222         71          71           71         48         48
     223         71          71           71         48         48
C*******************************************************************************
C                       Crop Evapotranspiration (ETc)
C
C    The following lists the ETc column pointers for each finite element, rice and
C    refuge combination.
C
C    IE          ;  Element ID (Enter 0 if following values are to be used for all element
C                     and ponded crop combinations)
C    ICETRI_FL   ;  ETc for rice with flooded decomposition - this number corresponds to the
```

```
C                   appropriate data column in the ET data file listed in the Main Control
C                   Data file.
C   ICETRI_NFL ;  ETc for rice with non-flooded decomposition - this number corresponds to
C                   the appropriate data column in the ET data file listed in the Main Control
C                   Data file.
C   ICETRI_NDC ;  ETc for rice with no decomposition - this number corresponds to
C                   the appropriate data column in the ET data file listed in the Main Control
C                   Data file.
C   ICETRF_SL  ;  ETc for seasonal refuge - this number corresponds to the appropriate data
C                   column in the ET data file listed in the Main Control Data file.
C   ICETRF_PR  ;  ETc for permanent refuge - this number corresponds to the appropriate data
C                   column in the ET data file listed in the Main Control Data file.
C
C-------------------------------------------------------------------------------
C   IE    ICETRI_FL    ICETRI_NFL    ICETRI_NDC    ICETRF_SL    ICETRF_PR
C-------------------------------------------------------------------------------
    1           18            18            18            19       19
    2           18            18            18            19       19
    3           18            18            18            19       19
    .           .             .             .             .        .
    .           .             .             .             .        .
    .           .             .             .             .        .
    221         18            18            18            19       19
    222         18            18            18            19       19
    223         18            18            18            19       19
C*******************************************************************************
C                         Water Supply Requirement
C
C   The following lists the water supply requirement column pointers for each finite
C   element and ponded crop combination.
C
C   IE          ;  Element ID (Enter 0 if following values are to be used for all element
C                   and ponded crop combinations)
C   ICAWRI_FL   ;  Water supply requirement for rice with flooded decomposition - this
C                   number corresponds to the appropriate data column in the agricultural
C                   water supply requirement data file (AGWDFL) listed in the Root Zone
C                   Parameters Data File.
C                   *** Note: Enter 0 if water supply requirement will be computed
C                             internally.
C   ICAWRI_NFL ;  Water supply requirement for rice with non-flooded decomposition - this
C                   number corresponds to the appropriate data column in the agricultural
C                   water supply requirement data file (AGWDFL) listed in the Root Zone
C                   Parameters Data File.
C                   *** Note: Enter 0 if water supply requirement will be computed
C                             internally.
C   ICAWRI_NDC ;  Water supply requirement for rice with no decomposition - this
C                   number corresponds to the appropriate data column in the agricultural
C                   water supply requirement data file (AGWDFL) listed in the Root Zone
C                   Parameters Data File.
C                   *** Note: Enter 0 if water supply requirement will be computed
C                             internally.
C   ICAWRF_SL  ;  Water supply requirement for seasonal refuge - this number corresponds
C                   to the appropriate data column in the agricultural water supply
C                   requirement data file (AGWDFL) listed in the Root Zone Parameters
C                   Data File.
C                   *** Note: Enter 0 if water supply requirement will be computed
C                             internally.
C   ICAWRF_PR  ;  Water supply requirement for permanentl refuge - this number corresponds
C                   to the appropriate data column in the agricultural water supply
C                   requirement data file (AGWDFL) listed in the Root Zone Parameters
C                   Data File.
C                   *** Note: Enter 0 if water supply requirement will be computed
C                             internally.
C
C-------------------------------------------------------------------------------
C   IE    ICAWRI_FL    ICAWRI_NFL    ICAWRI_NDC    ICAWRF_SL    ICAWRF_PR
C-------------------------------------------------------------------------------
    1            0             0             0             0       0
    2            0             0             0             0       0
    3            0             0             0             0       0
    .            .             .             .             .       .
    .            .             .             .             .       .
    .            .             .             .             .       .
    221          0             0             0             0       0
    222          0             0             0             0       31
    223          0             0             0             0       0
C*******************************************************************************
C                         Irrigation Periods
C
C   The following lists the irrigation period column pointers for each
C   finite element and ponded crop combinations.
C
C   IE        ;  Element ID (Enter 0 if following values are to be used for all element
C                 and ponded crop combinations)
C   ICIP_FL   ;  Irrigation period for rice with flooded decomposition - this number
C                 corresponds to the appropriate data column in the irrigation period
C                 data file (IPFL) listed in the Root Zone Parameters Data File.
C   ICIP_NFL ;  Irrigation period for rice with non-flooded decomposition - this number
C                 corresponds to the appropriate data column in the irrigation period
C                 data file (IPFL) listed in the Root Zone Parameters Data File.
C   ICIP_NDC ;  Irrigation period for rice with no decomposition - this number
C                 corresponds to the appropriate data column in the irrigation period
C                 data file (IPFL) listed in the Root Zone Parameters Data File.
C   ICIP_SL   ;  Irrigation period for seasonal refuge - this number corresponds to
C                 the appropriate data column in the irrigation period data file
C                 (IPFL) listed in the Root Zone Parameters Data File.
C   ICIP_PR   ;  Irrigation period for permanent refuge - this number corresponds to
C                 the appropriate data column in the irrigation period data file
C                 (IPFL) listed in the Root Zone Parameters Data File.
C
C-------------------------------------------------------------------------------
C   IE    ICIP_FL   ICIP_NFL   ICIP_NDC   ICIP_SL   ICIP_PR
C-------------------------------------------------------------------------------
    0        18         19          20         21        22
C*******************************************************************************
C                    Rice and Refuge Operations Input Files
C
C   The following lists the rice and refuge operations related data files.
C
C   PNDTHFL    ; File that lists the ponding depths for rice and refuge operations
C                (max. 1000 characters)
C   FLOWFL     ; File that lists rice/refuge pond operation flows (water application
```

```
C                depths for non-flooded decomposition of rice, re-use and return
C                flow depths (max. 1000 characters)
C
C-----------------------------------------------------------------------------
C        VALUE                                       DESCRIPTION
C-----------------------------------------------------------------------------
    RootZone\PondedAg\PondDepth.dat                  / PNDTHFL
    RootZone\PondedAg\PondOperationFlows.dat         / FLOWFL
C*****************************************************************************
C                                  Ponding Depths
C
C   IE        ; Element ID (Enter 0 if following values are to be used for all element
C                and ponded crop combinations)
C   ICPDRI_FL ; Ponding depth for rice with flooded decomposition including depths for
C                decomposition operations - this number corresponds to the appropriate
C                data column in the rice/refuge ponding depth data file (PNDTHFL).
C   ICPDRI_NFL; Ponding depth for rice with non-flooded decomposition - this number
C                corresponds to the appropriate data column in the rice/refuge
C                ponding depth data file (PNDTHFL).
C   ICPDRI_NDC; Ponding depth for rice with no decomposition - this number
C                corresponds to the appropriate data column in the rice/refuge
C                ponding depth data file (PNDTHFL).
C   ICPDRF_SL ; Ponding depth for seasonal refuge ponds - this number corresponds to the
C                appropriate data column in the rice/refuge ponding depth data file (PNDTHFL).
C   ICPDRF_PR ; Ponding depth for permanent refuge ponds - this number corresponds to the
C                appropriate data column in the rice/refuge ponding depth data file (PNDTHFL).
C
C-----------------------------------------------------------------------------
C   IE     ICPDRI_FL   ICPDRI_NFL   ICPDRI_NDC   ICPDRF_SL   ICPDRF_PR
C-----------------------------------------------------------------------------
     0      1            1            1            2           2
C*****************************************************************************
C               Application Depths for Non-Flooded Rice Decomposition
C
C   IE        ; Element ID (Enter 0 if following values are to be used for all elements)
C   ICDWRI_NFL; Water application depth for non-flooded decomposition of rice - this number
C                corresponds to the appropriate data column in the rice/refuge flows
C                data file (FLOWFL).
C
C-----------------------------------------------------------------------------
C   IE     ICDWRI_NFL
C-----------------------------------------------------------------------------
    0       5
C*****************************************************************************
C                             Return Flow Depths
C
C   IE        ;  Element ID (Enter 0 if following values are to be used for all element
C                 and ponded crop combinations)
C   ICRTRI_FL ;  Depth of return flow for rice with flooded decomposition - this number
C                 corresponds to the appropriate data column in the rice/refuge flows
C                 data file (FLOWFL).
C   ICRTRI_NFL;  Depth of return flow for rice with non-flooded decomposition - this number
C                 corresponds to the appropriate data column in the rice/refuge flows
C                 data file (FLOWFL).
C   ICRTRI_NDC;  Depth of return flow for rice with no decomposition - this number
C                 corresponds to the appropriate data column in the rice/refuge flows
C                 data file (FLOWFL).
C   ICRTRF_SL ;  Depth of return flow for seasonal refuges - this number corresponds to the
C                 appropriate data column in the rice/refuge flows data file (FLOWFL).
C   ICRTRF_PR ;  Depth of return flow for permanent refuges - this number corresponds to the
C                 appropriate data column in the rice/refuge flows data file (FLOWFL).
C                 *** Note: Return flow for rice and refuge includes circulation depths as well
C                           as lateral subsurface flow (i.e. seepage) to return flow collection
C                           ditches.
C
C-----------------------------------------------------------------------------
C   IE     ICRTRI_FL   ICRTRI_NFL   ICRTRI_NDC   ICRTRF_SL   ICRTRF_PR
C-----------------------------------------------------------------------------
    0       1           1            1            2           2
C*****************************************************************************
C                             Re-use Flow Depths
C
C   IE        ;  Element ID (Enter 0 if following values are to be used for all element
C                 and ponded crop combinations)
C   ICRUFRI_FL ; Depth of re-used water at rice with flooded decomposition - this number
C                 corresponds to the appropriate data column in the rice/refuge
C                 flows data file (FLOWFL).
C   ICRUFRI_NFL; Depth of re-used water at rice with non-flooded decomposition - this number
C                 corresponds to the appropriate data column in the rice/refuge
C                 flows data file (FLOWFL).
C   ICRUFRI_NDC; Depth of re-used water at rice with no decomposition - this number
C                 corresponds to the appropriate data column in the rice/refuge
C                 flows data file (FLOWFL).
C   ICRUFRF_SL ; Depth of re-used water at seasonal refuges - this number corresponds to the
C                 appropriate data column in the rice/refuge flows data file (FLOWFL).
C   ICRUFRF_PR ; Depth of re-used water at permanent refuges - this number corresponds to the
C                 appropriate data column in the rice/refuge flows data file (FLOWFL).
C
C-----------------------------------------------------------------------------
C   IE     ICRUFRI_FL   ICRUFRI_NFL   ICRUFRI_NDC   ICRUFRF_SL   ICRUFRF_PR
C-----------------------------------------------------------------------------
    0       3            3             3             4            4
C*****************************************************************************
C                          Initial Soil Moisture Condition
C                                For Ponded Lands
C
C   IE          ;   Element ID (0 if following values are to be used for all elements)
C   FSOILMP     ;   Fraction of initial soil moisture at element IE that is due to precipitation
C   SOILM_RI_FL ;   Initial root zone moisture content for rice with flooded decomposition; [L/L]
C   SOILM_RI_NFL;   Initial root zone moisture content for rice with non-flooded decomposition; [L/L]
C   SOILM_RI_NDC;   Initial root zone moisture content for rice with no decomposition; [L/L]
C   SOILM_RF_SL ;   Initial root zone moisture content for seasonal refuges; [L/L]
C   SOILM_RF_PR ;   Initial root zone moisture content for permanent refuges; [L/L]
C                   *** Note: SOILM can be greater than 1.0 to reflect
C                             ponding conditions for rice and refuge. When SOILM is
C                             greater than 1.0, the ponding depth will be computed as
C                             RootDepth x (SOILM-1)
C
C---------------------------------------------------------------------------------------
C   IE     FSOILMP    SOILM_RI_FL   SOILM_RI_NFL   SOILM_RI_NDC    SOILM_RF_SL   SOILM_RF_PR
C---------------------------------------------------------------------------------------
    1       0.5       0.1370        0.1370         0.1370          0.1370        0.1370
```

```
2       0.5     0.1571      0.1571      0.1571       0.1571      0.1571
3       0.5     0.1053      0.1053      0.1053       0.1053      0.1053
.       .       .           .           .            .           .
.       .       .           .           .            .           .
.       .       .           .           .            .           .
221     0.5     0.0485      0.0485      0.0485       0.0485      0.0485
222     0.5     0.2322      0.2322      0.2322       0.2322      0.2322
223     0.5     0.1210      0.1210      0.1210       0.1210      0.1210
```

8.3.8.8.b Ponded Crops Area Data File

Areas of each ponded crop at every element are listed in this file:

FACTLNP	Conversion factor for land use areas; enter 0.0 if land use distribution is given as a fraction of element area
NSPLNP	Number of time steps to update the land use data; enter any number if time-tracking option is on
NFQLNP	Repetition frequency of the crop area data; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Ponded Crops Area Data File

If the time series data is listed in the Ponded Crops Area Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using "C", "c" or "*", and the variables in the "Data Input from DSS File" section below should be populated.

ITLN	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
IE	Element identification number
ALANDRI_FL	Area (or fraction of area) of rice with flooded decomposition over element IE; [L^2] or [L^2/L^2] based on FACTLNP above
ALANDRI_NFL	Area (or fraction of area) of rice with non-flooded decomposition over element IE; [L^2] or [L^2/L^2] based on FACTLNP above
ALANDRI_NDC	Area (or fraction of area) of rice with no decomposition over element IE; [L^2] or [L^2/L^2] based on FACTLNP above
ALANDRF_SL	Area (or fraction of area) of seasonal refuges over element IE; [L^2] or [L^2/L^2] based on FACTLNP above
ALANDRF_PR	Area (or fraction of area) of rice with permanent refuges over element IE; [L^2] or [L^2/L^2] based on FACTLNP above

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

IE	Element identification number
LUTYPE	Land-use identification number entered sequentially (1 = rice with flooded decomposition, 2 = rice with non-flooded decomposition, 3 = rice with no decomposition, 4 = seasonal refuges, 5 = permanent refuges)
PATH	Pathname corresponding to element and ponded crop type combination

```
C*******************************************************************************
C
C                  INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                         PONDED CROP AREA FILE
C                          Root Zone Component
C                          *** Version 4.0 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: PondedAgArea.dat
C
C*******************************************************************************
C                          File Description
C
C   This data file contains the land use distribution of ponded crops for
C   each element for the simulation period.
C
C*******************************************************************************
C                           Land Use Data Specifications
C
C   FACTLNP;   Conversion factor for land use area
C                * Enter 0.0 if land use distribution is given as a fraction of element area
C   NSPLNP ;   Number of time steps to update the land use data
C                * Enter any number if time-tracking option is on
C   NFQLNP ;   Repetition frequency of the land use data
C                * Enter 0 if full time series data is supplied
C                * Enter any number if time-tracking option is on
C   DSSFL  ;    The name of the DSS file for data input
C                * Leave blank if DSS file is not used for data input
C
C-----------------------------------------------------------------------------------------
C         VALUE                                    DESCRIPTION
C-----------------------------------------------------------------------------------------
          10.763910417                             / FACTLNP  (sq.m. -> sq.ft.)
          1                                        / NSPLNP
          0                                        / NFQLNP
                                                   / DSSFL
C-----------------------------------------------------------------------------------------
C                              Land Use Data
C                          (READ FROM THIS FILE)
C
C   List the land use data below, if it will not be read from a DSS file
C   (i.e. DSSFL is left blank above).
C
C   ITLN        ;  Time
C   IE          ;  Element number
C   ALANDRI_FL ;  Rice area (or fraction of area) over an element with flooded
C                    decomposition; [L^2] or [L^2/L^2] (based on FACTLNP above)
C   ALANDRI_NFL;  Rice area (or fraction of area) over an element with non-flooded
C                    decomposition; [L^2] or [L^2/L^2] (based on FACTLNP above)
C   ALANDRI_NDC;  Rice area (or fraction of area) over an element with no
C                    decomposition; [L^2] or [L^2/L^2] (based on FACTLNP above)
C   ALANDRF_SL ;  Seasonal refuge area (or fraction of area) over an
C                    element; [L^2] or [L^2/L^2] (based on FACTLNP above)
C   ALANDRF_PR ;  Permanent refuge area (or fraction of area) over an
C                    element; [L^2] or [L^2/L^2] (based on FACTLNP above)
C                 * Note: Crop areas over elements that are designated as lake elements
C                         will be ignored
C
C-----------------------------------------------------------------------------------------------------------------
C   ITLN      IE               ALANDRI_FL      ALANDRI_NFL     ALANDRI_NDC         ALANDRF_SL      ALANDRF_PR
C-----------------------------------------------------------------------------------------------------------------
 12/31/2500_24:00    1            311.19          0.0000          0.0000             0.0000           0.00
                     2              0.00          0.0000          0.0000             0.0000           0.00
                     3         409749.34          0.0000          0.0000             0.0000           0.00
                     4        1155717.27          0.0000          0.0000             0.0000           0.00
                     5              0.00          0.0000          0.0000             0.0000           0.00
                     .              .               .               .                  .                .
                     .              .               .               .                  .                .
                     .              .               .               .                  .                .
                     219       505008.16          0.0000          0.0000             0.0000       27976.28
                     220      1607496.62          0.0000          0.0000             0.0000       46201.79
                     221        13063.29          0.0000          0.0000             0.0000           0.00
                     222            0.00          0.0000          0.0000             0.0000     1471081.66
                     223       958187.12          0.0000          0.0000             0.0000           0.00
C-----------------------------------------------------------------------------------------
C                              Pathnames for Land Use Data
C                                (READ FROM DSS FILE)
C
C   List the pathnames for the land use data below, if it will be read from a DSS file
C   (i.e. DSSFL is specified above).
C
C   The pathnames should be listed for each element and ponded crop combination.
C   They should be listed in an order such that, the crop type changes first.
C
C   * Example:
C
C       IE     LUTYPE      PATH
C        1        1       (pathname[1])
C        1        2       (pathname[2])
C        1        3       (pathname[3])
C        1        4       (pathname[4])
C        1        5       (pathname[5])
C        2        1       (pathname[6])
C        2        2       (pathname[7])
C        2        3       (pathname[8])
C        2        4       (pathname[9])
C        2        5       (pathname[10])
C        .        .            .
C        .        .            .
C        .        .            .
C       NE        1       (pathname[5*NE - 4])
C       NE        2       (pathname[5*NE - 3])
C       NE        3       (pathname[5*NE - 2])
C       NE        4       (pathname[5*NE - 1])
C       NE        5       (pathname[5*NE    ])
C
C   IE     ;  Element number
```

```
C   LUTYPE ;  Land use type
C               1 = Rice with flooded decomposition
C               2 = Rice with non-flooded decomposition
C               3 = Rice with no decomposition
C               4 = Seasonal refuge
C               5 = Permanent refuge
C   PATH   ;  Pathname corresponding to element and ponded crop type combination
C
C-----------------------------------------------------------------------------------------
C   IE        LUTYPE        PATH
C-----------------------------------------------------------------------------------------
*
*
```

8.3.8.8.c Ponding Depth Data File

This file includes the time series pond depths for rice and refuges. The ponded crops are associated with data columns in this file through pointers specified in the Ponded Crops Main File.

The following variables are listed in this file:

NCOLPND	Number of pond depth data columns
FACTPND	Conversion factor pond depths
NSPPND	Number of time steps to update the pond depths; enter any number if time-tracking option is on
NFQPND	Repetition frequency of the pond depths; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Ponding Depth Data File

If the time series data is listed in the Ponding Depth Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using “C”, “c” or “*”, and the variables in the “Data Input from DSS File” section below should be populated.

TIME	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
PND	Pond depth; [L]

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

REC	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*******************************************************************************
C
C                  INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                 RICE/REFUGE POND DEPTH DATA FILE
C                       Root Zone Component
C                       *** Version 4.0 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: PondDepth.dat
C
C*******************************************************************************
C                          File Description
C
C   This data file contains a set of ponding depths for rice fields and refuges.
C   These values are correlated to individual grid elements through the Rice/Refuge
C   Data File.
C
C*******************************************************************************
C                 Rice/Refuge Pond Depth Data Specifications
C
C   NCOLPND  ; Number of pond depth data columns
C   FACTPND  ; Conversion factor for pond depths
C   NSPPND   ; Number of time steps to update the pond depths
C                * Enter any number if time-tracking option is on
C   NFQPND   ; Repetition frequency of the pond depth data
C                * Enter 0 if full time series data is supplied
C                * Enter any number if time-tracking option is on
C   DSSFL    ; The name of the DSS file for data input
C                * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------
C         VALUE                                      DESCRIPTION
C-------------------------------------------------------------------------------
          2                                          / NCOLPND
          0.08333                                    / FACTPND (in -> ft)
          1                                          / NSPPND
          0                                          / NFQPND
                                                     / DSSFL
C-----------------------------------------------------------------------------------
C                          Rice/Refuge Pond Depth Data
C                             (READ FROM THIS FILE)
C
C   List the rice/refuge pond depths below, if it will not be read from
C   a DSS file (i.e. DSSFL is left blank above).
C
C   TIME ;  Time
C   PND  ;  Pond depths; [L]
C
*   Column 1: Growing season and decomp ponding depths for flooded-decomp rice
*   Column 2: Ponding depth for permanent refuges
C
C-----------------------------------------------------------------------------------
C  TIME                PND[1]   PND[2]    PND[3] ... PND[NCOLPND]
C-----------------------------------------------------------------------------------
C                       1        2
   01/31/4000_24:00    0.0      2.5
   02/29/4000_24:00    0.0      2.5
   03/31/4000_24:00    0.0      2.5
   04/30/4000_24:00    0.0      2.5
   05/31/4000_24:00    3.0      2.5
   06/30/4000_24:00    5.0      2.5
   07/31/4000_24:00    8.0      2.5
   08/31/4000_24:00    0.0      2.5
   09/30/4000_24:00    0.0      2.5
   10/31/4000_24:00    3.0      2.5
   11/30/4000_24:00    6.0      2.5
   12/31/4000_24:00    0.0      2.5
C-------------------------------------------------------------------------------
C                            Pathnames for Pond Depths
C                              (READ FROM DSS FILE)
C
C   List the pathnames for pond depths below, if it will be
C   read from a DSS file (i.e. DSSFL is specified above).
C
C   REC  ;  Time series record number
C   PATH ;  Pathname for the time series record
C
C-----------------------------------------------------------------------------------
C   REC     PATH
C-----------------------------------------------------------------------------------
*
*
```

8.3.8.8.d Pond Operation Flows Data File

This file lists unit flow rates that represent the pond and decomposition operations such as return flows, amounts of re-used return flows and the application rates for the non-flooded rice decomposition. The data columns in this file are associated with specific ponded crops through pointers specified in the Ponded Crops Main File.

The following variables are used:

NCOLFLW	Number of data columns for pond operation flow rates
FACTFLW	Conversion factor for the spatial component of the pond operation flow rates
NSPFLW	Number of time steps to update the pond operation flow rates; enter any number if time-tracking option is on
NFQFLW	Repetition frequency of the pond operation flow rates; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Pond Operation Flows Data File

If the time series data is listed in the Pond Operation Flows Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using "C", "c" or "*", and the variables in the "Data Input from DSS File" section below should be populated.

TIME	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
FLW	Pond operation flow rates; [L/T]

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

REC	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*******************************************************************************
C
C                 INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C             RICE/REFUGE OPERATION FLOW RATE DATA FILE
C                        Root Zone Component
C                        *** Version 4.0 ***
C
C
C            Project:  IDC Version ### Release
C                      California Department of Water Resources
C            Filename: PondOperationFlows.dat
C
C*******************************************************************************
C                          File Description
C
C   This data file contains a set of flow rates (in units of L/T) to be used for
C   simulating the rice and refuge return flows, re-use and water application rates
C   for non-flooded rice decomposition. These values are correlated to individual
C   grid elements through the Rice/Refuge Data File.
C
C*******************************************************************************
C              Rice/Refuge Operation Flow Rate Data Specifications
C
C   NCOLFLW  ; Number of data columns
C   FACTFLW  ; Conversion factor for operation flow rates
C               It is used to convert only the spatial component of the unit;
C               DO NOT include the conversion factor for time component of the unit.
C               * e.g. Unit of depth listed in this file         = INCHES/MONTH
C                      Consistent unit used in simulation        = FT/DAY
C                      Enter FACTOPS (INCHES/MONTH -> FT/MONTH) = 8.333333E-02
C                       (conversion of MONTH -> DAY is performed automatically)
C   NSPFLW   ; Number of time steps to update the operation flow rates
C               * Enter any number if time-tracking option is on
C   NFQFLW   ; Repetition frequency of the operation flow rate data
C               * Enter 0 if full time series data is supplied
C               * Enter any number if time-tracking option is on
C   DSSFL    ; The name of the DSS file for data input
C               * Leave blank if DSS file is not used for data input
C
C
C-------------------------------------------------------------------------------
C         VALUE                                      DESCRIPTION
C-------------------------------------------------------------------------------
          5                                          / NCOLFLW
          0.08333                                    / FACTFLW  (in/mon -> ft/mon)
          1                                          / NSPFLW
          0                                          / NFQFLW
                                                     / DSSFL
C-----------------------------------------------------------------------------------------------
C                      Rice/Refuge Operation Flow Rate Data
C                             (READ FROM THIS FILE)
C
C   List the rice/refuge operation flow rates below, if it will not be read from
C   a DSS file (i.e. DSSFL is left blank above).
C
C   TIME ;  Time
C   FLW  ;  Operation flow rates; [L/T]
C
*   Column 1: Flow-thru (return flow) depth for entire year for flooded-decomp rice
*   Column 2: Return flow depth for permanent refuges
*   Column 3: Re-use depth for flooded decomp rice
*   Column 4: Re-use depth for refuges
*   Column 5: Application depth for non-ponded decomp rice
C
C-----------------------------------------------------------------------------------------------
C  TIME     FLW[1]    FLW[2]    FLW[3] ... FLW[NCOLFLW]
C-----------------------------------------------------------------------------------------------
C                      1        2        3        4        5
   01/31/4000_24:00    2.0      0.0      0.0      0.0      0.0
   02/29/4000_24:00    1.0      0.0      0.0      0.0      0.0
   03/31/4000_24:00    0.0      0.0      0.0      0.0      0.0
   04/30/4000_24:00    0.0      0.0      0.0      0.0      0.0
   05/31/4000_24:00    3.0      0.0      0.0      0.0      0.0
   06/30/4000_24:00    0.0      0.0      0.0      0.0      0.0
   07/31/4000_24:00    1.9      0.0      0.0      0.0      0.0
   08/31/4000_24:00    1.9      0.0      0.0      0.0      0.0
   09/30/4000_24:00    0.95     0.0      0.0      0.0      0.0
   10/31/4000_24:00    0.0      0.0      0.0      0.0      0.0
   11/30/4000_24:00    2.0      0.0      0.0      0.0      0.0
   12/31/4000_24:00    2.0      0.0      0.0      0.0      0.0
C-------------------------------------------------------------------------------
C                        Pathnames for Operation Flow Rates
C                               (READ FROM DSS FILE)
C
C   List the pathnames for operation flow rates below, if it will be
C   read from a DSS file (i.e. DSSFL is specified above).
C
C   REC  ;  Time series record number
C   PATH ;  Pathname for the time series record
C
C-----------------------------------------------------------------------------------------------
C   REC     PATH
C-----------------------------------------------------------------------------------------------
*
*
```

8.3.8.9. Urban Component Files

8.3.8.9.a Urban Lands Main File

The Urban Lands Main File is the gateway file for all data that is necessary to simulate land surface and root zone flow processes in urban lands.

The file is divided into several sections and uses the following variables:

Land-Use Areas

The filename for the urban areas data file is listed in this section:

LUFLU	File that lists the urban areas (maximum 1000 characters)

Rooting Depth

FACT	Conversion factor for urban outdoors root zone depth
ROOTURB	Root zone depth for urban outdoors; [L]

Urban Water Use, Management and Simulation Parameters

POPULFL	File that lists the time series urban population data (maximum 1000 characters)
WTRUSEFL	File that lists the rates of per capita water use (maximum 1000 characters)
URBSPECFL	File that lists the urban water use specifications (maximum 1000 characters)
IE	Element identification number
PERV	Fraction of pervious area to total urban areas
CNURB	Curve number for urban lands
ICPOPUL	Population; this number corresponds to the appropriate data column in the Population Data File (POPULFL)
ICWTRUSE	Per capita water use; this number corresponds to the appropriate data column in the Per Capita Water Use Data File (WTRUSEFL)
FRACDM	Relative proportion of the urban demand computed by multiplying population with per capita water use to be applied to element IE; enter -1.0 for all elements if relative proportion will be computed with respect to urban area at each element

ICETURB	Urban evapotranspiration; this number corresponds to the appropriate data column in the Evapotranspiration File listed in the IDC Main Input File
ICRTFURB	Fraction of the urban applied water that becomes return flow; this number corresponds to the appropriate data column in the Return Flow Fractions Data File (RFFL) specified in the Root Zone Component Main File; for urban lands (return flow fraction applies only to pervious (lawns, parks, etc) urban areas; all water delivered to urban indoor areas becomes return flow)
ICRUFURB	Fraction of the urban applied water that is re-used; this number corresponds to the appropriate data column in the Re-use Fractions Data File (RUFL) specified in the Root Zone Component Main File
ICURBSPEC	Urban water use specification data as a fraction of total urban water that is used indoors; this number corresponds to the appropriate data column in the Urban Water Use Specifications Data File (URBSPECFL)

Initial Soil Moisture Conditions

The initial soil moisture content for urban outdoors at each element is listed in this section.

IE	Element identification number; enter 0 if following values are to be used for all elements
FSOILMP	Fraction of initial soil moisture at element IE that is due to precipitation
SOILM	Initial root zone moisture content for urban outdoors; [L/L]

```
C*******************************************************************************
C
C                    INTEGRATED WATER FLOW MODEL (IWFM)
C                           *** Version ### ***
C
C*******************************************************************************
C
C                          URBAN LANDS DATA FILE
C                           Root Zone Component
C                           for IWFM Simulation
C
C
C              Project:  IDC Version ### Release
C                        California Department of Water Resources
C              Filename: Urban_MAIN.dat
C
C*******************************************************************************
C                            File Description
C
C   This data file contains the parameters and data file names for the simulation
C   of root zone processes and managament of urban lands.
C
C*******************************************************************************
C                           Land Use Areas
C
C   LUFLU   ;  File that lists the urban areas (max. 1000 characters)
C
C-------------------------------------------------------------------------------
    RootZone\Urban\UrbanArea.dat                      / LUFLU
C*******************************************************************************
C                                Rooting Depth
C
C   FACT    ;    Conversion factor for urban root zone depth
C   ROOTURB;     Urban root zone depth; [L]
C
C-------------------------------------------------------------------------------
C   VALUE                  DESCRIPTION
C-------------------------------------------------------------------------------
    1.0                    / FACT
    2.0                    / ROOTURB
C*******************************************************************************
C                    Urban Water Use, Management and Simulation Parameters
C
C   POPULFL  ;  File that lists the urban population (max. 1000 characters)
C   WTRUSEFL ;  File that lists the per capita water use (max. 1000 characters)
C   URBSPECFL;  File that lists the urban water use specifications (max. 1000 characters)
C   IE       ;  Element ID (Enter 0 if following values are to be used for all elements)
C   PERV     ;  Fraction of pervious area to total urban areas
C   CNURB    ;  Curve number for urban lands
C   ICPOPUL  ;  Population - this number corresponds to the appropriate data
C                 column in the Population file (POPULFL)
C   ICWTRUSE ;  Per capita water use - this number corresponds to the appropriate data
C                 column in the Per Capita Water Use file (WTRUSEFL)
C   FRACDM   ;  Relative proportion of the urban demand computed by multiplying population
C                 with per capita water use to be applied to element IE
C                 * Note: Enter -1.0 for all FRACDM if relative proportion will be computed
C                         with respect to urban area at each element
C   ICETURB  ;  Urban ETc - this number corresponds to the appropriate data column
C                 in the ET data file listed in the Main Control Data file.
C   ICRTFURB ;  Fraction of the urban applied water that becomes return flow - this
C                 number corresponds to the appropriate data column in irrigation
C                 water return flow factor data file (RFFL).
C                 * Note: For urban lands, return flow fraction applies only to
C                         pervious (lawns, parks, etc) urban areas. All water
C                         delivered to urban indoor areas becomes return flow.
C   ICRUFURB ;  Fraction of the applied water that is re-used - this number corresponds
C                 to the appropriate data column in irrigation water re-use factor data
C                  file (RUFL).
C   ICURBSPEC;  Urban water use specification data as a fraction of total urban water that
C                is used indoors - this number corresponds to the appropriate data column
C                in the urban water use specifications data file (URBSPECFL).
C
C-------------------------------------------------------------------------------
C         VALUE                                     DESCRIPTION
C-------------------------------------------------------------------------------
          RootZone\Urban\Population.dat             / POPULFL
          RootZone\Urban\WaterUse.dat               / WTRUSEFL
          RootZone\Urban\UrbanSpecs.dat             / URBSPECFL
C----------------------------------------------------------------------------------------------------------
C   IE      PERV   CNURB   ICPOPUL  ICWTRUSE     FRACDM     ICETURB   ICRTFURB   ICRUFURB     ICURBSPEC
C----------------------------------------------------------------------------------------------------------
    1       0.62    79       1         4          -1.0         20        2           2             1
    2       0.62    79       1         4          -1.0         20        2           2             1
    3       0.62    69       1         4          -1.0         20        2           2             1
    .        .       .       .         .            .           .        .           .             .
    .        .       .       .         .            .           .        .           .             .
    .        .       .       .         .            .           .        .           .             .
    221     0.62    79       1         2          -1.0         20        2           2             1
    222     0.62    69       1         1          -1.0         20        2           2             1
    223     0.62    69       1         4          -1.0         20        2           2             1
C*******************************************************************************
C                             Initial Soil Moisture Condition
C                                     For Urban Lands
C
C   IE     ; Element ID (0 if following values are to be used for all elements)
C   FSOILMP; Fraction of initial soil moisture at element IE that is due to precipitation
C   SOILM  ; Initial root zone moisture content for urban land; [L/L]
C
C-----------------------------------------------------------------------------
C   IE    FSOILMP    SOILM
C-----------------------------------------------------------------------------
  1       0.5        0.1370
  2       0.5        0.1571
  3       0.5        0.1053
  .        .           .
  .        .           .
  .        .           .
  221     0.5        0.0485
  222     0.5        0.2322
  223     0.5        0.1210
```

8.3.8.9.b Urban Area Data File

Area of urban lands at every element are listed in this file:

FACTLNU	Conversion factor for land use areas; enter 0.0 if land use distribution is given as a fraction of element area
NSPLNU	Number of time steps to update the land use data; enter any number if time-tracking option is on
NFQLNU	Repetition frequency of the land use data; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Urban Area Data File

If the time series data is listed in the Urban Area Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using "C", "c" or "*", and the variables in the "Data Input from DSS File" section below should be populated.

ITLN	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
IE	Element identification number
ALANDU	Urban area (or fraction of area) over element IE; $[L^2]$ or $[L^2/L^2]$ based on FACTLNU above

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

IE	Element identification number
PATH	Pathname corresponding to urban area at element IE

```
C*******************************************************************************
C
C                 INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                          URBAN AREA FILE
C                         Root Zone Component
C                         *** Version 4.0 ***
C
C
C            Project:  IDC Version ### Release
C                      California Department of Water Resources
C            Filename: UrbanArea.dat
C
C*******************************************************************************
C                         File Description
C
C   This data file contains the land use distribution of urban lands for
C   each element for the simulation period.
C
C*******************************************************************************
C                          Land Use Data Specifications
C
C   FACTLNU;   Conversion factor for land use area
C                * Enter 0.0 if land use distribution is given as a fraction of element area
C   NSPLNU ;   Number of time steps to update the land use data
C                * Enter any number if time-tracking option is on
C   NFQLNU ;   Repetition frequency of the land use data
C                * Enter 0 if full time series data is supplied
C                * Enter any number if time-tracking option is on
C   DSSFL   ;   The name of the DSS file for data input
C                * Leave blank if DSS file is not used for data input
C
C----------------------------------------------------------------------------------------
C         VALUE                                     DESCRIPTION
C----------------------------------------------------------------------------------------
          10.763910417                              / FACTLNU    (sq. m. -> sq. ft.)
          1                                         / NSPLNU
          0                                         / NFQLNU
                                                    / DSSFL
C----------------------------------------------------------------------------------------
C                            Land Use Data
C                        (READ FROM THIS FILE)
C
C   List the land use data below, if it will not be read from a DSS file
C   (i.e. DSSFL is left blank above).
C
C   ITLN   ;   Time
C   IE     ;   Element number
C   ALANDU ;   Urban area (or fraction of area) over an element; [L^2] or [L^2/L^2] (based on FACTLNU above)
C              * Note: Urban areas over elements that are designated as lake elements
C                    will be ignored
C
C------------------------------------------------------------------------------------------------------------
C   ITLN             IE             ALANDU
C------------------------------------------------------------------------------------------------------------
 12/31/2500_24:00    1               633.00
                     2                 0.00
                     3              8771.34
                     4             60486.76
                     5                 0.00
                     .                  .
                     .                  .
                     .                  .
                     219           99096.04
                     220          110491.22
                     221            2989.20
                     222               0.00
                     223           23114.89
C----------------------------------------------------------------------------------------
C                             Pathnames for Land Use Data
C                               (READ FROM DSS FILE)
C
C   List the pathnames for the land use data below, if it will be read from a DSS file
C   (i.e. DSSFL is specified above).
C
C   IE     ;  Element number
C   PATH   ;  Pathname corresponding to urban area at element IE
C
C----------------------------------------------------------------------------------------
C   IE        PATH
C----------------------------------------------------------------------------------------
*
*
```

8.3.8.9.c Population Data File

This file lists urban population. Urban land in each element is associated with a data column in this file through pointers specified in the Urban Main File.

The following variables are listed in this file:

NCOLPOP	Number of population data columns
NSPPOP	Number of time steps to update the population data; enter any number if time-tracking option is on
NFQPOP	Repetition frequency of the population data; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Population Data File

If the time series data is listed in the Population Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using "C", "c" or "*", and the variables in the "Data Input from DSS File" section below should be populated.

ITPOP	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
POPUL	Population; [people]

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

I	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*******************************************************************************
C
C                   INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                      POPULATION DATA FILE
C                       Root Zone Component
C                       *** Version 4.0 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: Population.dat
C
C*******************************************************************************
C                               File Description
C
C   This data file contains a set of population data on a time-series basis
C
C*******************************************************************************
C                      Population Data Specifications
C
C   NCOLPOP;  Number of population data columns
C   NSPPOP ;  Number of time steps to update the population data
C              * Enter any number if time-tracking option is on
C   NFQPOP ;  Repetition frequency of the population data
C              * Enter 0 if full time series data is supplied
C              * Enter any number if time-tracking option is on
C   DSSFL  ;  The name of the DSS file for data input (maximum 50 characters);
C              * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------
C         VALUE                                      DESCRIPTION
C-------------------------------------------------------------------------------
           1                                         / NCOLPOP
           1                                         / NSPPOP
           0                                         / NFQPOP
                                                     / DSSFL
C-------------------------------------------------------------------------------
C                            Population Data
C                          (READ FROM THIS FILE)
C
C   List the population data below, if it will not be read from a
C   DSS file (i.e. DSSFL is left blank above).
C
C   ITPOP;   Time
C   POPUL;   Population; [People]
C
C-------------------------------------------------------------------------------
C ITPOP                 POPUL(1)  POPUL(2)  POPUL(3) ...
C-------------------------------------------------------------------------------
   12/31/2500_24:00     100000
*
C-------------------------------------------------------------------------------
C                       Pathnames for Population Data
C                           (READ FROM DSS FILE)
C
C   List the pathnames for the population data below, if it will be read
C   from a DSS file (i.e. DSSFL is specified above).
C
C   I    ;  Pathname number
C   PATH ;  Pathname for the time series record
C
C--------------------------------------------------------------------------------
C   I       PATH
C--------------------------------------------------------------------------------
*
*
```

8.3.8.9.d Per Capita Water Use Data File

Time series per-capita water use rates are listed in this file. The urban areas at each element are associated with a data column in this file through pointers specified in the Urban Lands Main File.

The following variables are used in this file:

NCOLWU	Number of per capita water use data columns
FACTWU	Conversion factor for the spatial component of the per capita water use data
NSPWU	Number of time steps to update the per capita water use data; enter any number if time-tracking option is on
NFQWU	Repetition frequency of the per capita water use data; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Per Capita Water Use Data File

If the time series data is listed in the Per Capita Water Use Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using "C", "c" or "*", and the variables in the "Data Input from DSS File" section below should be populated.

ITWU	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
WU	Per capita water use; $[(L^3/T)/\text{person}]$

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

REC	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*******************************************************************************
C
C                   INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                   PER CAPITA WATER USE DATA FILE
C                        Root Zone Component
C                        *** Version 4.0 ***
C
C
C              Project:  IDC Version ### Release
C                        California Department of Water Resources
C              Filename: WaterUse.dat
C
C*******************************************************************************
C                                File Description
C
C   This data file contains a set of per capita water use data on a time-series
C   basis.  Water use includes both indoors (M&I) and outdoors water.
C
C*******************************************************************************
C                       Per Capita Water Use Data Specifications
C
C   NCOLWU ;  Number of water use data columns
C   FACTWU ;  Conversion factor for the water use data
C               It is used to convert only the spatial component of the unit;
C               DO NOT include the conversion factor for time component of the unit.
C               * e.g. Unit of flow listed in this file          = AC-FT/MONTH
C                      Consistent unit used in simulation        = CU.FT/DAY
C                      Enter FACTWU (AC-FT/MONTH -> CU.FT/MONTH) = 43560.0
C                     (conversion of MONTH -> DAY is performed automatically)
C   NSPWU  ;  Number of time steps to update the water use data
C              * Enter any number if time-tracking option is on
C   NFQWU  ;  Repetition frequency of the water use data
C              * Enter 0 if full time series data is supplied
C              * Enter any number if time-tracking option is on
C   DSSFL  ;  The name of the DSS file for data input (maximum 50 characters);
C              * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------
C         VALUE                                      DESCRIPTION
C-------------------------------------------------------------------------------
          4                                          / NCOLWU
          43560.0                                    / FACTWU   (ac.ft. -> cu.ft.)
          1                                          / NSPWU
          0                                          / NFQWU
                                                     / DSSFL
C-------------------------------------------------------------------------------
C                        Per Capita Water Use Data
C                          (READ FROM THIS FILE)
C
C   List the per capita water use data below, if it will not be read from a
C   DSS file (i.e. DSSFL is left blank above).
C
C   ITWU;   Time
C   WU  ;   Per capita water use; [L^3/T/PERSON]
C
C-------------------------------------------------------------------------------
C ITWU    WU(1)  WU(2)  WU(3) ...
C-------------------------------------------------------------------------------
 01/31/4000_24:00   0.0014928   0.0013725       0.0000844       0.0059222
 02/29/4000_24:00   0.0014928   0.0013725       0.0000844       0.0059222
 03/31/4000_24:00   0.0018247   0.0016776       0.0001032       0.0072382
 04/30/4000_24:00   0.0028199   0.0025926       0.0001595       0.0111864
 05/31/4000_24:00   0.0036492   0.0033551       0.0002064       0.0144765
 06/30/4000_24:00   0.0041468   0.0038126       0.0002346       0.0164505
 07/31/4000_24:00   0.0046444   0.0042701       0.0002627       0.0184246
 08/31/4000_24:00   0.0043127   0.0039651       0.0002440       0.0171086
 09/30/4000_24:00   0.0034834   0.0032026       0.0001970       0.0138185
 10/31/4000_24:00   0.0021564   0.0019826       0.0001220       0.0085543
 11/30/4000_24:00   0.0016587   0.0015250       0.0000938       0.0065802
 12/31/4000_24:00   0.0014928   0.0013725       0.0000844       0.0059222
C-------------------------------------------------------------------------------
C                   Pathnames for Per Capita Water Use Data
C                           (READ FROM DSS FILE)
C
C   List the pathnames for the per capita water use data below, if it will be read
C   from a DSS file (i.e. DSSFL is specified above).
C
C   REC  ;  Time series record number
C   PATH ;  Pathname for the time series record
C
C------------------------------------------------------------------------------------
C   REC       PATH
C------------------------------------------------------------------------------------
*
*
```

8.3.8.9.e Urban Water Use Specifications Data File

Time series urban water use specifications in terms of the fraction of indoor water use to total urban water use are listed in this file. The urban areas at each element are associated with a data column in this file through pointers specified in the Urban Lands Main File.

The following variables are used in this file:

NURBSP	Number of urban water use specifications data columns
NSPURBSP	Number of time steps to update the urban water use specifications data; enter any number if time-tracking option is on
NFQURBSP	Repetition frequency of the urban water use specifications data; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Urban Water Use Specifications Data File

If the time series data is listed in the Urban Water Use Specifications Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using “C”, “c” or “*”, and the variables in the “Data Input from DSS File” section below should be populated.

ITUSP	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
URINDR	Fraction of total urban water that is used indoors

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

REC	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*******************************************************************************
C
C                   INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                   URBAN WATER USAGE SPECIFICATION DATA FILE
C                             Root Zone Component
C                             *** Version 4.0 ***
C
C
C              Project:  IDC Version ### Release
C                        California Department of Water Resources
C              Filename: UrbanSpecs.dat
C
C*******************************************************************************
C                               File Description
C
C   This data file contains a set of urban water usage specification data as the
C   fraction of total urban water that is used indoors.
C
C*******************************************************************************
C                             Urban Water Use Data Specifications
C
C   NURBSP   ;   Number of urban water use specifications data columns
C   NSPURBSP ;   Number of time steps to update the urban water use specification data
C                 * Enter any number if time-tracking option is on
C   NFQURBSP ;   Repitition frequency of the urban water use sepcification data
C                 * Enter 0 if full time series data is supplied
C                 * Enter any number if time-tracking option is on
C   DSSFL    ;   The name of the DSS file for data input (maximum 50 characters);
C                 * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------
C         VALUE                                          DESCRIPTION
C-------------------------------------------------------------------------------
           1                                            / NURBSP
           1                                            / NSPURBSP
           0                                            / NFQURBSP
                                                        / DSSFL
C--------------------------------------------------------------------------------------
C                             Urban Water Use Data
C                             (READ FROM THIS FILE)
C
C   List the urban water use data below, if it will not be read from
C   a DSS file (i.e. DSSFL is left blank above).
C
C   ITUSP ;  Time
C   URINDR;  Fraction of total urban water that is used indoors
C
C--------------------------------------------------------------------------------------
C   ITUSP         URINDR[1]  URINDR[2]  URINDR[3] ...
C--------------------------------------------------------------------------------------
10/31/4000_24:00     0.5
11/30/4000_24:00     0.7
12/31/4000_24:00     0.8
01/31/4000_24:00    1.00
02/29/4000_24:00    1.00
03/31/4000_24:00     0.6
04/30/4000_24:00     0.5
05/31/4000_24:00    0.45
06/30/4000_24:00     0.4
07/31/4000_24:00     0.4
08/31/4000_24:00     0.4
09/30/4000_24:00     0.4
C-------------------------------------------------------------------------------
C                        Pathnames for Urban Water Use Data
C                               (READ FROM DSS FILE)
C
C   List the pathnames for urban water use data below, if it will be read
C   from a DSS file (i.e. DSSFL is specified above).
C
C   REC  ;  Time series record number
C   PATH ;  Pathname for the time series record
C
C--------------------------------------------------------------------------------------
C   REC       PATH
C--------------------------------------------------------------------------------------
*
*
```

8.3.8.10. Native and Riparian Vegetation Component Files

8.3.8.10.a Native and Riparian Vegetation Lands Main File

The Native and Riparian Vegetation Lands Main File is the gateway file for all data that is necessary to simulate land surface and root zone flow processes in areas that are covered with native and riparian vegetation.

The file is divided into several sections and uses the following variables:

Land-Use Areas

The filename for the native and riparian areas data file is listed in this section:

LUFLNVRV	File that lists the urban areas (maximum 1000 characters)

Rooting Depths

FACT	Conversion factor for native and riparian vegetation root zone depths
ROOTNV	Root zone depth for native vegetation; [L]
ROOTRV	Root zone depth for riparian vegetation; [L]

Native and Riparian Vegetation Simulation Parameters

IE	Element identification number entered sequentially; enter 0 if the following values are to be used for all elements
CNNV	Curve number for native vegetation lands
CNRV	Curve number for riparian vegetation lands
ICETNV	Native vegetation evapotranspiration rate; this number corresponds to the appropriate data column in the Evapotranspiration File listed in the IDC Main Input File
ICETRV	Riparian vegetation evapotranspiration rate; this number corresponds to the appropriate data column in the Evapotranspiration File listed in the IDC Main Input File

Initial Soil Moisture Conditions

The initial soil moisture contents for native and riparian vegetation at each element are listed in this section.

IE	Element identification number; enter 0 if following values are to be used for all elements

SOILM_NV	Initial root zone moisture content for native vegetation at element IE; [L/L]
SOILM_RV	Initial root zone moisture content for riparian vegetation at element IE; [L/L]

```
C*******************************************************************************
C
C                   INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                 NATIVE AND RIPARIAN VEGETATION DATA FILE
C                         Root Zone Component
C                         *** Version 4.0 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: NVRV_MAIN.dat
C
C*******************************************************************************
C                          File Description
C
C   This data file contains the parameters and data file names for the simulation
C   of root zone processes for native and riparian vegetation.
C
C*******************************************************************************
C                         Land Use Areas
C
C   LUFLNVRV   ;  File that lists the land use areas (max. 1000 characters)
C
C-------------------------------------------------------------------------------
    RootZone\NVRV\NVRVArea.dat                      / LUFLNVRV
C*******************************************************************************
C                             Rooting Depths
C
C   FACT  ;  Conversion factor for root zone depths
C   ROOTNV;  Native veg. root zone depth; [L]
C   ROOTRV;  Riparian veg. root zone depth; [L]
C
C-------------------------------------------------------------------------------
C   VALUE                   DESCRIPTION
C-------------------------------------------------------------------------------
    1.0                   / FACT
    3.0                   / ROOTNV
    3.0                   / ROOTNV
C*******************************************************************************
C         Native and Riparian Vegetation Root Zone Simulation Parameters
C
C   IE       ;  Element ID (0 if following values are to be used for all elements)
C   CNNV     ;  Curve number for native vegetation lands
C   CNRV     ;  Curve number for riparian vegetation lands
C   ICETNV   ;  Native vegetation ETc - this number corresponds to the appropriate
C                 data column in the ET data file listed in the Main Control Data file.
C   ICETRV   ;  Riparian vegetation ETc - this number corresponds to the appropriate
C                 data column in the ET data file listed in the Main Control Data file.
C
C-------------------------------------------------------------------------------
C   IE       CNNV   CNRV    ICETNV    ICETRV
C-------------------------------------------------------------------------------
    1        71     71      21        22
    2        71     71      21        22
    3        58     58      21        22
    .        .      .       .         .
    .        .      .       .         .
    .        .      .       .         .
    221      71     71      21        22
    222      58     58      21        22
    223      58     58      21        22
C*******************************************************************************
C                           Initial Soil Moisture Condition
C                       For Native and Riparian Vegetation Areas
C
C   IE      ;   Element ID (0 if following values are to be used for all elements)
C   SOILM_NV;   Initial root zone moisture content for native vegetation area; [L/L]
C   SOILM_RV;   Initial root zone moisture content for riparian vegetation area; [L/L]
C
C----------------------------------------------------------------------------
C   IE      SOILM_NV    SOILM_RV
C----------------------------------------------------------------------------
    1       0.1370      0.1370
    2       0.1571      0.1571
    3       0.1053      0.1053
    .        .           .
    .        .           .
    .        .           .
    221     0.0485      0.0485
    222     0.2322      0.2322
    223     0.1210      0.1210
```

8.3.8.10.b Native and Riparian Vegetation Area Data File

Areas of native and riparian vegetation at every element are listed in this file:

FACTLNVRV	Conversion factor for land use areas; enter 0.0 if land use distribution is given as a fraction of element area
NSPLNVRV	Number of time steps to update the land use data; enter any number if time-tracking option is on
NFQLNVRV	Repetition frequency of the land use data; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Native and Riparian Vegetation Area Data File

If the time series data is listed in the Native and Riparian Vegetation Area Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using "C", "c" or "*", and the variables in the "Data Input from DSS File" section below should be populated.

ITLN	Time. For time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number.
IE	Element identification number
ALANDNV	Native vegetation area (or fraction of area) over element IE; $[L^2]$ or $[L^2/L^2]$ based on FACTLNVRV above
ALANDRV	Riparian vegetation area (or fraction of area) over element IE; $[L^2]$ or $[L^2/L^2]$ based on FACTLNVRV above

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

IE	Element identification number
LUTYPE	Land-use type entered sequentially (1 = native vegetation, 2 = riparian vegetation)
PATH	Pathname corresponding to element and land-use type combination

```
C*******************************************************************************
C
C                   INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                  NATIVE AND RIPARIAN VEGETATION AREA FILE
C                            Root Zone Component
C                            *** Version 4.0 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: NVRVArea.dat
C
C*******************************************************************************
C                          File Description
C
C   This data file contains the land use distribution of native and riparian vegetation
C   for each element for the simulation period.
C
C*******************************************************************************
C                          Land Use Data Specifications
C
C   FACTLNVRV;   Conversion factor for land use area
C                  * Enter 0.0 if land use distribution is given as a fraction of element area
C   NSPLNVRV ;   Number of time steps to update the land use data
C                  * Enter any number if time-tracking option is on
C   NFQLNVRV ;   Repetition frequency of the land use data
C                  * Enter 0 if full time series data is supplied
C                  * Enter any number if time-tracking option is on
C   DSSFL    ;   The name of the DSS file for data input
C                  * Leave blank if DSS file is not used for data input
C
C-----------------------------------------------------------------------------------------
C         VALUE                                       DESCRIPTION
C-----------------------------------------------------------------------------------------
          10.763910417                                / FACTLNNRV    (sq. m. -> sq. ft.)
          1                                           / NSPLNVRV
          0                                           / NFQLNVRV
                                                      / DSSFL
C-----------------------------------------------------------------------------------------
C                            Land Use Data
C                        (READ FROM THIS FILE)
C
C   List the land use data below, if it will not be read from a DSS file
C   (i.e. DSSFL is left blank above).
C
C   ITLN   ;   Time
C   IE     ;   Element number
C   ALANDNV;   Native vegetation area (or fraction of area) over an element;
C                 [L^2] or [L^2/L^2] (based on FACTLNVRV above)
C   ALANDRV;   Riparian vegetation area (or fraction of area) over an element;
C                 [L^2] or [L^2/L^2] (based on FACTLNVRV above)
C              * Note: Areas over elements that are designated as lake elements
C                      will be ignored
C
C------------------------------------------------------------------------------------------------------
C   ITLN            IE            ALANDNV                 ALANDRV
C------------------------------------------------------------------------------------------------------
 12/31/2500_24:00    1           964286.26                 0.0001
                     2          2414291.17                 0.0001
                     3           400223.27                 0.0001
                     4           380287.64                 0.0001
                     5          2113855.82                 0.0001
                     .                .                     .
                     .                .                     .
                     .                .                     .
                     219        1391742.52                 0.0001
                     220         136979.26                 0.0001
                     221        1080191.08                 0.0001
                     222              0.00                 0.0001
                     223         190938.21                 0.0001
C-----------------------------------------------------------------------------------------
C                             Pathnames for Land Use Data
C                               (READ FROM DSS FILE)
C
C   List the pathnames for the land use data below, if it will be read from a DSS file
C   (i.e. DSSFL is specified above).
C
C   The pathnames should be listed for each element and native and riparian vegetation combination.
C   They should be listed in an order such that, the land use type changes first.
C
C   * Example:
C
C       IE     LUTYPE      PATH
C        1        1       (pathname[1])
C        1        2       (pathname[2])
C        2        1       (pathname[3])
C        2        2       (pathname[4])
C        .        .            .
C        .        .            .
C        .        .            .
C       NE        1       (pathname[2*NE - 1])
C       NE        2       (pathname[2*NE])
C
C   IE     ;  Element number
C   LUTYPE ;  Land use type
C               1 = Native veg.
C               2 = Riparian veg.
C   PATH   ;  Pathname corresponding to element and land use type combination
C
C-----------------------------------------------------------------------------------------
C   IE        LUTYPE        PATH
C-----------------------------------------------------------------------------------------
*
*
```

8.3.9. Input Files for Root Zone Component Version 4.01

All input files for the root zone component version 4.01 except the Root Zone Component Main File are the same as those for the component version 4.0. Therefore, only the Root Zone Component Main File for version 4.01 will be explained in this section. For a detailed description of the other input files, please refer to section 8.3.8.

8.3.9.1. Root Zone Component Main File

This file is exactly the same as that for the root zone component version 4.0, except that it allows the specification of two additional filenames to print out cell-level Land and Water Use as well as the Root Zone budget data. These output files are optional and are generated as HDF5 files. They can later be post-processed using the Z-Budget post-processor to generate water budgets for "*zones*" which are groups of cells defined by the user.

The following sections and variables are defined in the rest of this file:

Root Zone Simulation Scheme Control and Filenames

In this section convergence criteria for the iterative solution methodology and names of additional input and output files are listed.

RZCONV	Convergence criteria for iterative soil moisture accounting as a fraction of total porosity; [L/L]
RZITERMX	Maximum number of iterations for iterative soil moisture accounting
FACTCN	Conversion factor to convert inches to the simulation unit of length
AGNPFL	Filename for the Non-Ponded Crops Main File (maximum 1000 characters); leave blank if non-ponded crops are not simulated
PFL	Filename for the Ponded Crops Main File (maximum 1000 characters); leave blank if rice and/or refuge lands are not simulated
URBFL	Filename for the Urban Lands Main File (maximum 1000 characters); leave blank if urban lands are not simulated

NVRVFL	Filename for the Natural Lands Main File (maximum 1000 characters); leave blank if native and/or riparian vegetation lands are not simulated
RFFL	File that lists the return flow fractions (maximum 1000 characters); leave blank if only native and/or riparian vegetation lands are simulated
RUFL	File that lists the irrigation water re-use factors (maximum 1000 characters); leave blank if only native and/or riparian vegetation lands are simulated
IPFL	File that lists the irrigation periods for each ponded and non-ponded crop (maximum 1000 characters); this is a required file even if ponded and non-ponded crops are not simulated
MSRCFL	File that lists generic source of moisture rates other than precipitation and irrigation (maximum 1000 characters); leave blank if there are no generic sources of moisture simulated
AGWDFL	File that lists agricultural water supply requirement (maximum 1000 characters); leave blank if agricultural water supply requirement for all crops will be computed dynamically
LWUBUDFL	HDF5 output file for subregional land and water use budget (maximum 1000 characters); leave blank if this output is not required
RZBUDFL	HDF5 output file for subregional root zone moisture (maximum 1000 characters); leave blank if this output is not required
ZLWUBUDFL	HDF5 output file for land and water use zone budget post-processor (maximum 1000 characters); leave blank if this output is not required
ZRZBUDFL	HDF5 output file for root zone zone budget post-processor (maximum 1000 characters); leave blank if this output is not required
FNSMFL	Output file for end-of-simulation soil moisture (maximum 1000 characters); leave blank if this output is not required

Soil Parameters and Surface Flow Destinations

In this section soil parameters, precipitation rates, generic soil moisture sources (if any) and surface runoff destinations are listed for each finite element.

FACTK	Conversion factor for the spatial component of the root zone hydraulic conductivity
TUNITK	Time unit of root zone hydraulic conductivity this should be one of the units recognized by HEC-DSS that are listed in the IDC Main Input File
IE	Element identification number
WP	Wilting point; [L/L]
FC	Field capacity; [L/L]
TN	Total porosity; [L/L]
LAMBDA	Pore size distribution index
K	Saturated hydraulic conductivity; [L/T]
RHC	Method to represent hydraulic conductivity versus moisture content curve (1 = Campbell's equation, 2 = van Genucten-Mualem equation)
IRNE	Precipitation rate; this number corresponds to the appropriate data column in the Precipitation File
FRNE	Factor to convert rainfall at the precipitation data column IRNE to rainfall at element IE
IMSRC	Generic source of moisture; this number corresponds to the appropriate data column in the Generic Moisture Source File that applies to element IE (enter any number if the Generic Moisture Source File, MSRCFL, is not defined)
TYPDEST	Destination type for the surface flow from element IE (0 = surface flow goes outside of model area, 1 = surface flow goes to a stream node, 3 = surface flow goes to a lake, 5 = surface flow recharges the groundwater)
DEST	Destination identification number for the surface flow from element IE; enter any number if surface flow from the element goes outside the model area (TYPDEST = 0) or recharges the groundwater (TYPDEST = 5)

KPonded	Saturated hydraulic conductivity to be used for ponded crops in the element (enter −1.0 if KPonded is the same as K); [L/T]

```
#4.01
C***  DO NOT DELETE ABOVE LINE ***
C
C*****************************************************************************
C
C                   INTEGRATED WATER FLOW MODEL (IWFM)
C
C*****************************************************************************
C
C                     ROOT ZONE PARAMETERS DATA FILE
C                          Root Zone Component
C                          *** Version 4.01 ***
C
C
C              Project:  IDC Version ### Release
C                        California Department of Water Resources
C              Filename: ROOTZONE_v401_MAIN.dat
C
C*****************************************************************************
C                           File Description
C
C   This data file contains the parameters and data file names for the simulation
C   of root zone processes.
C
C*****************************************************************************
C                 Root Zone Simulation Scheme Control and File Names
C
C   RZCONV   ;  Convergence criteria for iterative soil moisture accounting as a
C                fraction of total porosity; [L/L]
C   RZITERMX ;  Maximum number of iterations for iterative soil moisture accounting
C   FACTCN   ;  Conversion factor to convert inches to the simulation unit of length
C   AGNPFL   ;  Non-ponded agricultural crop data file (max. 1000 characters)
C                  * Leave blank if non-ponded crops are not simulated
C   PFL      ;  Rice/refuge data file (max. 1000 characters)
C                * Leave blank if rice and/or refuge lands are not simulated
C   URBFL    ;  Urban lands data file (max. 1000 characters)
C                * Leave blank if urban lands are not simulated
C   NVRVFL   ;  Native/riparian vegetation lands data file (max. 1000 characters)
C                * Leave blank if native and/or riparion veg. lands are not simulated
C   RFFL     ;  File that lists the return flow fractions (max. 1000 characters)
C                * Leave blank if only native/riparian vegetation lands are simulated
C   RUFL     ;  File that lists the irrigation water re-use factors (max. 1000 characters)
C                * Leave blank if only native/riparian vegetation lands are simulated
C   IPFL     ;  File that lists the irrigation periods for each ponded and
C                non-ponded crop (max. 1000 characters)
C                * Leave blank if both ponded and non-ponded crops are not simulated
C   MSRCFL   ;  File that lists generic source of moisture rates other than precipitation
C                and irrigation (max. 1000 characters)
C                * Leave blank if there are no generic sources of moisture simulated
C   AGWDFL   ;  File that lists agricultural water supply requirement (max. 1000 characters)
C                * Leave blank if agricultural water supply requirement will be computed
C                  dynamically
C   LWUBUDFL ;  HDF5 output file for land and water use budget at each
C                  subregion (max. 1000 characters)
C                * Leave blank if this output is not required
C   RZBUDFL  ;  HDF5 output file for root zone moisture budget at each
C                  subregion (max. 1000 characters)
C                * Leave blank if this output is not required
C   ZLWUBUDFL;  HDF5 output file for land and water use zone budget
C                  post-processor (max. 1000 characters)
C                 * Leave blank if this output is not required
C   ZRZBUDFL ;  HDF5 output file for root zone zone budget
C                  post-processor (max. 1000 characters)
C                 * Leave blank if this output is not required
C   FNSMFL   ;  Output file for end-of-simulation soil moisture (max. 1000 characters)
C                * Leave blank if this output is not required
C
C-----------------------------------------------------------------------------------------
C         VALUE                                      DESCRIPTION
C-----------------------------------------------------------------------------------------
          0.0001                                     / RZCONV
          200                                        / RZITERMX
          0.08333                                    / FACTCN  (in -> ft)
          RootZone\NonPondedAg\NonPondedAg.dat       / AGNPFL
          RootZone\PondedAg\PondedAg.dat             / PFL
          RootZone\Urban\Urban.dat                   / URBFL
          RootZone\NVRV\NVRV.dat                     / NVRVFL
          RootZone\ReturnFlowFrac.dat                / RFFL
          RootZone\ReuseFrac.dat                     / RUFL
          RootZone\IrrigPeriod.dat                   / IPFL
                                                     / MSRCFL
          RootZone\AgWaterDemand.dat                 / AGWDFL
          Budget\LWU.hdf                             / LWUBUDFL
          Budget\RZ.hdf                              / RZBUDFL
          ZBudget\LWU_ZBud.hdf                       / ZLWUBUDFL
          ZBudget\RZ_ZBud.hdf                        / ZRZBUDFL
                                                     / FNSMFL
C*****************************************************************************
C              Parameters for Soil, Precipitation and Runoff Destination
C
C   Enter conversion factors.
C
C   FACTK  ;  Conversion factor for root zone hydraulic conductivity
C               It is used to convert only the spatial component of the unit;
C               DO NOT include the conversion factor for time component of the unit.
C               * e.g. Unit of hydraulic conductivity listed in this file = FT/MONTH
C                      Consistent unit used in simulation                = IN/DAY
C                      Enter FACT (FT/MONTH -> IN/MONTH)                 = 8.33333E-02
C                      (conversion of MONTH -> DAY is performed automatically)
C   TUNITK ;  Time unit of root zone hydraulic conductivity.  This should be one of the
C              units recognized by HEC-DSS that are listed in the Main Control File.
C
C-----------------------------------------------------------------------------------------
C         VALUE                                      DESCRIPTION
C-----------------------------------------------------------------------------------------
          0.283464                                   / FACTK (micrometers/sec -> ft/day)
          1day                                       / TUNITK
C-----------------------------------------------------------------------------------------
C
C   Enter soil parameters, precipitaion and surface flow destination data below for each
C   grid element.
C
```

```
C   IE     ;  Element ID
C   WP     ;  Wilting point; [L/L]
C   FC     ;  Field capacity; [L/L]
C   TN     ;  Total porosity; [L/L]
C   LAMBDA ;  Pore size distribution index; [dimensionless]
C   K      ;  Saturated hydraulic conductivity; [L/T]
C   RHC    ;  Method to represent hydraulic conductivity vs. moisture content curve
C               1 = Campbell's equation
C               2 = van Genucten-Mualem equation
C   IRNE   ;  Precipitation data column in the Precipitation file that applies to element IE
C   FRNE   ;  Factor to convert rainfall at the precipitation data column to
C               rainfall at element IE
C   IMSRC  ;  Generic source of moisture data column in the Generic Moisture Source file (MSRCFL
C               file listed above) that applies to element IE
C               * Note: Enter any number if MSRCFL above is left blank
C   TYPDEST;  Destination type for the surface flow from element IE
C               0 = Surface flow goes outside of model area
C               1 =   "       "    "  to a stream node
C               3 =   "       "    "   " a lake
C               5 =   "       "    "   " groundwater
C   DEST   ;  Destination for the surface flow from element IE
C               * Note: Enter any number if TYPDEST is set to 0 or 5
C   KPonded;  Saturated hydraulic conductivity to be used for ponded crops in the element; [L/T]
C               * Note: Enter -1.0 if KPonded is the same as K
C
C-----------------------------------------------------------------------------------------------------------
C  IE      WP        FC        TN        LAMBDA   K        RHC   IRNE  FRNE   IMSRC   TYPDEST  DEST   KPonded
C-----------------------------------------------------------------------------------------------------------
   1       0.0000    0.1370    0.4530    0.378    5.0E-02   2     1    1.0      0        0      3      -1.0
   2       0.0000    0.1571    0.4640    0.242    5.1E+01   2     1    1.0      0        0      3      -1.0
   3       0.0000    0.1053    0.4630    0.252    5.0E-02   2     1    1.0      0        0      3      -1.0
   .         .         .         .         .        .       .     .    .        .        .      .        .
   .         .         .         .         .        .       .     .    .        .        .      .        .
   .         .         .         .         .        .       .     .    .        .        .      .        .
   220     0.0000    0.1210    0.4300    0.223    5.0E-02   2     3    1.0      0        0      3      1.0E-03
   221     0.0000    0.0485    0.4530    0.378    5.0E-02   2     3    1.0      0        0      0      1.0E-03
   222     0.0000    0.2322    0.5010    0.234    1.9E+01   2     3    1.0      0        0      0      1.0E-03
   223     0.0000    0.1210    0.4300    0.223    5.0E-02   2     3    1.0      0        0      3      1.0E-03
```

8.3.10. Input Files for Root Zone Component Version 4.1

Most of the input data files required by the root zone component version 4.1 and the parameters required to be specified are the same as those for root zone component version 4.0. Therefore, only those input files that are different than the ones in version 4.0 will be explained in this section. For a detailed description of the other input files, please refer to section 8.3.8.

8.3.10.1. Root Zone Component Main File

Similar to the Root Zone Component Main File for version 4.0, this file includes the convergence criteria for the iterative solution of the non-linear soil moisture mass balance equation, names of additional input files that are used to simulate land surface and root zone flow processes for agricultural, urban and natural lands, and agricultural and urban water demands. Subregional Land and Water Use as well as Subregional Root Zone Moisture Budget output filenames are also listed in this file. Data to simulate root water uptake from groundwater and riparian vegetation access to stream flows are also listed in this file. Soil properties at each grid cell and the destination for the surface flow generated at each cell are listed in the last section of the Root Zone Component Main File.

First data line of the Root Zone Component Main File lists the version number (i.e. 4.1) of the root zone component that will be used in simulating the land surface and root zone flow processes. IDC first reads this data line to figure out what other parameters will be read and what flow processes are to be simulated. This first line of data entry must not be modified.

The following sections and variables are defined in the rest of this file:

Root Zone Simulation Scheme Control and Filenames
In this section convergence criteria for the iterative solution methodology and names of additional input and output files are listed.

RZCONV	Convergence criteria for iterative soil moisture accounting as a fraction of total porosity; [L/L]
RZITERMX	Maximum number of iterations for iterative soil moisture accounting

FACTCN	Conversion factor to convert inches to the simulation unit of length
GWUPTK	Flag to turn on or off the root water uptake from groundwater (0 = root water uptake from groundwater is NOT simulated; 1 = root water uptake from groundwater is simulated); this flag is effective only when IDC is executed when linked to an integrated hydrologic model such as IWFM
AGNPFL	Filename for the Non-Ponded Crops Main File (maximum 1000 characters); leave blank if non-ponded crops are not simulated
PFL	Filename for the Ponded Crops Main File (maximum 1000 characters); leave blank if rice and/or refuge lands are not simulated
URBFL	Filename for the Urban Lands Main File (maximum 1000 characters); leave blank if urban lands are not simulated
NVRVFL	Filename for the Natural Lands Main File (maximum 1000 characters); leave blank if native and/or riparian vegetation lands are not simulated
RFFL	File that lists the return flow fractions (maximum 1000 characters); leave blank if only native and/or riparian vegetation lands are simulated
RUFL	File that lists the irrigation water re-use factors (maximum 1000 characters); leave blank if only native and/or riparian vegetation lands are simulated
IPFL	File that lists the irrigation periods for each ponded and non-ponded crop (maximum 1000 characters); this is a required file even if ponded and non-ponded crops are not simulated
MSRCFL	File that lists generic source of moisture rates other than precipitation and irrigation (maximum 1000 characters); leave blank if there are no generic sources of moisture simulated
AGWDFL	File that lists agricultural water supply requirement (maximum 1000 characters); leave blank if agricultural water supply requirement for all crops will be computed dynamically

LWUBUDFL	HDF5 output file for subregional land and water use budget (maximum 1000 characters); leave blank if this output is not required
RZBUDFL	HDF5 output file for subregional root zone moisture (maximum 1000 characters); leave blank if this output is not required
FNSMFL	Output file for end-of-simulation soil moisture (maximum 1000 characters); leave blank if this output is not required

Soil Parameters and Surface Flow Destinations

In this section soil parameters, precipitation rates, generic soil moisture sources (if any) and surface runoff destinations are listed for each finite element.

FACTK	Conversion factor for the spatial component of the root zone hydraulic conductivity
FACTCPRISE	Conversion factor for capillary rise
TUNITK	Time unit of root zone hydraulic conductivity this should be one of the units recognized by HEC-DSS that are listed in the IDC Main Input File
IE	Element identification number
WP	Wilting point; [L/L]
FC	Field capacity; [L/L]
TN	Total porosity; [L/L]
LAMBDA	Pore size distribution index
K	Saturated hydraulic conductivity; [L/T]
RHC	Method to represent hydraulic conductivity versus moisture content curve (1 = Campbell's equation, 2 = van Genucten-Mualem equation)
CPRISE	Capillary rise; [L]
IRNE	Precipitation rate; this number corresponds to the appropriate data column in the Precipitation File
FRNE	Factor to convert rainfall at the precipitation data column IRNE to rainfall at element IE
IMSRC	Generic source of moisture; this number corresponds to the appropriate data column in the Generic Moisture Source File

	that applies to element IE (enter any number if the Generic Moisture Source File, MSRCFL, is not defined)
TYPDEST	Destination type for the surface flow from element IE (0 = surface flow goes outside of model area, 1 = surface flow goes to a stream node, 3 = surface flow goes to a lake, 5 = surface flow recharges the groundwater)
DEST	Destination identification number for the surface flow from element IE; enter any number if surface flow from the element goes outside the model area (TYPDEST = 0) or recharges the groundwater (TYPDEST = 5)
KPonded	Saturated hydraulic conductivity to be used for ponded crops in the element (enter −1.0 if KPonded is the same as K); [L/T]

```
#4.1
C***  DO NOT DELETE ABOVE LINE ***
C
C*****************************************************************************
C
C                   INTEGRATED WATER FLOW MODEL (IWFM)
C
C*****************************************************************************
C
C                     ROOT ZONE PARAMETERS DATA FILE
C                          Root Zone Component
C                          *** Version 4.1 ***
C
C
C              Project:  IDC Version ### Release
C                        California Department of Water Resources
C              Filename: ROOTZONE_MAIN.dat
C
C*****************************************************************************
C                            File Description
C
C   This data file contains the parameters and data file names for the simulation
C   of root zone processes.
C
C*****************************************************************************
C                 Root Zone Simulation Scheme Control and File Names
C
C   RZCONV   ;  Convergence criteria for iterative soil moisture accounting as a
C                fraction of total porosity; [L/L]
C   RZITERMX ;  Maximum number of iterations for iterative soil moisture accounting
C   FACTCN   ;  Conversion factor to convert inches to the simulation unit of length
C   GWUPTK   ;  Flag to turn on or off the root water uptake from groundwater
C                0 = DO NOT allow root water uptake from groundwater
C                1 = Allow root water uptake from groundwater
C   AGNPFL   ;  Non-ponded agricultural crop data file (max. 1000 characters)
C                * Leave blank if non-ponded crops are not simulated
C   PFL      ;  Rice/refuge data file (max. 1000 characters)
C                * Leave blank if rice and/or refuge lands are not simulated
C   URBFL    ;  Urban lands data file (max. 1000 characters)
C                * Leave blank if urban lands are not simulated
C   NVRVFL   ;  Native/riparian vegetation lands data file (max. 1000 characters)
C                * Leave blank if native and/or riparion veg. lands are not simulated
C   RFFL     ;  File that lists the return flow fractions (max. 1000 characters)
C                * Leave blank if only native/riparian vegetation lands are simulated
C   RUFL     ;  File that lists the irrigation water re-use factors (max. 1000 characters)
C                * Leave blank if only native/riparian vegetation lands are simulated
C   IPFL     ;  File that lists the irrigation periods for each ponded and
C                non-ponded crop (max. 1000 characters)
C                * Leave blank if both ponded and non-ponded crops are not simulated
C   MSRCFL   ;  File that lists generic source of moisture rates other than precipitation
C                and irrigation (max. 1000 characters)
C                * Leave blank if there are no generic sources of moisture simulated
C   AGWDFL   ;  File that lists agricultural water supply requirement (max. 1000 characters)
C                * Leave blank if agricultural water supply requirement will be computed
C                  dynamically
C   LWUBUDFL ;  HDF5 output file for land and water use budget at each
C                  subregion (max. 1000 characters)
C                * Leave blank if this output is not required
C   RZBUDFL  ;  HDF5 output file for root zone moisture budget at each
C                  subregion (max. 1000 characters)
C                * Leave blank if this output is not required
C   FNSMFL   ;  Output file for end-of-simulation soil moisture (max. 1000 characters)
C                * Leave blank if this output is not required
C
C-----------------------------------------------------------------------------------------
C          VALUE                                    DESCRIPTION
C-----------------------------------------------------------------------------------------
           0.0001                                   / RZCONV
           200                                      / RZITERMX
           0.08333                                  / FACTCN
           1                                        / GWUPTK
           RootZone\NonPondedAg\NonPondedAg.dat     / AGNPFL
           RootZone\PondedAg\PondedAg.dat           / PFL
           RootZone\Urban\Urban.dat                 / URBFL
           RootZone\NVRV\NVRV.dat                   / NVRVFL
           RootZone\ReturnFlowFrac.dat              / RFFL
           RootZone\ReuseFrac.dat                   / RUFL
           RootZone\IrrigPeriod.dat                 / IPFL
                                                    / MSRCFL
           RootZone\AgWaterDemand.dat               / AGWDFL
           Budget\LWU.hdf                           / LWUBUDFL
           Budget\RZ.hdf                            / RZBUDFL
                                                    / FNSMFL
C*****************************************************************************
C              Parameters for Soil, Precipitation and Runoff Destination
C
C   Enter conversion factors.
C
C   FACTK      ;  Conversion factor for root zone hydraulic conductivity
C                   It is used to convert only the spatial component of the unit;
C                   DO NOT include the conversion factor for time component of the unit.
C                   * e.g. Unit of hydraulic conductivity listed in this file = IN/DAY
C                          Consistent unit used in simulation                = FT/MONTH
C                          Enter FACT (IN/MONTH -> FT/MONTH)                  = 8.33333E-02
C                          (conversion of DAY -> MONTH is performed automatically)
C   FACTCPRISE;  Conversion factor for capillary rise
C   TUNITK     ;  Time unit of root zone hydraulic conductivity.  This should be one of the
C                   units recognized by HEC-DSS that are listed in the Main Control File.
C
C-----------------------------------------------------------------------------------------
C          VALUE                                    DESCRIPTION
C-----------------------------------------------------------------------------------------
           0.283464                                 / FACTK          (micrometers/sec -> ft/day)
           1.0                                      / FACTCPRISE
           1day                                     / TUNITK
C-----------------------------------------------------------------------------------------
C
C   Enter soil parameters, precipitaion and surface flow destination data below for each
C   grid element.
C
C   IE     ;  Element ID
C   WP     ;  Wilting point; [L/L]
```

```
C   FC     ;  Field capacity; [L/L]
C   TN     ;  Total porosity; [L/L]
C   LAMBDA ;  Pore size distribution index; [dimensionless]
C   K      ;  Saturated hydraulic conductivity; [L/T]
C   RHC    ;  Method to represent hydraulic conductivity vs. moisture content curve
C               1 = Campbell's equation
C               2 = van Genucten-Mualem equation
C   CPRISE ;  Capillary rise; [L]
C   IRNE   ;  Precipitation data column in the Precipitation file that applies to element IE
C   FRNE   ;  Factor to convert rainfall at the precipitation data column to
C               rainfall at element IE
C   IMSRC  ;  Generic source of moisture data column in the Generic Moisture Source file (MSRCFL
C               file listed above) that applies to element IE
C               * Note: Enter any number if MSRCFL above is left blank
C   TYPDEST;  Destination type for the surface flow from element IE
C               0 = Surface flow goes outside of model area
C               1 =   "       "    "  to a stream node
C               3 =   "       "    "   " a lake
C               5 =   "       "    "   " groundwater
C   DEST   ;  Destination for the surface flow from element IE
C               * Note: Enter any number if TYPDEST is set to 0 or 5
C   KPonded;  Saturated hydraulic conductivity to be used for ponded crops in the element; [L/T]
C               * Note: Enter -1.0 if KPonded is the same as K
C
C------------------------------------------------------------------------------------------------------------------
C  IE      WP      FC      TN      LAMBDA   K        RHC    CPRISE  IRNE    FRNE    IMSRC  TYPDEST  DEST   KPonded
C------------------------------------------------------------------------------------------------------------------
   1       0.00    0.137   0.453   0.378    5.0E-02   2     10.0    1       1.0      0      0        3     -1.0
   2       0.00    0.157   0.464   0.242    5.1E+01   2     10.0    1       1.0      0      0        3     -1.0
   3       0.00    0.105   0.463   0.252    5.0E-02   2     10.0    1       1.0      0      0        3     -1.0
   .         .       .       .       .        .       .      .      .        .       .      .        .       .
   .         .       .       .       .        .       .      .      .        .       .      .        .       .
   .         .       .       .       .        .       .      .      .        .       .      .        .       .
   220     0.00    0.121   0.430   0.223    5.0E-02   2     10.0    3       1.0      0      0        3     1.0E-03
   221     0.00    0.048   0.453   0.378    5.0E-02   2     10.0    3       1.0      0      0        0     1.0E-03
   222     0.00    0.232   0.501   0.234    1.9E+01   2     10.0    3       1.0      0      0        0     1.0E-03
   223     0.00    0.121   0.430   0.223    5.0E-02   2     10.0    3       1.0      0      0        3     1.0E-03
```

8.3.10.2. Native and Riparian Vegetation Component Files

8.3.10.2.a Native and Riparian Vegetation Lands Main File

The Native and Riparian Vegetation Lands Main File is the gateway file for all data that is necessary to simulate land surface and root zone flow processes in areas that are covered with native and riparian vegetation.

The file is divided into several sections and uses the following variables:

Land-Use Areas

The filename for the native and riparian areas data file is listed in this section:

LUFLNVRV	File that lists the urban areas (maximum 1000 characters)

Rooting Depths

FACT	Conversion factor for native and riparian vegetation root zone depths
ROOTNV	Root zone depth for native vegetation; [L]
ROOTRV	Root zone depth for riparian vegetation; [L]

Native and Riparian Vegetation Simulation Parameters

IE	Element identification number entered sequentially; enter 0 if the following values are to be used for all elements
CNNV	Curve number for native vegetation lands
CNRV	Curve number for riparian vegetation lands
ICETNV	Native vegetation evapotranspiration rate; this number corresponds to the appropriate data column in the Evapotranspiration File listed in the IDC Main Input File
ICETRV	Riparian vegetation evapotranspiration rate; this number corresponds to the appropriate data column in the Evapotranspiration File listed in the IDC Main Input File
ISTRMRV	Stream node at which water will be used to satisfy unmet riparian evapotranspirative demand in element IE; enter 0 if riparian vegetation in element IE has no access to a stream node

Initial Soil Moisture Conditions

The initial soil moisture contents for native and riparian vegetation at each element are listed in this section.

IE	Element identification number; enter 0 if following values are to be used for all elements
SOILM_NV	Initial root zone moisture content for native vegetation at element IE; [L/L]
SOILM_RV	Initial root zone moisture content for riparian vegetation at element IE; [L/L]

```
C*******************************************************************************
C
C                  INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                 NATIVE AND RIPARIAN VEGETATION DATA FILE
C                         Root Zone Component
C                         *** Version 4.1 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: NVRV_MAIN.dat
C
C*******************************************************************************
C                          File Description
C
C   This data file contains the parameters and data file names for the simulation
C   of root zone processes for native and riparian vegetation.
C
C*******************************************************************************
C                         Land Use Areas
C
C   LUFLNVRV   ;  File that lists the land use areas (max. 1000 characters)
C
C-------------------------------------------------------------------------------
    RootZone\NVRV\NVRVArea.dat                     / LUFLNVRV
C*******************************************************************************
C                              Rooting Depths
C
C   FACT  ;  Conversion factor for root zone depths
C   ROOTNV;  Native veg. root zone depth; [L]
C   ROOTRV;  Riparian veg. root zone depth; [L]
C
C-------------------------------------------------------------------------------
C   VALUE                 DESCRIPTION
C-------------------------------------------------------------------------------
    1.0                   / FACT
    3.0                   / ROOTNV
    3.0                   / ROOTRV
C*******************************************************************************
C         Native and Riparian Vegetation Root Zone Simulation Parameters
C
C   IE       ;  Element ID (0 if following values are to be used for all elements)
C   CNNV     ;  Curve number for native vegetation lands
C   CNRV     ;  Curve number for riparian vegetation lands
C   ICETNV   ;  Native vegetation ETc - this number corresponds to the appropriate
C                 data column in the ET data file listed in the Main Control Data file.
C   ICETRV   ;  Riparian vegetation ETc - this number corresponds to the appropriate
C                 data column in the ET data file listed in the Main Control Data file.
C   ISTRMRV  ;  Stream node at which water will be used to satisfy unmet riparain ET
C                 requirement in element IE
C                 * Enter 0 if riparian vegetation in element IE has no access to a
C                   stream node
C
C-------------------------------------------------------------------------------
C   IE    CNNV    CNRV    ICETNV    ICETRV    ISTRMRV
C-------------------------------------------------------------------------------
    1       71     71       21        22        23
    2       71     71       21        22        23
    3       58     58       21        22        0
    .       .      .        .         .         .
    .       .      .        .         .         .
    .       .      .        .         .         .
    221     71     71       21        22        78
    222     58     58       21        22        0
    223     58     58       21        22        0
C*******************************************************************************
C                       Initial Soil Moisture Condition
C                   For Native and Riparian Vegetation Areas
C
C   IE       ;  Element ID (0 if following values are to be used for all elements)
C   SOILM_NV;   Initial root zone moisture content for native vegetation area; [L/L]
C   SOILM_RV;   Initial root zone moisture content for riparian vegetation area; [L/L]
C
C----------------------------------------------------------------------------
C   IE     SOILM_NV     SOILM_RV
C----------------------------------------------------------------------------
    1       0.1370       0.1370
    2       0.1571       0.1571
    3       0.1053       0.1053
    .         .            .
    .         .            .
    .         .            .
    221     0.0485       0.0485
    222     0.2322       0.2322
    223     0.1210       0.1210
```

8.3.11. Input Files for Root Zone Component Version 4.11

All input files for the root zone component version 4.11 except the Root Zone Component Main File are the same as those for the component version 4.1. Therefore, only the Root Zone Component Main File for version 4.11 will be explained in this section. For a detailed description of the other input files, please refer to section 8.3.10.

8.3.11.1. Root Zone Component Main File

This file is exactly the same as that for the root zone component version 4.1, except that it allows the specification of two additional filenames to print out cell-level Land and Water Use as well as the Root Zone budget data. These output files are optional and are generated as HDF5 files. They can later be post-processed using the Z-Budget post-processor to generate water budgets for "*zones*" which are groups of cells defined by the user.

The following sections and variables are defined in the rest of this file:

Root Zone Simulation Scheme Control and Filenames

In this section convergence criteria for the iterative solution methodology and names of additional input and output files are listed.

RZCONV	Convergence criteria for iterative soil moisture accounting as a fraction of total porosity; [L/L]
RZITERMX	Maximum number of iterations for iterative soil moisture accounting
FACTCN	Conversion factor to convert inches to the simulation unit of length
GWUPTK	Flag to turn on or off the root water uptake from groundwater (0 = root water uptake from groundwater is NOT simulated; 1 = root water uptake from groundwater is simulated); this flag is effective only when IDC is executed when linked to an integrated hydrologic model such as IWFM
AGNPFL	Filename for the Non-Ponded Crops Main File (maximum 1000 characters); leave blank if non-ponded crops are not simulated

PFL	Filename for the Ponded Crops Main File (maximum 1000 characters); leave blank if rice and/or refuge lands are not simulated
URBFL	Filename for the Urban Lands Main File (maximum 1000 characters); leave blank if urban lands are not simulated
NVRVFL	Filename for the Natural Lands Main File (maximum 1000 characters); leave blank if native and/or riparian vegetation lands are not simulated
RFFL	File that lists the return flow fractions (maximum 1000 characters); leave blank if only native and/or riparian vegetation lands are simulated
RUFL	File that lists the irrigation water re-use factors (maximum 1000 characters); leave blank if only native and/or riparian vegetation lands are simulated
IPFL	File that lists the irrigation periods for each ponded and non-ponded crop (maximum 1000 characters); this is a required file even if ponded and non-ponded crops are not simulated
MSRCFL	File that lists generic source of moisture rates other than precipitation and irrigation (maximum 1000 characters); leave blank if there are no generic sources of moisture simulated
AGWDFL	File that lists agricultural water supply requirement (maximum 1000 characters); leave blank if agricultural water supply requirement for all crops will be computed dynamically
LWUBUDFL	HDF5 output file for subregional land and water use budget (maximum 1000 characters); leave blank if this output is not required
RZBUDFL	HDF5 output file for subregional root zone moisture (maximum 1000 characters); leave blank if this output is not required
ZLWUBUDFL	HDF5 output file for land and water use zone budget post-processor (maximum 1000 characters); leave blank if this output is not required

ZRZBUDFL	HDF5 output file for root zone zone budget post-processor (maximum 1000 characters); leave blank if this output is not required
FNSMFL	Output file for end-of-simulation soil moisture (maximum 1000 characters); leave blank if this output is not required

Soil Parameters and Surface Flow Destinations

In this section soil parameters, precipitation rates, generic soil moisture sources (if any) and surface runoff destinations are listed for each finite element.

FACTK	Conversion factor for the spatial component of the root zone hydraulic conductivity
FACTCPRISE	Conversion factor for capillary rise
TUNITK	Time unit of root zone hydraulic conductivity this should be one of the units recognized by HEC-DSS that are listed in the IDC Main Input File
IE	Element identification number
WP	Wilting point; [L/L]
FC	Field capacity; [L/L]
TN	Total porosity; [L/L]
LAMBDA	Pore size distribution index
K	Saturated hydraulic conductivity; [L/T]
RHC	Method to represent hydraulic conductivity versus moisture content curve (1 = Campbell's equation, 2 = van Genucten-Mualem equation)
CPRISE	Capillary rise; [L]
IRNE	Precipitation rate; this number corresponds to the appropriate data column in the Precipitation File
FRNE	Factor to convert rainfall at the precipitation data column IRNE to rainfall at element IE
IMSRC	Generic source of moisture; this number corresponds to the appropriate data column in the Generic Moisture Source File that applies to element IE (enter any number if the Generic Moisture Source File, MSRCFL, is not defined)
TYPDEST	Destination type for the surface flow from element IE (0 = surface flow goes outside of model area, 1 = surface flow goes

	to a stream node, 3 = surface flow goes to a lake, 5 = surface flow recharges the groundwater)
DEST	Destination identification number for the surface flow from element IE; enter any number if surface flow from the element goes outside the model area (TYPDEST = 0) or recharges the groundwater (TYPDEST = 5)
KPonded	Saturated hydraulic conductivity to be used for ponded crops in the element (enter –1.0 if KPonded is the same as K); [L/T]

```
#4.11
C***  DO NOT DELETE ABOVE LINE ***
C
C*****************************************************************************
C
C                   INTEGRATED WATER FLOW MODEL (IWFM)
C
C*****************************************************************************
C
C                     ROOT ZONE PARAMETERS DATA FILE
C                          Root Zone Component
C                          *** Version 4.11 ***
C
C
C              Project:  IDC Version ### Release
C                        California Department of Water Resources
C              Filename: ROOTZONE_v411_MAIN.dat
C
C*****************************************************************************
C                           File Description
C
C   This data file contains the parameters and data file names for the simulation
C   of root zone processes.
C
C*****************************************************************************
C                 Root Zone Simulation Scheme Control and File Names
C
C   RZCONV   ;  Convergence criteria for iterative soil moisture accounting as a
C                fraction of total porosity; [L/L]
C   RZITERMX ;  Maximum number of iterations for iterative soil moisture accounting
C   FACTCN   ;  Conversion factor to convert inches to the simulation unit of length
C   GWUPTK   ;  Flag to turn on or off the root water uptake from groundwater
C                0 = DO NOT allow root water uptake from groundwater
C                1 = Allow root water uptake from groundwater
C   AGNPFL   ;  Non-ponded agricultural crop data file (max. 1000 characters)
C                * Leave blank if non-ponded crops are not simulated
C   PFL      ;  Rice/refuge data file (max. 1000 characters)
C                * Leave blank if rice and/or refuge lands are not simulated
C   URBFL    ;  Urban lands data file (max. 1000 characters)
C                * Leave blank if urban lands are not simulated
C   NVRVFL   ;  Native/riparian vegetation lands data file (max. 1000 characters)
C                * Leave blank if native and/or riparion veg. lands are not simulated
C   RFFL     ;  File that lists the return flow fractions (max. 1000 characters)
C                * Leave blank if only native/riparian vegetation lands are simulated
C   RUFL     ;  File that lists the irrigation water re-use factors (max. 1000 characters)
C                * Leave blank if only native/riparian vegetation lands are simulated
C   IPFL     ;  File that lists the irrigation periods for each ponded and
C                non-ponded crop (max. 1000 characters)
C                * Leave blank if both ponded and non-ponded crops are not simulated
C   MSRCFL   ;  File that lists generic source of moisture rates other than precipitation
C                and irrigation (max. 1000 characters)
C                * Leave blank if there are no generic sources of moisture simulated
C   AGWDFL   ;  File that lists agricultural water supply requirement (max. 1000 characters)
C                * Leave blank if agricultural water supply requirement will be computed
C                  dynamically
C   LWUBUDFL ;  HDF5 output file for land and water use budget at each
C                  subregion (max. 1000 characters)
C                * Leave blank if this output is not required
C   RZBUDFL  ;  HDF5 output file for root zone moisture budget at each
C                  subregion (max. 1000 characters)
C                * Leave blank if this output is not required
C   ZLWUBUDFL;  HDF5 output file for land and water use zone budget
C                  post-processor (max. 1000 characters)
C                 * Leave blank if this output is not required
C   ZRZBUDFL ;  HDF5 output file for root zone zone budget
C                  post-processor (max. 1000 characters)
C                 * Leave blank if this output is not required
C   FNSMFL   ;  Output file for end-of-simulation soil moisture (max. 1000 characters)
C                * Leave blank if this output is not required
C
C-----------------------------------------------------------------------------------------
C         VALUE                                      DESCRIPTION
C-----------------------------------------------------------------------------------------
          0.0001                                     / RZCONV
          200                                        / RZITERMX
          0.08333                                    / FACTCN
          1                                          / GWUPTK
          RootZone\NonPondedAg\NonPondedAg.dat       / AGNPFL
          RootZone\PondedAg\PondedAg.dat             / PFL
          RootZone\Urban\Urban.dat                   / URBFL
          RootZone\NVRV\NVRV.dat                     / NVRVFL
          RootZone\ReturnFlowFrac.dat                / RFFL
          RootZone\ReuseFrac.dat                     / RUFL
          RootZone\IrrigPeriod.dat                   / IPFL
                                                     / MSRCFL
          RootZone\AgWaterDemand.dat                 / AGWDFL
          Budget\LWU.hdf                             / LWUBUDFL
          Budget\RZ.hdf                              / RZBUDFL
          ZBudget\LWU_ZBud.hdf                       / ZLWUBUDFL
          ZBudget\RZ_ZBud.hdf                        / ZRZBUDFL
                                                     / FNSMFL
C*****************************************************************************
C              Parameters for Soil, Precipitation and Runoff Destination
C
C   Enter conversion factors.
C
C   FACTK      ;  Conversion factor for root zone hydraulic conductivity
C                  It is used to convert only the spatial component of the unit;
C                  DO NOT include the conversion factor for time component of the unit.
C                  * e.g. Unit of hydraulic conductivity listed in this file = IN/DAY
C                         Consistent unit used in simulation                = FT/MONTH
C                         Enter FACT (IN/MONTH -> FT/MONTH)                 = 8.33333E-02
C                         (conversion of DAY -> MONTH is performed automatically)
C   FACTCPRISE;  Conversion factor for capillary rise
C   TUNITK     ;  Time unit of root zone hydraulic conductivity.  This should be one of the
C                  units recognized by HEC-DSS that are listed in the Main Control File.
C
C-----------------------------------------------------------------------------------------
C         VALUE                                      DESCRIPTION
C-----------------------------------------------------------------------------------------
          0.283464                                   / FACTK          (micrometers/sec -> ft/day)
          1.0                                        / FACTCPRISE
```

```
         1day                                      / TUNITK
C-----------------------------------------------------------------------------------------
C
C   Enter soil parameters, precipitaion and surface flow destination data below for each
C   grid element.
C
C   IE     ;  Element ID
C   WP     ;  Wilting point; [L/L]
C   FC     ;  Field capacity; [L/L]
C   TN     ;  Total porosity; [L/L]
C   LAMBDA ;  Pore size distribution index; [dimensionless]
C   K      ;  Saturated hydraulic conductivity; [L/T]
C   RHC    ;  Method to represent hydraulic conductivity vs. moisture content curve
C               1 = Campbell's equation
C               2 = van Genucten-Mualem equation
C   CPRISE ;  Capillary rise; [L]
C   IRNE   ;  Precipitation data column in the Precipitation file that applies to element IE
C   FRNE   ;  Factor to convert rainfall at the precipitation data column to
C               rainfall at element IE
C   IMSRC  ;  Generic source of moisture data column in the Generic Moisture Source file (MSRCFL
C               file listed above) that applies to element IE
C               * Note: Enter any number if MSRCFL above is left blank
C   TYPDEST;  Destination type for the surface flow from element IE
C               0 = Surface flow goes outside of model area
C               1 =   "       "    "  to a stream node
C               3 =   "       "    "   " a lake
C               5 =   "       "    "   " groundwater
C   DEST   ;  Destination for the surface flow from element IE
C               * Note: Enter any number if TYPDEST is set to 0 or 5
C   KPonded;  Saturated hydraulic conductivity to be used for ponded crops in the element; [L/T]
C               * Note: Enter -1.0 if KPonded is the same as K
C
C----------------------------------------------------------------------------------------------------------------
C  IE      WP      FC      TN      LAMBDA   K       RHC    CPRISE  IRNE    FRNE   IMSRC  TYPDEST  DEST   KPonded
C----------------------------------------------------------------------------------------------------------------
   1       0.00    0.137   0.453   0.378    5.0E-02   2    10.0    1       1.0      0      0       3     -1.0
   2       0.00    0.157   0.464   0.242    5.1E+01   2    10.0    1       1.0      0      0       3     -1.0
   3       0.00    0.105   0.463   0.252    5.0E-02   2    10.0    1       1.0      0      0       3     -1.0
   .        .       .       .       .        .        .    .       .        .       .      .       .       .
   .        .       .       .       .        .        .    .       .        .       .      .       .       .
   .        .       .       .       .        .        .    .       .        .       .      .       .       .
   220     0.00    0.121   0.430   0.223    5.0E-02   2    10.0    3       1.0      0      0       3     1.0E-03
   221     0.00    0.048   0.453   0.378    5.0E-02   2    10.0    3       1.0      0      0       0     1.0E-03
   222     0.00    0.232   0.501   0.234    1.9E+01   2    10.0    3       1.0      0      0       0     1.0E-03
   223     0.00    0.121   0.430   0.223    5.0E-02   2    10.0    3       1.0      0      0       3     1.0E-03
```

8.3.12. Input Files for Root Zone Component Version 5.0

Root zone component version 5.0 simulates root zone flow processes for each land-use and soil type combinations for user-defined number of soil types. Additionally, agricultural water demand and agricultural root zone flow processes are calculated for an average crop over each soil type defined by the user. The average agricultural crop characteristics are calculated with respect to the area of each crop in a subregion. In other words, it is assumed that each model subregion has a different average crop with different crop characteristics. The following sections describe the input files used for the root zone component version 5.0.

8.3.12.1. Root Zone Component Main File

The Root Zone Component Main File includes the convergence criteria for the iterative solution of the non-linear soil moisture mass balance equation, names of additional input files that are used to simulate land surface and root zone flow processes for agricultural, urban and natural lands, and agricultural and urban water demands. Subregional and cell-level Land and Water Use as well as the Root Zone Moisture budget output filenames are also listed in this file. Number of soil types that are simulated, soil parameters for the soil types at each subregion and a list of grid cells specifying the soil type that each cell belongs to and the destination of surface runoff from each cell are included in this file.

First data line of the Root Zone Component Main File lists the version number (i.e. 5.0) of the root zone component that will be used in simulating the land surface and root zone flow processes. IDC first reads this data line to figure out what other parameters will be read and what flow processes are to be simulated. This first line of data entry must not be modified.

The following sections and variables are defined in the rest of this file:

Root Zone Simulation Scheme Control and Filenames

In this section convergence criteria for the iterative solution methodology and names of additional input and output files are listed.

RZCONV — Convergence criteria for iterative soil moisture accounting as a fraction of total porosity; [L/L]

RZITERMX	Maximum number of iterations for iterative soil moisture accounting
NSOIL	Number of simulated soil types
FACTCN	Conversion factor to convert inches to the simulation unit of length
AGFL	Filename for the agricultural Lands Main File (maximum 1000 characters); leave blank if non-ponded crops are not simulated
URBFL	Filename for the Urban Lands Main File (maximum 1000 characters); leave blank if urban lands are not simulated
NVRVFL	Filename for the Natural Lands Main File (maximum 1000 characters); leave blank if native and/or riparian vegetation lands are not simulated
RFFL	File that lists the return flow fractions (maximum 1000 characters); leave blank if only native and/or riparian vegetation lands are simulated
RUFL	File that lists the irrigation water re-use factors (maximum 1000 characters); leave blank if only native and/or riparian vegetation lands are simulated
MSRCFL	File that lists generic source of moisture rates other than precipitation and irrigation (maximum 1000 characters); leave blank if there are no generic sources of moisture simulated
LWUBUDFL	HDF5 output file for subregional land and water use budget (maximum 1000 characters); leave blank if this output is not required
RZBUDFL	HDF5 output file for subregional root zone moisture (maximum 1000 characters); leave blank if this output is not required
ZLWUBUDFL	HDF5 output file for land and water use zone budget post-processor (maximum 1000 characters); eave blank if this output is not required
ZRZBUDFL	HDF5 output file for root zone zone budget post-processor (maximum 1000 characters); leave blank if this output is not required

FNSMFL	Output file for end-of-simulation soil moisture (maximum 1000 characters); leave blank if this output is not required

Soil Parameters

In this section soil parameters and generic soil moisture sources (if any) are listed for each subregion and soil type combination.

FACTK	Conversion factor for the spatial component of the root zone hydraulic conductivity
TUNITK	Time unit of root zone hydraulic conductivity; this should be one of the units recognized by HEC-DSS that are listed in the IDC Main Input File
IR	Subregion identification number
WP	Wilting point; [L/L]
FC	Field capacity; [L/L]
TN	Total porosity; [L/L]
LAMBDA	Pore size distribution index
K	Saturated hydraulic conductivity; [L/T]
RHC	Method to represent hydraulic conductivity versus moisture content curve (1 = Campbell's equation, 2 = van Genucten-Mualem equation)
IMSRC	Generic source of moisture; this number corresponds to the appropriate data column in the Generic Moisture Source File that applies to element IE (enter any number if the Generic Moisture Source File, MSRCFL, is not defined)

Element Soil Type, Precipitation and Flow Destination Characteristics

This section lists the soil type at each element, precipitation rate and the surface flow destination for each element.

IE	Element identification number
ISLID	Soil type at element IE
IRNE	Precipitation rate; this number corresponds to the appropriate data column in the Precipitation File
FRNE	Factor to convert rainfall at the precipitation data column IRNE to rainfall at element IE

TYPDEST	Destination type for the surface flow from element IE (0 = surface flow goes outside of model area, 1 = surface flow goes to a stream node, 3 = surface flow goes to a lake, 5 = surface flow recharges the groundwater)
DEST	Destination identification number for the surface flow from element IE; enter any number if surface flow from the element goes outside the model area (TYPDEST = 0) or recharges the groundwater (TYPDEST = 5)

```
#5.0
C***  DO NOT DELETE ABOVE LINE ***
C
C*******************************************************************************
C
C                  INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                    ROOT ZONE PARAMETERS DATA FILE
C                         Root Zone Component
C                         *** Version 5.0 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: ROOTZONE_v50_MAIN.dat
C
C*******************************************************************************
C                           File Description
C
C   This data file contains the parameters and data file names for the simulation
C   of root zone processes.
C
C*******************************************************************************
C                 Root Zone Simulation Scheme Control and File Names
C
C   RZCONV   ;  Convergence criteria for iterative soil moisture accounting as a
C                fraction of total porosity; [L/L]
C   RZITERMX ;  Maximum number of iterations for iterative soil moisture accounting
C   NSOIL    ;  Number of simulated soil types
C   FACTCN   ;  Conversion factor to convert inches to the simulation unit of length
C   AGFL     ;  Agricultural lands data file (max. 1000 characters)
C                * Leave blank if agricultural lands are not simulated
C   URBFL    ;  Urban lands data file (max. 1000 characters)
C                * Leave blank if urban lands are not simulated
C   NVRVFL   ;  Native/riparian vegetation lands data file (max. 1000 characters)
C                * Leave blank if native and/or riparion veg. lands are not simulated
C   RFFL     ;  File that lists the return flow fractions (max. 1000 characters)
C                * Leave blank if only native/riparian vegetation lands are simulated
C   RUFL     ;  File that lists the irrigation water re-use factors (max. 1000 characters)
C                * Leave blank if only native/riparian vegetation lands are simulated
C   MSRCFL   ;  File that lists generic source of moisture rates other than precipitation
C                and irrigation (max. 1000 characters)
C                * Leave blank if there are no generic sources of moisture simulated
C   LWUBUDFL ;  HDF5 output file for land and water use budget at each
C                  subregion (max. 1000 characters)
C                * Leave blank if this output is not required
C   RZBUDFL  ;  HDF5 output file for root zone moisture budget at each
C                  subregion (max. 1000 characters)
C                * Leave blank if this output is not required
C   ZLWUBUDFL;  HDF5 output file for land and water use zone budget
C                  post-processor (max. 1000 characters)
C                 * Leave blank if this output is not required
C   ZRZBUDFL ;  HDF5 output file for root zone zone budget
C                  post-processor (max. 1000 characters)
C                 * Leave blank if this output is not required
C   FNSMFL   ;  Output file for end-of-simulation soil moisture (max. 1000 characters)
C                * Leave blank if this output is not required
C
C-----------------------------------------------------------------------------------------
C         VALUE                                         DESCRIPTION
C-----------------------------------------------------------------------------------------
      0.0001                                          / RZCONV
      200                                             / RZITERMX
      4                                               / NSOIL
      0.083333                                        / FACTCN
      Ag_MAIN.dat                                     / AGFL
      Urban_MAIN.dat                                  / URBFL
      NativeVeg_MAIN.dat                              / NVRVFL
      ReturnFlowFrac.dat                              / RFFL
      ReuseFrac.dat                                   / RUFL
                                                      / MSRCFL
      ..\Results\LWU.hdf                              / LWUBUDFL
      ..\Results\RZ.hdf                               / RZBUDFL
      ..\Results\LWU_ZBud.hdf                         / ZLWUBUDFL
      ..\Results\RZ_ZBud.hdf                          / ZRZBUDFL
      FinRootZone.out                                 / FNSMFL
C*******************************************************************************
C                                   Soil Parameters
C
C   Enter conversion factors.
C
C   FACTK  ;  Conversion factor for root zone hydraulic conductivity
C              It is used to convert only the spatial component of the unit;
C              DO NOT include the conversion factor for time component of the unit.
C              * e.g. Unit of hydraulic conductivity listed in this file = IN/DAY
C                     Consistent unit used in simulation                = FT/MONTH
C                     Enter FACT (IN/MONTH -> FT/MONTH)                 = 8.33333E-02
C                     (conversion of DAY -> MONTH is performed automatically)
C   TUNITK ;  Time unit of root zone hydraulic conductivity.  This should be one of the
C             units recognized by HEC-DSS that are listed in the Main Control File.
C
C-----------------------------------------------------------------------------------------
C         VALUE                                         DESCRIPTION
C-----------------------------------------------------------------------------------------
          1.9685e-4                                   / FACTK    (micrometer/sec -> ft/min)
          1min                                        / TUNITK
C-----------------------------------------------------------------------------------------
C
C   Enter soil parameters for each soil-subregion combination.
C
C   IR     ;  Subregion ID
C   WP     ;  Wilting point (1 to NSOIL); [L/L]
C   FC     ;  Field capacity (1 to NSOIL); [L/L]
C   TN     ;  Total porosity (1 to NSOIL); [L/L]
C   LAMBDA ;  Pore size distribution index (1 to NSOIL); [dimensionless]
C   K      ;  Saturated hydraulic conductivity (1 to NSOIL); [L/T]
C   RHC    ;  Method to represent hydraulic conductivity vs. moisture content curve (1 to NSOIL)
C               1 = Campbell's equation
C               2 = van Genucten-Mualem equation
C   IMSRC  ;  Generic source of moisture data column in the Generic Moisture Source file, MSRCFL,
```

```
C              listed above (1 to NSOIL)
C              * Note: Enter any number if MSRCFL above is left blank
C
C-----------------------------------------------------------------------------------------------
C  IR    WP[1]       FC[1]       TN[1]       LAMBDA[1]      K[1]       RHC[1]       IMSRC[1]
C        WP[2]       FC[2]       TN[2]       LAMBDA[2]      K[2]       RHC[2]       IMSRC[2]
C         .           .           .           .             .           .            .
C         .           .           .           .             .           .            .
C        WP[NSOIL]   FC[NSOIL]   TN[NSOIL]   LAMBDA[NSOIL]  K[NSOIL]   RHC[NSOIL]   IMSRC[NSOIL]
C-----------------------------------------------------------------------------------------------
    1      0.000       0.067        0.477       0.755         0.250        1             0
           0.000       0.473        0.483       0.755         0.014        1             0
           0.000       0.303        0.385       0.755         0.250        1             0
           0.000       0.333        0.343       0.755         0.250        1             0
    2      0.000       0.089        0.440       0.755         0.500        1             0
           0.000       0.110        0.481       0.755         1.000        1             0
           0.000       0.239        0.477       0.755         0.402        1             0
           0.000       0.111        0.500       0.755         1.000        1             0
    3      0.000       0.119        0.438       0.755         0.620        1             0
           0.000       0.033        0.471       0.755         0.632        1             0
           0.000       0.490        0.500       0.755         0.394        1             0
           0.000       0.031        0.281       0.755         0.053        1             0
             .           .            .           .             .          .             .
             .           .            .           .             .          .             .
             .           .            .           .             .          .             .
   19      0.000       0.080        0.440       0.755         1.000        1             0
           0.000       0.208        0.478       0.755         0.873        1             0
           0.000       0.065        0.389       0.755         0.956        1             0
           0.000       0.322        0.460       0.755         0.993        1             0
   20      0.000       0.081        0.440       0.755         0.850        1             0
           0.000       0.131        0.482       0.755         0.584        1             0
           0.000       0.127        0.389       0.755         0.783        1             0
           0.000       0.094        0.459       0.755         0.843        1             0
   21      0.000       0.080        0.440       0.755         1.000        1             0
           0.000       0.418        0.478       0.755         0.914        1             0
           0.000       0.390        0.400       0.755         0.997        1             0
           0.000       0.234        0.462       0.755         1.000        1             0
C******************************************************************************
C          Soil Type, Precipitation and Runoff Destination for Elements
C
C   Enter soil type, precipitation and surface runoff destination data for each element.
C
C   IE     ;  Element ID
C   ISLID  ;  Soil type ID number
C   IRNE   ;  Precipitation data column in the Precipitation file that applies to element IE
C   FRNE   ;  Factor to convert rainfall at the precipitation data column to
C               rainfall at element IE
C   TYPDEST;  Destination type for the surface flow from element IE
C               0 = Surface flow goes outside of model area
C               1 =   "       "    "  to a stream node
C               3 =   "       "    "   " a lake
C               5 =   "       "    "   " groundwater
C   DEST   ;  Destination for the surface flow from element IE
C               * Note: Enter any number if TYPDEST is set to 0 or 5
C
C-----------------------------------------------------------------------------------------------
C    IE   ISLID   IRNE     FRNE   TYPDEST    DEST
C-----------------------------------------------------------------------------------------------
      1     3       1       1.0      1       207
      2     3       2       1.0      1       206
      3     3       3       1.0      1       206
      4     3       4       1.0      1       206
      5     4       5       1.0      1       207
      .     .       .        .       .       .
      .     .       .        .       .       .
      .     .       .        .       .       .
   1387     3    1387       1.0      1       9
   1388     2    1388       1.0      1       4
   1389     2    1389       1.0      1       4
   1390     3    1390       1.0      1       9
   1391     2    1391       1.0      1       4
   1392     2    1392       1.0      1       4
```

8.3.12.2. Return Flow Fractions Data File

This file is exactly the same as the Return Flow Fractions Data File for root zone component version 4.0. Refer to section 8.3.8.2 for a detailed explanation of the variables used in this file.

8.3.12.3. Re-use Fractions Data File

This file is exactly the same as the Re-use Fractions Data File for root zone component version 4.0. Refer to section 8.3.8.3 for a detailed explanation of the variables used in this file.

8.3.12.4. Agricultural Lands Component Files

8.3.12.4.a Agricultural Lands Main File

The Agricultural Crops Main File is the gateway file for all data that is necessary to simulate agricultural water demands as well as the land surface and root zone flow processes for the agricultural lands.

The file is divided into several sections and uses the following variables:

General Data

Number of agricultural crops simulated, input files that list the subregional crop and cell-level total agricultural land areas, and the output file to print the average crop characteristics are specified in this section.

NCROP	Number of simulated agricultural crops
LUFLAGSR	File that lists the crop areas at each subregion (maximum 1000 characters)
LUFLAG	File that lists the total agricultural area at each element (maximum 1000 characters)
FACTLTOU	Factor to convert simulation unit of length into the intended output unit to be used in printing average crop characteristics
UNITLTOU	Output length unit for the average crop characteristics (maximum 10 characters)

AVGCRPFL	Output file for the average crop characteristics (maximum 1000 characters); leave blank if this output is not required

Rooting Depths

This section lists the rooting depths for each of the simulated agricultural crop

FACT	Conversion factor for crop root zone depth
ROOTCP	Root zone depth for each of the simulated crops; [L]

Curve Numbers for Rainfall Runoff Simulation

Curve numbers for each subregion and soil type combination are entered in this section.

IR	Subregion identification number entered sequentially; enter 0 if curve numbers defined for each soil type are to be used for all subregions
CNAG	Curve number for each soil type

Crop Evapotranspiration

Crop evapotranspiration for each subregion and crop combination is listed here by specifying a column number in the Evapotranspiration File:

IR	Subregion identification number entered sequentially; enter 0 if following values are to be used for all subregions
ICET	Crop ET; this number corresponds to the appropriate data column the Evapotranspiration File

Irrigation Periods

Time series irrigation period data is listed in this section for each subregion and crop combination:

IPFL	Irrigation period data file (maximum 1000 characters)
IR	Subregion identification number; enter 0 if following values are to be used for all subregions
ICIP	Irrigation period; this number corresponds to the appropriate data column in the Irrigation Period Data File (IPFL)

Minimum Soil Moisture

The minimum soil moisture that is used to trigger an irrigation event for each crop and subregion combination is listed in this section:

MINSMFL	File that lists the minimum soil moisture (maximum 1000 characters)
IR	Subregion identification number; enter 0 if following values are to be used for all subregions
ICMSM	Minimum soil moisture as a fraction of total available water (i.e. field capacity less wilting point); this corresponds to the appropriate data column in the Minimum Soil Moisture Data File (MINSMFL)

Target Soil Moisture for Irrigation

The moisture level which is targeted to be achieved by the irrigation event is listed for each crop and subregion combination in this section:

TRGSMFL	File that lists the target soil moisture during irrigation (maximum 1000 characters); leave blank if target soil moisture is the field capacity
IR	Subregiont identification number; enter 0 if following values are to be used for all subregions
ICTRGSM	Target soil moisture as a fraction of field capacity; this number corresponds to the appropriate data column in the Target Soil Moisture Data File (TRGSMFL)

Agricultural Water Supply, Return Flow and Re-Use Fractions

If the agricultural water supply requirement is pre-specified instead of being computed dynamically, they are specified in this section. Irrigation water return flow and re-use fractions are also listed.

AGWDFL	File that lists the agricultural water supply requirement (maximum 1000 characters); leave blank if agricultural water demand is simulated dynamically
FLDMD	Flag for the root zone moisture to be used for the computation of agricultural water demand and the timing of irrigation (0 = use the soil moisture at the beginning of time step, 1 = use the soil moisture at the end of time step); setting FLDMD to 0 works well when the simulation time step is

	small (e.g. 1 day) while it should be set to 1 when the simulation time step is longer (e.g. 1 month)
IR	Subregion identification number; enter0 if the following values are to be used for all subregions
ICAGWD	Water supply requirement for subregion IR; this number corresponds to the appropriate data column in the Agricultural Water Supply Requirement file (AGWDFL); enter any number if AGWDFL is not specified or enter 0 if agricultural water supply requirement will be computed internally for the subregion
ICRTFAG	Fraction of the agricultural applied water that becomes return flow; this number corresponds to the appropriate data column in Return Flow Factor Data File (RFFL) listed in the Root Zone Main File
ICRUFAG	Fraction of the applied water that is re-used; this number corresponds to the appropriate data column in the Re-use Factor Data File (RUFL) listed in the Root Zone Main File.

Initial Soil Moisture Conditions

IR	Subregion identification number; enter 0 if following values are to be used for all subregions
FSOILMP	Fraction of initial soil moisture at subregion IR that is due to precipitation for each soil type
SOILM	Initial root zone moisture content for agricultural area for each soil type; [L/L]

```
C*******************************************************************************
C
C                 INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                     AGRICULTURAL LANDS DATA FILE
C                        Root Zone Component
C                        *** Version 5.0 ***
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: Ag_MAIN.dat
C
C*******************************************************************************
C                          File Description
C
C   This data file contains the parameters and data file names for the simulation
C   of root zone processes and crop water managament of agricultural lands.
C
C*******************************************************************************
C                     Number of Crops and Land Use Areas
C
C   NCROP    :  Number of simulated agricultrural crops
C   LUFLAGSR ;  File that lists the crop areas at each subregion (max. 1000 characters)
C   LUFLAG   ;  File that lists the total agricultural area at each element (max. 1000 characters)
C   FACTLTOU ;  Factor to convert simulation unit of length into the intended output unit
C                 to be used in printing average crop characteristics
C   UNITLTOU ;  Output length unit for the average crop characteristics (max. 10 characters)
C   AVGCRPFL ;  Output file for the average crop characteristics (max. 1000 characters)
C                 * Leave blank if this output is not required
C
C-------------------------------------------------------------------------------
*     Crop No.                      Name
*   -------------                ----------
*        1                     PA = Pasture
*        2                     AL = Alfalfa
*        3                     SB = Sugar Beets
*        4                     FI = Field Crops
*        5                     RI = Rice
*        6                     TR = Truck Crops
*        7                     TO = Tomato
*        8                     TH = Tomato (Hand)
*        9                     TM = Tomato (Machine)
*       10                     OR = Orchard
*       11                     GR = Grains
*       12                     VI = Vineyards
*       13                     CO = Cotton
*       14                     SO = Citrus and Olives
C-------------------------------------------------------------------------------
C   VALUE                    DESCRIPTION
C-------------------------------------------------------------------------------
    14                        / NCROP
    CVCropArea.dat            / LUFLAGSR
    CVAgElemArea.dat          / LUFLAG
    12.0                      / FACTLTOU   (ft -> in)
    inches                    / UNITLTOU
    ..\Results\AvgCrop.out    / AVGCRPFL
C*******************************************************************************
C                               Rooting Depths
C
C   FACT    ;    Conversion factor for crop root zone depth
C   ROOTCP ;     Crop root zone depths (1 to NCROP); [L]
C
C-------------------------------------------------------------------------------
C   VALUE                    DESCRIPTION
C-------------------------------------------------------------------------------
    1.0                      / FACT
    2.0                      / ROOTCP[1]      Pasture
    6.0                      / ROOTCP[2]      Alfalfa
    5.0                      / ROOTCP[3]      Sugar Beets
    4.0                      / ROOTCP[4]      Field Crops
    2.0                      / ROOTCP[5]      Rice
    3.0                      / ROOTCP[6]      Truck Crops
    5.0                      / ROOTCP[7]      Tomato
    5.0                      / ROOTCP[8]      Tomato (Hand)
    5.0                      / ROOTCP[9]      Tomato (Machine)
    6.0                      / ROOTCP[10]     Orchard
    4.0                      / ROOTCP[11]     Grains
    5.0                      / ROOTCP[12]     Vineyards
    6.0                      / ROOTCP[13]     Cotton
    4.0                      / ROOTCP[14]     Citrus and Olives
C*******************************************************************************
C                     Curve Numbers for Rainfall Runoff Simulation
C
C   Enter curve numbers for each subregion and soil-type combination for
C   agricultural areas.
C
C   IR       ;  Subregion ID (0 if following values are to be used for all subregions)
C   CNAG     ;  Curve number for agricultural lands for each simulated
C                 soil type (1 to NSOIL)
C
C-------------------------------------------------------------------------------
C   IR    CNURB[1]   CNURB[2]   CNURB[3]   CNURB[4]
C-------------------------------------------------------------------------------
    1     79.0       84.0       92.0       94.0
    2     83.0       86.0       93.0       95.9
    3     83.0       86.0       93.0       96.1
    4     83.0       86.0       93.0       96.0
    .      .          .          .          .
    .      .          .          .          .
    .      .          .          .          .
   18     87.0       90.0       94.0       97.0
   19     92.0       93.0       96.0       97.0
   20     89.0       91.0       94.0       97.0
   21     89.0       91.0       94.0       97.0
C*******************************************************************************
C                     Crop Evapotranspiration (ETc)
C
C   The following lists the ETc column pointers for each subregion and agricultural
C   crop combination.
```

```
C   IR       ;  Subregion ID (Enter 0 if following values are to be used for all
C                 subregion and agricultural crop combinations)
C   ICETAG   ;  Crop ET (ETc) - this number corresponds to the appropriate data column
C                 in the ET data file listed in the Main Input File.  List for each
C                 agricultural crop (1 to NCROP).
C
C-------------------------------------------------------------------------------
C   IR     ICETAG[1]  ICETAG[2] ... ICETAG[NCROP]
C-------------------------------------------------------------------------------
C          PA      AL      SB      FI      RI      TR      TO      TH      TM      OR      GR      VI      CO      SO
    1       1       2       3       4       5       6       7       8       9      10      11      12      13      14
    2      18      19      20      21      22      23      24      25      26      27      28      29      30      31
    3      35      36      37      38      39      40      41      42      43      44      45      46      47      48
    4      52      53      54      55      56      57      58      59      60      61      62      63      64      65
    .       .       .       .       .       .       .       .       .       .       .       .       .       .       .
    .       .       .       .       .       .       .       .       .       .       .       .       .       .       .
    .       .       .       .       .       .       .       .       .       .       .       .       .       .       .
   18     290     291     292     293     294     295     296     297     298     299     300     301     302     303
   19     307     308     309     310     311     312     313     314     315     316     317     318     319     320
   20     324     325     326     327     328     329     330     331     332     333     334     335     336     337
   21     341     342     343     344     345     346     347     348     349     350     351     352     353     354
C*******************************************************************************
C                        Irrigation Periods
C
C   The following lists the irrigation period column pointers for each
C   subregion and agricultural crop combination.
C
C   IPFL     ;  Irrigation period data file (max. 1000 characters)
C   IR       ;  Subregion ID (Enter 0 if following values are to be used for all subregion
C                 and agricultural crop combinations)
C   ICIP     ;  Irrigation period - this number corresponds to the appropriate data
C                 column in the Irrigation Period Data File (IPFL). List for each
C                 crop (1 to NCROP).
C
C-------------------------------------------------------------------------------
C   VALUE                                        DESCRIPTION
C-------------------------------------------------------------------------------
    CVAgIrrigPeriod.dat                          / IPFL
C-------------------------------------------------------------------------------
C   IR     ICIP[1]  ICIP[2] ... ICIP[NCROP]
C-------------------------------------------------------------------------------
C          PA      AL      SB      FI      RI      TR      TO      TH      TM      OR      GR      VI      CO      SO
    1       1       2       3       4       5       6       7       8       9      10      11      12      13      14
    2      15      16      17      18      19      20      21      22      23      24      25      26      27      28
    3      29      30      31      32      33      34      35      36      37      38      39      40      41      42
    4      43      44      45      46      47      48      49      50      51      52      53      54      55      56
    .       .       .       .       .       .       .       .       .       .       .       .       .       .       .
    .       .       .       .       .       .       .       .       .       .       .       .       .       .       .
    .       .       .       .       .       .       .       .       .       .       .       .       .       .       .
   18     239     240     241     242     243     244     245     246     247     248     249     250     251     252
   19     253     254     255     256     257     258     259     260     261     262     263     264     265     266
   20     267     268     269     270     271     272     273     274     275     276     277     278     279     280
   21     281     282     283     284     285     286     287     288     289     290     291     292     293     294
C*******************************************************************************
C                        Minimum Soil Moisture
C
C   The following lists the minimum soil moisture column pointers for
C   each subregion and agricultural crop combination.
C
C   MINSMFL  ;  File that lists the minimum soil moisture requirements (max. 1000 characters)
C   IR       ;  Subregion ID (Enter 0 if following values are to be used for all subregion
C                 and crop combinations)
C   ICMSM    ;  Minimum soil moisture as a fraction of Total Available Water
C                 (TAW = field capacity - wilting point) - this number corresponds to
C                 the appropriate data column in the Minimum Soil Moisture Requirement
C                 Data File (MINSMFL).  List for each crop (1 to NCROP).
C
C-------------------------------------------------------------------------------
C   VALUE                                        DESCRIPTION
C-------------------------------------------------------------------------------
    CVAgMinMoist.dat                             / MINSMFL
C-------------------------------------------------------------------------------
C   IR     ICMSM[1]  ICMSM[2] ... ICMSM[NCROP]
C-------------------------------------------------------------------------------
C          PA      AL      SB      FI      RI      TR      TO      TH      TM      OR      GR      VI      CO      SO
    0       1       2       3       4       5       6       7       8       9      10      11      12      13      14
C*******************************************************************************
C                     Target Soil Moisture for Irrigation
C
C   The following lists the target soil moisture column pointers for
C   each subregion and agricultural crop combination. If irrigtaion target soil
C   moisture is field capacity, then leave TRGSMFL variable blank and comment out
C   the section where IR and ICTRGSM variables are specified.
C
C   TRGSMFL  ;  File that lists the target soil moisture for each crop during irrigation
C                 (max. 1000 characters)
C                 * Leave blank if target soil moisture is field capacity
C   IR       ;  Subregion ID (Enter 0 if following values are to be used for all subregion
C                 and agricultural crop combinations)
C   ICTRGSM  ;  Target soil moisture as a fraction of field capacity - this number
C                 corresponds to the appropriate data column in the target soil moisture
C                 data file (TRGSMFL).  List for each agricultural crop (1 to NCROP).
C
C-------------------------------------------------------------------------------
C         VALUE                                        DESCRIPTION
C-------------------------------------------------------------------------------
                                                       / TRGSMFL
C-------------------------------------------------------------------------------
C   IR     ICTRGSM[1]  ICTRGSM[2] ... ICTRGSM[NCROP]
C-------------------------------------------------------------------------------
*
*
C*******************************************************************************
C            Specified Water Supply Requirement, Return Flow and Re-use Factors
C
C   AGWDFL   ;  File that lists the agricultural water supply requirement (max. 1000 characters)
C                * Leave blank if agricultural water demand is simulated dynamically
C   FLDMD    ;  Flag for the root zone moisture to be used for the computation of
C                agricultural water supply requirement and the timing of irrigation
C                * 0: Use the soil moisture at the beginning of time step
C                * 1: Use the soil moisture at the end of time step
```

```
C   IR       ;  Subregion ID (Enter 0 if following values are to be used for all subregions)
C   ICAGWD   ;  Water supply requirement - this number corresponds to the appropriate data
C                 column in the Agricultural Water Supply Requirement file (AGWDFL)
C                 * Enter any number if AGWDFL is not specified
C                 * Enter 0 if agricultural water supply requirement will be computed
C                   internally for the subregion
C   ICRTFAG  ;  Fraction of the agricultural applied water that becomes return flow - this
C                 number corresponds to the appropriate data column in Return Flow Factor
C                 Data File (RFFL) listed in the Root Zone Main Data File.
C   ICRUFAG  ;  Fraction of the applied water that is re-used - this number corresponds
C                 to the appropriate data column in Re-use Factor Data File (RUFL) listed
C                 in the Root Zone Data File.
C
C-------------------------------------------------------------------------------
C         VALUE                                     DESCRIPTION
C-------------------------------------------------------------------------------
                                                    / AGWDFL
          1                                         / FLDMD
C---------------------------------------------------------------------------------------
C   IR    ICAGWD    ICRTFAG   ICRUFAG
C---------------------------------------------------------------------------------------
    1      0          1         1
    2      0          2         2
    3      0          3         3
    4      0          4         4
    .      .          .         .
    .      .          .         .
    .      .          .         .
   18      0         18        18
   19      0         19        19
   20      0         20        20
   21      0         21        21
C*******************************************************************************
C                          Initial Soil Moisture Condition
C                               For Agricultural Lands
C
C   IR     ; Subregion ID (0 if following values are to be used for all subregions)
C   FSOILMP; Fraction of initial soil moisture due to precipitation for each soil
C              type (1 to NSOIL)
C   SOILM  ; Initial root zone moisture content for agricultural area for each
C              soil type (1 to NSOIL); [L/L]
C
C-------------------------------------------------------------------------------------------
C   IR    FSOILMP[1]       SOILM[1]
C         FSOILMP[2]       SOILM[2]
C            .                .
C            .                .
C         FSOILMP[NSOIL]   SOILM[NSOIL]
C-------------------------------------------------------------------------------------------
    1      0.5          0.067
           0.5          0.473
           0.5          0.303
           0.5          0.333
    2      0.5          0.089
           0.5          0.110
           0.5          0.239
           0.5          0.111
    3      0.5          0.119
           0.5          0.033
           0.5          0.490
           0.5          0.031
    4      0.5          0.121
           0.5          0.286
           0.5          0.382
           0.5          0.243
    .       .            .
            .            .
            .            .
            .            .
    .       .            .
            .            .
            .            .
            .            .
    .       .            .
            .            .
            .            .
            .            .
   18      0.5          0.199
           0.5          0.109
           0.5          0.119
           0.5          0.116
   19      0.5          0.080
           0.5          0.208
           0.5          0.065
           0.5          0.322
   20      0.5          0.081
           0.5          0.131
           0.5          0.127
           0.5          0.094
   21      0.5          0.080
           0.5          0.418
           0.5          0.390
           0.5          0.234
```

8.3.12.4.b Subregional Crop Area Data File

Areas of each crop at every subregion are listed in this file:

FACTLNCR	Conversion factor for crop areas; enter 0.0 if crop areas are given as fractions of the subregion areas
NSPLNCR	Number of time steps to update the subregional crop area; enter any number if time-tracking option is on
NFQLNCR	Repetition frequency of the subregional crop area data; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Subregional Crop Area Data File

If the time series data is listed in the Subregional Crop Area Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using "C", "c" or "*", and the variables in the "Data Input from DSS File" section below should be populated.

ITLN	Time; for time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number
IR	Subregion identification number
ALAND	Area (or fraction of subregion area) corresponding to the crops over a subregion; [L^2] or [L^2/L^2] based on FACTLNCR above

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

IR	Subregion identification number
LUTYPE	Crop identification number entered sequentially
PATH	Pathname corresponding to subregion and crop type combination

```
C*******************************************************************************
C
C                 INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                      SUBREGIONAL CROP AREA FILE
C                         Root Zone Component
C                         *** Version 5.0 ***
C
C
C              Project:  IDC Version ### Release
C                        California Department of Water Resources
C             Filename:  SubregionCropArea.dat
C
C*******************************************************************************
C                         File Description
C
C   This data file contains the individual crop areas for each subregion
C   for the simulation period.
C
C*******************************************************************************
C                        Land Use Data Specifications
C
C   FACTLNCR;   Conversion factor for crop area
C                 * Enter 0.0 if crop area is given as a fraction of subregion area
C   NSPLNCR ;   Number of time steps to update the land use data
C                 * Enter any number if time-tracking option is on
C   NFQLNCR ;   Repetition frequency of the land use data
C                 * Enter 0 if full time series data is supplied
C                 * Enter any number if time-tracking option is on
C   DSSFL   ;   The name of the DSS file for data input
C                 * Leave blank if DSS file is not used for data input
C
C-----------------------------------------------------------------------------------------
C        VALUE                                    DESCRIPTION
C-----------------------------------------------------------------------------------------
          43560.0                                 / FACTLNCR
          1                                       / NSPLNCR
          0                                       / NFQLNCR
                                                  / DSSFL
C-----------------------------------------------------------------------------------------
C                          Land Use Data
C                      (READ FROM THIS FILE)
C
C   List the crop areas below, if it will not be read from a DSS file
C   (i.e. DSSFL is left blank above).
C
C   ITLN    ;   Time
C   IR      ;   Subregion number
C   ALANDCR;    Crop area (or fraction of area) over a subregion; [L^2] or
C               [L^2/L^2] (based on FACTLNCR above). List for each
C               crop (1 to NCROP)
C
C--------------------------------------------------------------------------------------------------------------------------------------
C                                                           ALANDCR
C                       -------------------------------------------------------------------------------------------------------------
C   ITLN              IR       PA         AL         SB         FI         RI    ...      OR       GR       VI       CO       SO
C--------------------------------------------------------------------------------------------------------------------------------------
09/30/1922_24:00       1    12692        765          0        393          0    ...     674        0        0        0        0
                       2    22800      11100          0       2700          0    ...   16900        0        0        0        0
                       3    22400       8600          0       6200      40000    ...   11400        0        0        0        0
                       4     5100       2600          0      31900      22000    ...    6800        0        0        0        0
                       5    27200      15800        600      11400      31800    ...   42700        0        0        0        0
                       6     6200       5300        600       3400       6000    ...    5500        0      400        0        0
                       7    19800       5200       1200       8600       1200    ...   22200        0        0        0        0
                       8    40000       7800        500      10300       3100    ...   15500        0    22700        0        0
                       9    23200      40100      19500      79900       2900    ...   29200    74100        0        0        0
                      10     8937      44348       1012      51482       5844    ...    7817        0      298    17808        0
                      11    25709      11311        163      27674       3708    ...   16379        0     7185      386        0
                      12    12672      16298         33      39301         22    ...   16612        0     8890        0        0
                      13    31982      61743        794      35543       5826    ...   22284        0    36926    12206        0
                      14      741      27419       3281      56059        637    ...    2410        0     1610    76990        0
                      15    13456      94550       2300      77785       1890    ...    7221        0    17160    76273        0
                      16    16986       9140         96      11873          0    ...    9241        0    22302     5579        0
                      17     9604       7972        285      12821          0    ...   18987        0    37128     5018        0
                      18    21473      54838        990      84272       1869    ...   18482        0    17310    50558        0
                      19     2621      43917       1634      30845        223    ...   11766        0     3320    48002        0
                      20      643      11943        180       8537          1    ...   14061        0    11681    10972        0
                      21     4376      42223       1233      23837        381    ...    6450        0    14290    38277        0
09/30/1923_24:00       1    12692        765          0        393          0    ...     674        0        0        0        0
                       2    22300      10900          0       2700          0    ...   16600        0        0        0        0
                       3    22400       8600          0       6200      40000    ...   11400        0        0        0        0
                       4     5200       2600          0      32600      22000    ...    6900        0        0        0        0
                       5    27600      15900        700      11600      31800    ...   42900        0        0        0        0
                       6     6600       5700        600       3600       7000    ...    5900        0      400        0        0
                       7    20500       5300       1200       8800       1200    ...   23000        0        0        0        0
                       8    41800       8100        600      10800       3200    ...   16300        0    23700        0        0
                       9    24000      40100      20900      80700       2900    ...   30100    69500      100        0        0
                      10     9016      44780       1012      50646       5427    ...    8065        0      312    19214        0
                      11    25936      11421        163      27225       3443    ...   16898        0     7522      417        0
                      12    12784      16457         33      38663         20    ...   17139        0     9307        0        0
                      13    32264      62343        794      34966       5410    ...   22991        0    38658    13169        0
                      14      744      27550       3281      56279        637    ...    2421        0     1618    77484        0
                      15    13514      95003       2300      78090       1890    ...    7254        0    17243    76762        0
                      16    17059       9183         96      11919          0    ...    9283        0    22409     5615        0
                      17     9645       8010        285      12872          0    ...   19073        0    37307     5051        0
                      18    21565      55101        990      84603       1869    ...   18565        0    17393    50882        0
                      19     2633      44127       1634      30966        223    ...   11819        0     3336    48310        0
                      20      646      12000        180       8571          1    ...   14124        0    11737    11042        0
                      21     4395      42426       1233      23931        381    ...    6479        0    14358    38522        0
                       .        .          .          .          .          .    ...       .        .        .        .        .
                       .        .          .          .          .          .    ...       .        .        .        .        .
                       .        .          .          .          .          .    ...       .        .        .        .        .
                       .        .          .          .          .          .    ...       .        .        .        .        .
                       .        .          .          .          .          .    ...       .        .        .        .        .
                       .        .          .          .          .          .    ...       .        .        .        .        .
                       .        .          .          .          .          .    ...       .        .        .        .        .
                       .        .          .          .          .          .    ...       .        .        .        .        .
                       .        .          .          .          .          .    ...       .        .        .        .        .
                       .        .          .          .          .          .    ...       .        .        .        .        .
09/30/2009_24:00       1    24516        715          0        204          0    ...    2860     1328      102        0      919
```

```
                      2    35071     7256      302     8969     2016  ...    86469     6047        0        0    22373
                      3    13844    14902     3269    34419   165364  ...    59896    26439     7211    13556     2115
                      4     1999     5298     1000    53682   110763  ...    30890    14695        0     1100    12796
                      5    20235     5403        0     8644   185259  ...   138011     5992       98      491     4911
                      6     8768    50170        0    43819    16452  ...    28724    51571     1551      969     8919
                      7    22160     3393      636     9012    72842  ...    11981     9118        0        0      318
                      8    41769    15028     2902    48091     3317  ...    56901    24149    92658        0      311
                      9    15224    50403     5381   131936      625  ...    10707    40758    21588        0      104
                     10    10927    76582     4296    53701     5977  ...    38478    37544     1681    90778      654
                     11    48341     9304        0    32766     5764  ...    88692    12237    12742        0      303
                     12    18556    21418      185    54376        0  ...    94627    12094    14309        0      185
                     13    30394    61061     2548    55419     3640  ...   136682    57239    95186    42042     5096
                     14     1088    10791     4534    18681        0  ...    43257    38088    10066   170578      453
                     15     5270   107990     2311    71654        0  ...    54827    73965    53163   179644      647
                     16     6961     9076        0     5375        0  ...    25554     2291    63621     5375    10574
                     17     5917     7027        0     8321        0  ...    74150     8876    99299     2866    34856
                     18     3557    91713     3172   129975        0  ...    83638    77677    49702    83061    98154
                     19     1223    36601     2258    14772        0  ...    77247    40835     8938    72543     2258
                     20       97    17332      484     9005        0  ...    69618    10457    40570    10554    27111
                     21     1129    53066      282    54101        0  ...    25875    35378    36130    62569    17971
C-------------------------------------------------------------------------------------------
C                               Pathnames for Land Use Data
C                                 (READ FROM DSS FILE)
C
C   List the pathnames for the land use data below, if it will be read from a DSS file
C   (i.e. DSSFL is specified above).
C
C   The pathnames should be listed for each subregion and crop combination.
C   They should be listed in an order such that, the crop type changes first.
C
C   * Example with 3 agricultural crops (i.e. NCROP=3):
C
C       IR     LUTYPE      PATH
C        1        1       (pathname[1])
C        1        2       (pathname[2])
C        1        3       (pathname[3])
C        2        1       (pathname[4])
C        2        2       (pathname[5])
C        2        3       (pathname[6])
C        .        .            .
C        .        .            .
C        .        .            .
C     NREGN       1       (pathname[(NCROP)*NREGN - 2])
C     NREGN       2       (pathname[(NCROP)*NREGN - 1])
C     NREGN       3       (pathname[(NCROP)*NREGN])
C
C   IR     ;  Subregion number
C   LUTYPE ;  Land use type
C               1       = Agricultural crop 1
C               2       = Agricultural crop 2
C                             .
C                             .
C                             .
C             NCROP   = Agricultural crop NCROP
C   PATH   ;  Pathname corresponding to subregion and crop type combination
C
C-------------------------------------------------------------------------------------------
C   IR        LUTYPE        PATH
C-------------------------------------------------------------------------------------------
*
*
```

8.3.12.4.c Elemental Total Agricultural Area Data File

Total agricultural area at each element are listed in this file:

FACTLNA	Conversion factor for agricultural areas; enter 0.0 if areas are given as fractions of the element areas
NSPLNA	Number of time steps to update the total agricultural areas at each element; enter any number if time-tracking option is on
NFQLNA	Repetition frequency of the element-level total agricultural area data; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Elemental Total Agricultural Area Data File

If the time series data is listed in the Elemental Total Agricultural Area Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using "C", "c" or "*", and the variables in the "Data Input from DSS File" section below should be populated.

ITLN	Time; for time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number
IE	Element identification number
ALANDA	Agricultural area (or fraction of element area) over an element; [L^2] or [L^2/L^2] based on FACTLNA above

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

IE	Element identification number
PATH	Pathname corresponding to the total agricultural area at element IE

```
C*******************************************************************************
C
C                    INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                       ELEMENTAL AGRICULTRAL AREA FILE
C                            Root Zone Component
C                            *** Version 5.0 ***
C
C
C            Project:  IDC Version ### Release
C                      California Department of Water Resources
C            Filename: ElemAgArea.dat
C
C*******************************************************************************
C                            File Description
C
C   This data file contains the total agricultural area for each element
C   for the simulation period.
C
C*******************************************************************************
C                             Land Use Data Specifications
C
C   FACTLNA;   Conversion factor for land use area
C                * Enter 0.0 if land use distribution is given as a fraction of element area
C   NSPLNA ;   Number of time steps to update the land use data
C                * Enter any number if time-tracking option is on
C   NFQLNA ;   Repetition frequency of the land use data
C                * Enter 0 if full time series data is supplied
C                * Enter any number if time-tracking option is on
C   DSSFL   ;   The name of the DSS file for data input
C                * Leave blank if DSS file is not used for data input
C
C-----------------------------------------------------------------------------------------
C         VALUE                                        DESCRIPTION
C-----------------------------------------------------------------------------------------
          43560.0                                      / FACTLNA
          1                                            / NSPLNA
          0                                            / NFQLNA
                                                       / DSSFL
C-----------------------------------------------------------------------------------------
C                               Land Use Data
C                             (READ FROM THIS FILE)
C
C   List the land use data below, if it will not be read from a DSS file
C   (i.e. DSSFL is left blank above).
C
C   ITLN    ;   Time
C   IE      ;   Element number
C   ALANDA ;   Agricultural area (or fraction of area) over an element; [L^2] or
C              [L^2/L^2] (based on FACTLNA above)
C              * Note: Agricultural areas over elements that are designated as lake elements
C                      will be ignored
C
C--------------------------------------------------------------------------------------------
C   ITLN             IE          ALANDA
C--------------------------------------------------------------------------------------------
09/30/1922_24:00      1           812.39
                      2             0.00
                      3             0.00
                      4             0.00
                      .              .
                      .              .
                      .              .
                   1389          1615.33
                   1390             0.00
                   1391             0.00
                   1392             0.00
09/30/1923_24:00      1           806.27
                      2             0.00
                      3             0.00
                      4             0.00
                      .              .
                      .              .
                      .              .
                   1389          1654.52
                   1390             0.00
                   1391             0.00
                   1392             0.00
                      .              .
                      .              .
                      .              .
                      .              .
                      .              .
                      .              .
09/30/2009_24:00      1            89.96
                      2           180.79
                      3          1379.60
                      4           781.58
                      .              .
                      .              .
                      .              .
                   1389          5536.55
                   1390          5945.77
                   1391          6233.13
                   1392          1375.83
C-----------------------------------------------------------------------------------------
C                             Pathnames for Land Use Data
C                               (READ FROM DSS FILE)
C
C   List the pathnames for the land use data below, if it will be read from a DSS file
C   (i.e. DSSFL is specified above).
C
C   IE      ;  Element number
C   PATH    ;  Pathname corresponding to agricultrural area at element IE
C
C-----------------------------------------------------------------------------------------
C   IE        PATH
C-----------------------------------------------------------------------------------------
*
*
```

8.3.12.4.d Irrigation Period Data File

This file is exactly the same as the Irrigation Period Data File for the root zone component version 4.0. Refer to section 8.3.8.4 for a detailed explanation of this file.

8.3.12.4.e Minimum Soil Moisture Data File

This file is exactly the same as the Minimum Soil Moisture Data File for the root zone component version 4.0. Refer to section 8.3.8.7.d for a detailed explanation of this file.

8.3.12.4.f Irrigation Target Moisture Data File

This file is exactly the same as the Irrigation Target Moisture Data File for the root zone component version 4.0. Refer to section 8.3.8.7.e for a detailed explanation of this file.

8.3.12.4.g Agricultural Supply Requirement Data File

This file is exactly the same as the Agricultural Supply Requirement Data File for the root zone component version 4.0. Refer to section 8.3.8.6 for a detailed explanation of this file.

8.3.12.5. Urban Component Files

8.3.12.5.a Urban Lands Main File

The Urban Lands Main File is the gateway file for all data that is necessary to simulate land surface and root zone flow processes in urban lands.

The file is divided into several sections and uses the following variables:

Land-Use Areas

The filename for the urban areas data file is listed in this section:

LUFLU File that lists the urban areas (maximum 1000 characters)

Rooting Depth

FACT	Conversion factor for urban outdoors root zone depth
ROOTURB	Root zone depth for urban outdoors; [L]

Curve Numbers

IR	Subregion identification number; enter 0 if following values are to be used for all subregions
CNURB	Curve number for urban lands for each simulated soil in subregion IR

Urban Water Use, Management and Simulation Parameters

WTRDMDFL	File that lists the urban water demand (maximum 1000 characters)
URBSPECFL	File that lists the urban water use specifications (maximum 1000 characters)
IR	Subregion identification number; enter 0 if following values are to be used for all subregions
PERV	Fraction of pervious area to total urban areas
ICWTRDMD	Water demand in surgeion IR; this number corresponds to the appropriate data column in the Urban Water Demand File, WTRDMDFL, listed above
ICURBSPEC	Urban water use specification data as a fraction of total urban water that is used indoors; this number corresponds to the appropriate data column in the Urban Water Use Specifications File, URBSPECFL, listed above
ICETURB	Urban evapotranspiration; this number corresponds to the appropriate data column in the Evapotranspiration File listed in the IDC Main Input File
ICRTFURB	Fraction of the urban applied water that becomes return flow; this number corresponds to the appropriate data column in the Return Flow Fractions Data File (RFFL) specified in the Root Zone Component Main File; for urban lands (return flow fraction applies only to pervious (lawns, parks, etc) urban areas; all water delivered to urban indoor areas becomes return flow)

ICRUFURB	Fraction of the urban applied water that is re-used; this number corresponds to the appropriate data column in the Re-use Fractions Data File (RUFL) specified in the Root Zone Component Main File

Destination for Urban Surface Flow

In this section, the destination for surface flow generated in urban lands at each grid cell is listed.

IE	Element identification number
TYPDESTUR	Destination type for the urban surface flow from element IE (0 = surface flow goes outside of model area; 1= surface flow goes to a stream node; 3 = surface flow goes to a lake; 4 = surface flow goes to a subregion; 5 = surface flow goes to groundwater)
DESTUR	Destination identification number for the urban surface flow from element IE; enter any number if TYPDESTUR is set to 0 or 5

Initial Soil Moisture Conditions

The initial soil moisture content for urban outdoors at each subregiont is listed in this section.

IR	Subregion identification number; enter 0 if following values are to be used for all subregions
FSOILMP	Fraction of initial soil moisture in subregion IR at each soil type that is due to precipitation
SOILM	Initial root zone moisture content for urban outdoors for each type at each subregion; [L/L]

```
C*******************************************************************************
C
C                    INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                          URBAN LANDS DATA FILE
C                           Root Zone Component
C                            *** Version 5.0 ***
C
C
C              Project:  IDC Version ### Release
C                        California Department of Water Resources
C              Filename: Urban_MAIN.dat
C
C*******************************************************************************
C                              File Description
C
C
C   This data file contains the parameters and data file names for the simulation
C   of root zone processes and managament of urban lands.
C
C*******************************************************************************
C                              Land Use Areas
C
C   LUFLU   ;  File that lists the urban areas (max. 1000 characters)
C
C-------------------------------------------------------------------------------
    UrbanArea.dat                           / LUFLU
C*******************************************************************************
C                                 Rooting Depth
C
C   FACT    ;    Conversion factor for urban root zone depth
C   ROOTURB;     Urban root zone depth; [L]
C
C-------------------------------------------------------------------------------
C   VALUE                   DESCRIPTION
C-------------------------------------------------------------------------------
    1.0                     / FACT
    2.0                     / ROOTURB
C*******************************************************************************
C                    Curve Numbers for Rainfall Runoff Simulation
C
C   Enter curve numbers for each subregion and soil-type combination for
C   urban areas.
C
C   IR        ;  Subregion ID (0 if following values are to be used for all subregions)
C   CNURB     ;  Curve number for urban lands lands for each simulated
C                  soil type (1 to NSOIL)
C
C-------------------------------------------------------------------------------
C   IR     CNURB[1]   CNURB[2]   CNURB[3]   CNURB[4]
C-------------------------------------------------------------------------------
    1      83.0       86.0        94.0       97.0
    2      85.0       87.0        94.0       97.0
    3      86.0       87.0        94.0       97.0
    .       .          .           .          .
    .       .          .           .          .
    .       .          .           .          .
   19      93.0       94.0        97.0       97.0
   20      91.0       93.0        96.0       97.0
   21      91.0       93.0        96.0       97.0
C*******************************************************************************
C                   Urban Water Use, Management and Simulation Parameters
C
C   WTRDMDFL ;  File that lists the urban water demand (max. 1000 characters)
C   URBSPECFL;  File that lists the urban water use specifications (max. 1000 characters)
C   IR       ;  Subregion ID (Enter 0 if following values are to be used for all elements)
C   PERV     ;  Fraction of pervious area to total urban areas
C   ICWTRDMD ;  Water demand - this number corresponds to the appropriate data
C                 column in the Urban Water Demand file (WTRDMDFL)
C   ICURBSPEC;  Urban water use specification data as a fraction of total urban water that
C                is used indoors - this number corresponds to the appropriate data column
C                in the Urban Water Use Specifications file (URBSPECFL).
C   ICETURB  ;  Urban ETc - this number corresponds to the appropriate data column
C                 in the ET data file listed in the Main Control Data file.
C   ICRTFURB ;  Fraction of the urban applied water that becomes return flow - this
C                 number corresponds to the appropriate data column in irrigation
C                 water return flow factor data file (RFFL).
C                 * Note: For urban lands, return flow fraction applies only to
C                         pervious (lawns, parks, etc) urban areas. All water
C                         delivered to urban indoor areas becomes return flow.
C   ICRUFURB ;  Fraction of the applied water that is re-used - this number corresponds
C                 to the appropriate data column in irrigation water re-use factor data
C                  file (RUFL).
C
C-------------------------------------------------------------------------------
C         VALUE                                       DESCRIPTION
C-------------------------------------------------------------------------------
   UrbanWaterDemand.dat                              / WTRDMDFL
   UrbanWaterUseSpecs.dat                            / URBSPECFL
C---------------------------------------------------------------------------------------
C   IR     PERV    ICWTRDMD    ICURBSPEC    ICETURB    ICRTFURB    ICRUFURB
C---------------------------------------------------------------------------------------
    1      0.62      1            1            15         22          22
    2      0.62      2            2            32         22          22
    3      0.62      3            3            49         22          22
    .       .        .            .             .          .           .
    .       .        .            .             .          .           .
    .       .        .            .             .          .           .
   19      0.62     19           19           321         22          22
   20      0.62     20           20           338         22          22
   21      0.62     21           21           355         22          22
C*******************************************************************************
C                   Destination for Urban Surface Flow
C
C   List the destination type and number for urban surface flow from each element.
C   Destinations for urban surface flow can be different than those for surface
C   flows generated on other land use areas as listed in the Root Zone Component
C   Main Input File.
C
C   IE         ;  Element ID
C   TYPDESTUR  ;  Destination type for the urban surface flow from element IE
```

```
C                 0 = Surface flow goes outside of model area
C                 1 =  "        "    "  to a stream node
C                 3 =  "        "    "   " a lake
C                 4 =  "        "    "   " a subregion
C                 5 =  "        "    "   " groundwater
C   DESTUR     ;  Destination for the urban surface flow from element IE
C                 * Note: Enter any number if TYPDESTUR is set to 0 or 5
C
C-------------------------------------------------------------------------------
C    IE     TYPDESTUR     DESTUR
C-------------------------------------------------------------------------------
      1         1          207
      2         1          206
      3         1          206
      4         1          206
      .         .            .
      .         .            .
      .         .            .
   1389         5            0
   1390         5            0
   1391         5            0
   1392         5            0
C******************************************************************************
C                            Initial Soil Moisture Condition
C                                    For Urban Lands
C
C   IR     ; Subregion ID (0 if following values are to be used for all subregions)
C   FSOILMP; Fraction of initial soil moisture due to precipitation for each soil
C               type (1 to NSOIL)
C   SOILM  ; Initial root zone moisture content for urban area for each
C               soil type (1 to NSOIL); [L/L]
C
C----------------------------------------------------------------------------------
C   IR     FSOILMP[1]   SOILM[1]
C          FSOILMP[2]   SOILM[2]
C          FSOILMP[3]   SOILM[3]
C          FSOILMP[4]   SOILM[4]
C----------------------------------------------------------------------------------
    1        0.5          0.067
             0.5          0.473
             0.5          0.303
             0.5          0.333
    2        0.5          0.089
             0.5          0.110
             0.5          0.239
             0.5          0.111
    3        0.5          0.119
             0.5          0.033
             0.5          0.490
             0.5          0.031
    .         .            .
              .            .
              .            .
    .         .            .
              .            .
              .            .
    .         .            .
              .            .
              .            .
   19        0.5          0.080
             0.5          0.208
             0.5          0.065
             0.5          0.322
   20        0.5          0.081
             0.5          0.131
             0.5          0.127
             0.5          0.094
   21        0.5          0.080
             0.5          0.418
             0.5          0.390
             0.5          0.234
```

8.3.12.5.b Urban Area Data File

This file is exactly the same as the Urban Area Data File for the root zone component version 4.0. Refer to section 8.3.8.9.b for a detailed explanation of this file.

8.3.12.5.c Urban Water Demand Data File

This file lists total urban water demand. Urban land in each subregion is associated with a data column in this file through pointers specified in the Urban Lands Main File.

The following variables are listed in this file:

NCOLWD	Number of urban water demand data columns
FACTWD	Conversion factor for the spatial component of the urban water demand data
NSPWD	Number of time steps to update the urban water demand data; enter any number if time-tracking option is on
NFQWD	Repetition frequency of the urban water demand; a value of zero indicates that a full time series data set is supplied; if time tracking simulation, enter any number
DSSFL	The name of the DSS file for data input; leave blank if DSS file is not used for data input

Data Input from Urban Water Demand Data File

If the time series data is listed in the Urban Water Demand Data File, then the following variables need to be populated. Otherwise, these variables should be commented out using "C", "c" or "*", and the variables in the "Data Input from DSS File" section below should be populated.

ITWD	Time; for time tracking simulations use MM/DD/YYYY_hh:mm format, for non-time tracking simulations enter an integer number
WD	Urban water demand; $[L^3/T]$

Data Input from DSS File

If time series data is stored in a DSS file then the following variables should be populated:

REC	Record number that coincides with the data column number for the time series data
PATH	Pathname for the time series record that will be used for data retrieval

```
C*******************************************************************************
C
C                 INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                  URBAN WATER DEMAND DATA FILE
C                      Root Zone Component
C                      *** Version 5.0 ***
C
C
C            Project:  IDC Version ### Release
C                      California Department of Water Resources
C            Filename: UrbanWaterDemand.dat
C
C*******************************************************************************
C                             File Description
C
C   This data file contains urban water demand data on a time-series
C   basis.
C
C*******************************************************************************
C                   Urban Water Demand Data Specifications
C
C   NCOLWD ;  Number of urban water demand data columns
C   FACTWD ;  Conversion factor for urban water demand
C               It is used to convert only the spatial component of the unit;
C               DO NOT include the conversion factor for time component of the unit.
C               * e.g. Unit of flow listed in this file          = AC-FT/MONTH
C                      Consistent unit used in simulation         = CU.FT/DAY
C                      Enter FACTDWD (AC-FT/MONTH -> CU.FT/MONTH) = 43560.0
C                     (conversion of MONTH -> DAY is performed automatically)
C   NSPWD  ;  Number of time steps to update the water demand data
C              * Enter any number if time-tracking option is on
C   NFQWD  ;  Repetition frequency of the water demand data
C              * Enter 0 if full time series data is supplied
C              * Enter any number if time-tracking option is on
C   DSSFL  ;  The name of the DSS file for data input (maximum 1000 characters);
C              * Leave blank if DSS file is not used for data input
C
C-------------------------------------------------------------------------------
C         VALUE                                      DESCRIPTION
C-------------------------------------------------------------------------------
          21                                         / NCOLWD
          43560000.0                                 / FACTWD (TAF/mon --> ft^3/month)
          1                                          / NSPWD
          0                                          / NFQWD
                                                     / DSSFL
C-------------------------------------------------------------------------------
C                       Urban Water Demand Data
C                        (READ FROM THIS FILE)
C
C   List the water demand data below, if it will not be read from a
C   DSS file (i.e. DSSFL is left blank above).
C
C   ITWD;   Time
C   WD  ;   Water demand; [L^3/T]
C
C-------------------------------------------------------------------------------
C ITWD    WD(1)  WD(2)  WD(3) ...
C-------------------------------------------------------------------------------
C                     1       2       3       4       5    ...    18      19      20      21
 10/31/1921_24:00    0.2     0.4     0.2     0.1     0.7   ...    1.1     0.2     0.3     1.1
 11/30/1921_24:00    0.2     0.3     0.1     0.1     0.5   ...    0.8     0.1     0.2     0.7
 12/31/1921_24:00    0.2     0.3     0.2     0.1     0.5   ...    0.7     0.1     0.2     0.7
 01/31/1922_24:00    0.2     0.3     0.2     0.1     0.5   ...    0.7     0.1     0.2     0.7
 02/28/1922_24:00    0.1     0.3     0.1     0.1     0.5   ...    0.6     0.1     0.2     0.6
 03/31/1922_24:00    0.2     0.4     0.2     0.1     0.5   ...    0.8     0.1     0.2     0.8
         .            .       .       .       .       .    ...     .       .       .       .
         .            .       .       .       .       .    ...     .       .       .       .
         .            .       .       .       .       .    ...     .       .       .       .
 04/30/2009_24:00    2.8     2.5     1.0     0.5     6.0   ...   12.7     1.7     5.7    16.7
 05/31/2009_24:00   11.5     5.2     1.5     0.7    11.1   ...   16.9     2.4     7.9    22.2
 06/30/2009_24:00   16.6     6.9     2.0     0.8    13.7   ...   18.5     2.7     8.9    24.3
 07/31/2009_24:00   17.7     7.4     2.1     0.9    14.8   ...   19.3     2.8     9.2    25.3
 08/31/2009_24:00   15.2     6.4     1.8     0.8    12.8   ...   17.8     2.6     8.4    23.4
 09/30/2009_24:00   13.1     5.7     1.6     0.7    11.5   ...   14.4     2.0     6.6    19.0
C-------------------------------------------------------------------------------
C                  Pathnames for Urban Water Demand Data
C                          (READ FROM DSS FILE)
C
C   List the pathnames for the urban water demand data below, if it will be read
C   from a DSS file (i.e. DSSFL is specified above).
C
C   REC  ;  Time series record number
C   PATH ;  Pathname for the time series record
C
C----------------------------------------------------------------------------------------------
C   REC       PATH
C----------------------------------------------------------------------------------------------
*
*
```

8.3.12.5.d Urban Water Use Specifications Data File

This file is exactly the same as the Urban Water Use Specifications Data File for the root zone component version 4.0. Refer to section 8.3.8.9.e for a detailed explanation of this file.

8.3.12.6. Native and Riparian Vegetation Component Files

8.3.12.6.a Native and Riparian Vegetation Lands Main File

The Native and Riparian Vegetation Lands Main File is the gateway file for all data that is necessary to simulate land surface and root zone flow processes in areas that are covered with native and riparian vegetation.

The file is divided into several sections and uses the following variables:

Land-Use Areas

The filename for the native and riparian areas data file is listed in this section:

LUFLNVRV	File that lists the urban areas (maximum 1000 characters)

Rooting Depths

FACT	Conversion factor for native and riparian vegetation root zone depths
ROOTNV	Root zone depth for native vegetation; [L]
ROOTRV	Root zone depth for riparian vegetation; [L]

Native and Riparian Vegetation Simulation Parameters

IR	Subregion identification number entered sequentially; enter 0 if the following values are to be used for all subregions
CNNV	Curve number for native vegetation lands for each soil type simulated
CNRV	Curve number for riparian vegetation lands for each soil type simulated
ICETNV	Native vegetation evapotranspiration rate; this number corresponds to the appropriate data column in the Evapotranspiration File listed in the IDC Main Input File

ICETRV	Riparian vegetation evapotranspiration rate; this number corresponds to the appropriate data column in the Evapotranspiration File listed in the IDC Main Input File

Initial Soil Moisture Conditions

The initial soil moisture contents for native and riparian vegetation at each subregion and soil type combination are listed in this section.

IR	Subregion identification number; enter 0 if following values are to be used for all elements
SOILM_NV	Initial root zone moisture content for native vegetation at subregion IR for each of the simulated soil types; [L/L]
SOILM_RV	Initial root zone moisture content for riparian vegetation at subregion IR for each of the simulated soil types; [L/L]

```
C*******************************************************************************
C
C                   INTEGRATED WATER FLOW MODEL (IWFM)
C
C*******************************************************************************
C
C                  NATIVE AND RIPARIAN VEGETATION DATA FILE
C                          Root Zone Component
C                          *** Version 5.0 ***
C
C
C              Project:  IDC Version ### Release
C                        California Department of Water Resources
C              Filename: NativeVeg_MAIN.dat
C
C*******************************************************************************
C                           File Description
C
C   This data file contains the parameters and data file names for the simulation
C   of root zone processes for native and riparian vegetation.
C
C*******************************************************************************
C                          Land Use Areas
C
C   LUFLNVRV   ;  File that lists the land use areas (max. 1000 characters)
C
C-------------------------------------------------------------------------------
    NativeVegArea.dat   / LUFLNVRV
C*******************************************************************************
C                               Rooting Depths
C
C   FACT  ;  Conversion factor for root zone depths
C   ROOTNV;  Native veg. root zone depth; [L]
C   ROOTRV;  Riparian veg. root zone depth; [L]
C
C-------------------------------------------------------------------------------
C   VALUE                 DESCRIPTION
C-------------------------------------------------------------------------------
    1.0                   / FACT
    5.0                   / ROOTNV
    5.0                   / ROOTRV
C*******************************************************************************
C                     Curve Numbers for Rainfall Runoff Simulation
C
C   Enter curve numbers for each subregion and soil-type combination for native
C   and riparian vegetation.
C
C   IR       ;  Subregion ID (0 if following values are to be used for all subregions)
C   CNNV     ;  Curve number for native vegetation lands for each simulated
C                 soil type (1 to NSOIL)
C   CNRV     ;  Curve number for riparian vegetation lands for each simulated
C                 soil type (1 to NSOIL)
C
C-------------------------------------------------------------------------------
C   IR    CNNV[1]  CNNV[2]  CNNV[3]  CNNV[4]  CNRV[1]  CNRV[2]  CNRV[3]  CNRV[4]
C-------------------------------------------------------------------------------
    1     81       84       90       94       81       84       90       94
    2     84       86       91       94       84       86       91       94
    3     84       86       92       94       84       86       92       94
    .     .        .        .        .        .        .        .        .
    .     .        .        .        .        .        .        .        .
    .     .        .        .        .        .        .        .        .
   19     92       93       96       97       92       93       96       97
   20     90       92       94       96       90       92       94       96
   21     90       92       94       96       90       92       94       96
C*******************************************************************************
C                           Evapotranspiration (ETc)
C
C   The following lists the ETc column pointers for each subregion for native and
C   riparian vegetation.
C
C   IR       ;  Subregion ID (Enter 0 if following values are to be used for all subregions)
C   ICETNV   ;  Native vegetation ETc - this number corresponds to the appropriate data column
C                 in the ET data file listed in the Main Control Data file.
C   ICETRV   ;  Riparian vegetation ETc - this number corresponds to the appropriate data column
C                 in the ET data file listed in the Main Control Data file.
C
C-------------------------------------------------------------------------------
C   IR    ICETNV    ICETRV
C-------------------------------------------------------------------------------
    1       16         17
    2       33         34
    3       50         51
    .        .          .
    .        .          .
    .        .          .
   19      322        323
   20      339        340
   21      356        357
C*******************************************************************************
C                            Initial Soil Moisture Condition
C                        For Native and Riparian Vegetation Areas
C
C   IR      ;   Subregion ID (0 if following values are to be used for all subregions)
C   SOILM_NV;   Initial root zone moisture content for native vegetation area for
C                 each soil type (1 to NSOIL); [L/L]
C   SOILM_RV;   Initial root zone moisture content for riparian vegetation area for
C                 each soil type (1 to NSOIL); [L/L]
C
C-----------------------------------------------------------------------------------------------
C   IR     SOILM_NV[1]     SOILM_RV[1]
C          SOILM_NV[2]     SOILM_RV[2]
C          SOILM_NV[3]     SOILM_RV[3]
C          SOILM_NV[4]     SOILM_RV[4]
C-----------------------------------------------------------------------------------------------
    1      0.067           0.067
           0.473           0.473
           0.303           0.303
           0.333           0.333
    2      0.089           0.089
           0.110           0.110
           0.239           0.239
```

```
         0.111          0.111
  3      0.119          0.119
         0.033          0.033
         0.490          0.490
         0.031          0.031
  .        .              .
           .              .
           .              .
  .        .              .
           .              .
           .              .
  .        .              .
           .              .
           .              .
 19      0.080          0.080
         0.208          0.208
         0.065          0.065
         0.322          0.322
 20      0.081          0.081
         0.131          0.131
         0.127          0.127
         0.094          0.094
 21      0.080          0.080
         0.418          0.418
         0.390          0.390
         0.234          0.234
```

8.3.12.6.b Native and Riparian Vegetation Area Data File

This file is exactly the same as the Native and Riparian Vegetation Area Data File for the root zone component version 4.0. Refer to section 8.3.8.10.b for a detailed explanation of this file.

8.4. Output Files

IDC produces several optional output files. In the Root Zone Component Main File, the user can specify file names to which soil moisture as well as land and water use budgets are printed for 4 main land-use types at each subregion. These files are created in HDF5 file format for run-time efficiency and to save computer storage space. A post-processing tool, Budget, which is available for download from the IDC web site and discussed later in this document is required to process these HDF5 files and create tables in ASCII text file format.

Root zone component versions 4.01, 4.11 and 5.0 also allow optional soil moisture and land and water use budgets to be printed at each grid cell to HDF5 files. These files can then be post-processed using the Z-Budget tool for user-defined cell groups, called zones, to generate budget tables for regions other than the pre-defined subregions of the model domain. The Z-Budget tool, which is also available for download from the IDC web site and discussed later in this document, creates tables in ASCII text file format.

Alternatively, *IWFM Tools Add-in for Excel 2016* can be downloaded from IWFM Support Tools page (https://water.ca.gov/Library/Modeling-and-Analysis/Modeling-Platforms/Integrated-Water-Flow-Model). This add-in allows quick transfer of data stored in the IDC HDF5 output files into Excel for further analysis.

Optionally, IDC can generate an end-of-simulation moisture content output file that is already in ASCII text format. This file lists soil moisture for each land-use type at each element for root zone component versions 4.0 through 4.11, and at each subregion for version 5.0. The name for this file is specified in the Root Zone Component Main File.

The soil moisture and land and water use budget files specified in the Root Zone Component Main File stores information for 4 main land-use types at each subregion. Budget information for individual crops is not stored in these files.

Optionally, for versions 4.0 through 4.11, IDC can generate budget files for specific non-ponded and ponded crops at each subregion. This can be achieved by specifying crop codes and output file names in non-ponded and ponded parameter files. As mentioned earlier, the generated files will be in HDF5 file format and the user will need either the Budget post-processor to process these files and generate tables in ASCII text format or the *IWFM Tools Add-in for Excel 2007-2013* to transfer the data stored in these files to MS Excel. The usage of Budget post-processor is explained later in this document. The user's manual for the *IWFM Tools Add-in for Excel 2007-2013* is included with the tool itself.

In the following sections, a detailed explanation of the budget tables that are produced by IDC and post-processed by the Budget post-processor is given.

8.4.1. Output Files for Root Zone Component Version 4.0

8.4.1.1. Subregional Land and Water Use Budget

The subregional land and water use budget HDF5 file is generated by specifying a proper filename in the Root Zone Component Main File. A budget table is produced for each subregion listed for the LPRNT variable in the Budget Main Input File. The title printed for each subregional land and water use budget includes root zone component version number, subregion name given by the user, the unit of data columns and the area of the subregion. All land and water use budget columns are in volumetric units except *Time*, *Agricultural Area* and *Urban Area*. The output units and conversion factors for area (UNITAROU and FACTAROU) and volume (UNITVLOU and FACTVLOU) are specified by the user in the Budget Main Input File.

The total agricultural and urban areas, as well as the agricultural potential consumptive use of applied water and the water supply requirements are reported in the output, followed by the components that the land and water use budget is comprised of. For agricultural lands, potential consumptive use is the amount of water needed to bring the soil moisture up to the irrigation target moisture (field capacity, by default) after the effects of precipitation and generic moisture sources, excluding the net return flow, are taken into account. The agricultural supply requirement is the potential consumptive use of applied water plus the net return flow.

A positive or negative sign is given for each column that is a component of the subregional land and water use. The *Shortage* column is the resulting balance, based on water use components. A value of zero in this column indicates that the available water supply (surface water deliveries, groundwater pumping and surface runoff from upstream elements) meets the agricultural or urban supply requirements. A positive value indicates that the supply is not a large enough quantity to satisfy water requirements. Conversely, a negative value in the *Shortage* column signifies a water supply surplus. The last three columns for agricultural areas are informational and show the sources of water that are used in meeting the crop evapotranspirative requirement.

The following table defines each column in the subregional land and water use budget table printed out to a text file:

SUBREGIONAL LAND AND WATER USE BUDGET		
Column No.	Column Name	Description
1	Time	Simulation date and time
Agricultural Area		
2	Area	Agricultural area
3	Potential CUAW	Applied water needed to increase the soil moisture to irrigation target moisture before taking into account the net return flow
4	Agricultural Supply Requirement	If agricultural water demands are computed internally, this is the total amount of applied water needed to increase the soil moisture to irrigation target moisture plus the net return flow. If agricultural water demands are specified, then this term equals the pre-specified water demand.
5	Pumping (–)	Portion of groundwater pumping that is used to meet the agricultural supply requirement
6	Deliveries (–)	Portion of the stream diversions that is used to meet the agricultural supply requirement
7	Inflow as Srfc. Runoff (–)	Surface runoff (combination of rainfall runoff, and agricultural and urban return flow) from upstream elements and subregions that is captured and used to meet part of the agricultural supply requirement
8	Shortage (=)	Resulting water balance with respect to the agricultural supply requirements and actual water supply specified in preceding columns
9	ETAW	Amount of crop evapotranspiration that is met by applied water (summation of pumping, deliveries and captured surface runoff from upstream elements) through current and previous irrigation events

10	Effective Precip	Amount of crop evapotranspiration that is met by current and previous precipitation events
11	ET from Other Sources	Amount of crop evapotranspiration that is met by generic water sources (e.g. lateral seepage, fog)
Urban Area		
12	Area	Urban area
13	Urban Supply Requirement	Sum of indoor and outdoor urban water demand
14	Pumping (–)	Portion of groundwater pumping that is used to meet the urban supply requirement
15	Deliveries (–)	Portion of stream diversions that is used to meet the urban supply requirement
16	Inflow as Srfc. Runoff (–)	Surface runoff (combination of rainfall runoff, and agricultural and urban return flow) from upstream elements and subregions that is captured and used to meet part of the urban supply requirement
17	Shortage (=)	Resulting water balance with respect to the urban supply requirements and actual water supply specified in preceding columns

If a DSS file is used for print-out, the following pathnames are used:

Part A:

IWFM_L&W_USE_BUD

Part B:

TTT (SR*XXX*) where *TTT* is the name of the subregion and *XXX* is the subregion number

Part C:

One of the following, depending on the output data:

i. *AREA*
ii. *VOLUME*

Part D:

Start date of the time series depending on the values of the BDT and EDT variables (starting and ending date and time of budget print-out)

Part E:

Print-out interval for the subregional land and water use budget as specified in the Budget Main Input File

Part F:

One of the following, depending on the output data (refer to the table above for further details):

i. *AG_AREA* (corresponds to column 2 in text output file)

ii. *AG_POTNL_CUAW* (corresponds to column 3 in text output file)
iii. *AG_SUP_REQ* (corresponds to column 4 in text output file)
iv. *AG_PUMPING* (corresponds to column 5 in text output file)
v. *AG_DELIVERY* (corresponds to column 6 in text output file)
vi. *AG_SR_INFLOW* (corresponds to column 7 in text output file)
vii. *AG_SHORTAGE* (corresponds to column 8 in text output file)
viii. *AG_ETAW* (corresponds to column 9 in text output file)
ix. *AG_EFF_PRECIP* (corresponds to column 10 in text output file)
x. *AG_ET_OTH* (corresponds to column 11 in text output file)
xi. *URB_AREA* (corresponds to column 12 in text output file)
xii. *URB_SUP_REQ* (corresponds to column 13 in text output file)
xiii. *URB_PUMPING* (corresponds to column 14 in text output file)
xiv. *URB_DELIVERY* (corresponds to column 15 in text output file)
xv. *URB_SR_INFLOW* (corresponds to column 16 in text output file)
xvi. *URB_SHORTAGE* (corresponds to column 17 in text output file)

8.4.1.2. Crop-Specific Land and Water Use Budget

The crop-specific land and water use budget HDF5 files are generated by specifying the individual crops and proper filenames in the non-ponded and ponded crops section of the Root Zone Component Main File.

A budget table is produced for each subregion and crop combination listed for the LPRNT variable in the Budget Main Input File. The indices for subregion and crop combinations are arranged in the Root Zone Component such that crops are listed first and subregions second. For instance, if 5 non-ponded crops are specified for crop-specific land and water use budget output in a model with 2 subregions, indices 1 through 5 represent crops 1 through 5 in subregion 1, indices 6 through 10 represent crops 1 through 5 in subregion 2, and indices 11 through 15 represent crops 1 through 5 in the entire model domain. So, if LPRNT variable is set to {1, 7, 9}, budget tables for crop 1 in subregion 1 (index 1), crop 2 in subregion 2 (index 7) and crop 4 in subregion 2 (index 9) will be printed.

The generated budget table is similar to that generated for the subregional land and water use budget except that there is no information for urban lands. The title printed for each crop-specific land and water use budget includes root zone component version number, subregion name given by the user, the crop code, the unit of data columns and the area of the subregion. All land and water use budget columns are in volumetric units except *Time and Area*. The output units and conversion factors for area (UNITAROU and FACTAROU) and volume (UNITVLOU and FACTVLOU) are specified by the user in the Budget Main Input File.

The crop area, potential consumptive use of applied water and the supply requirement are reported in the output, followed by the components that the crop-specific land and water use budget is comprised of. A positive or negative sign is given for each column that is a component of the crop-specific land and water use. The *Shortage* column is the resulting balance, based on water use components. A value of zero in this column indicates that the available water supply (surface water deliveries, groundwater pumping and surface runoff from upstream elements) meets the agricultural or urban supply requirements. A positive value indicates that the supply is not a large enough quantity to satisfy water requirements. Conversely, a negative value in the *Shortage* column signifies a water supply surplus. The last three columns are informational and show the sources of water that are used in meeting the crop evapotranspirative requirement. The following table defines each column in the crop-specific land and water use budget table printed out to a text file:

CROP-SPECIFIC LAND AND WATER USE BUDGET		
Column No.	Column Name	Description
1	Time	Simulation date and time
2	Area	Crop area
3	Potential CUAW	Applied water needed to increase the soil moisture to irrigation target moisture before taking into account the net return flow
4	Agricultural Supply Requirement	If crop water demand is computed internally, this is the total amount of applied water needed to increase the soil moisture to irrigation target moisture plus the net return flow. If crop water demand is specified, then this term equals the pre-specified crop water demand.
5	Pumping (–)	Portion of groundwater pumping that is used to meet the crop water supply requirement
6	Deliveries (–)	Portion of the stream diversions that is used to meet the crop water supply requirement

7	Inflow as Srfc. Runoff (–)	Surface runoff (combination of rainfall runoff, and agricultural and urban return flow) from upstream elements and subregions that is captured and used to meet part of the crop water supply requirement
8	Shortage (=)	Resulting water balance with respect to the crop water supply requirement and actual water supply specified in preceding columns
9	ETAW	Amount of crop evapotranspiration that is met by applied water (summation of pumping, deliveries and captured surface runoff from upstream elements) through current and previous irrigation events
10	Effective Precip	Amount of crop evapotranspiration that is met by current and previous precipitation events
11	ET from Other Sources	Amount of crop evapotranspiration that is met by generic water sources (e.g. lateral seepage, fog)

If a DSS file is used for print-out, the following pathnames are used:

Part A:

IWFM_L&W_USE_BUD

Part B:

TTT (SR*XXX*)_*YY* where *TTT* is the name of the subregion, *XXX* is the subregion number and *YY* is the user-specified crop code

Part C:

One of the following, depending on the output data:

i. *AREA*
ii. *VOLUME*

Part D:

Start date of the time series depending on the values of the BDT and EDT variables (starting and ending date and time of budget print-out)

Part E:

Print-out interval for the crop-specific land and water use budget as specified in the Budget Main Input File

Part F:

One of the following, depending on the output data (refer to the table above for further details):

i. *AREA* (corresponds to column 2 in text output file)
ii. *POTNL_CUAW* (corresponds to column 3 in text output file)
iii. *SUP_REQ* (corresponds to column 4 in text output file)
iv. *PUMPING* (corresponds to column 5 in text output file)

v. *DELIVERY* (corresponds to column 6 in text output file)
vi. *SR_INFLOW* (corresponds to column 7 in text output file)
vii. *SHORTAGE* (corresponds to column 8 in text output file)
viii. *ETAW* (corresponds to column 9 in text output file)
ix. *EFF_PRECIP* (corresponds to column 10 in text output file)
x. *ET_OTHER* (corresponds to column 11 in text output file)

8.4.1.3. Subregional Root Zone Moisture Budget

The subregional root zone moisture budget is produced for each subregion listed for processing in the Budget Main Input File. The title printed for each subregional root zone moisture budget includes root zone component version number, subregion name given by the user, the unit of data columns and the area of the subregion. The output units are specified by the user in the Budget Main Input File.

The root zone moisture budget provides information on processes that are used to compute soil moisture in the root zone. Agricultural areas represent the areas where crops are located. Urban area includes indoor and outdoor urban areas and the native and riparian lands represent the undeveloped area in the subregion. For each area type (agricultural, urban, and native and riparian vegetation) precipitation and irrigation (except for native and riparian vegetation areas) along with direct runoff and return flows are listed. The *Infiltration* column is computed by adding the *Precipitation*, *Prime Applied Water* and *Inflow as Surface Runoff* columns and subtracting the *Runoff* and *Net Return Flow* columns. The following table describes the columns in the subregional root zone moisture budget when printed out to a text file:

SUBREGIONAL ROOT ZONE MOISTURE BUDGET		
Column No.	Column Name	Description
1	Time	Simulation date and time
Agricultural Area		
2	Area	Agricultural area
3	Potential ET	Potential evapotranspiration for agricultural lands
4	Precipitation	Precipitation that falls on agricultural lands
5	Runoff	Direct runoff of precipitation that falls on agricultural lands

6	Prime Applied Water	Amount of water applied as a summation of surface water deliveries and pumping for irrigation purposes
7	Inflow as Surface Runoff	Surface runoff (sum of rainfall runoff and return flow from agricultural and urban lands) from upstream elements and subregions that is captured and used for irrigation purposes
8	Reused Water	Amount of return flow that is captured and re-used for irrigation
9	Net Return Flow	Net return flow of irrigation on agricultural lands (after re-use)
10	Beginning Storage (+)	Root zone moisture in agricultural lands at the beginning of time step
11	Net Gain from Land Expansion (+)	The net moisture gained from other land use areas as the area of agricultural lands increase (a negative value represents loss of moisture due to the decrease of agricultural area)
12	Infiltration (+)	Total infiltration on the agricultural lands; computed as the summation of precipitation, prime applied water and inflow as surface runoff less runoff and net return flow
13	Other Inflow (+)	Moisture inflow from other generic moisture sources such as lateral seepage
14	Pond Drain (–)	Drainage of rice and refuge ponds
15	Actual ET (–)	Actual evapotranspiration in agricultural lands
16	Percolation (–)	Percolation from the root zone which is the vertical moisture outflow from the bottom of the root zone in agricultural areas
17	Ending Storage (–)	Root zone moisture in agricultural lands at the end of the time step computed as the summation of the beginning storage and the net inflow into the root zone
18	Discrepancy (=)	Mass balance error check for the moisture storage in the root zone of agricultural lands
Urban Area		
19	Area	Urban area
20	Potential ET	Potential evapotranspiration for urban lands
21	Precipitation	Precipitation that falls on urban lands
22	Runoff	Direct runoff of precipitation that falls on urban lands
23	Prime Applied Water	Total amount of pumping and surface water deliveries that is used to meet urban indoors and outdoors water demand
24	Inflow as Surface Runoff	Surface runoff (sum of rainfall runoff and return flow from agricultural and urban lands) from upstream elements and subregions that is captured and used to meet urban water demand

25	Reused Water	The amount of return flow that is captured and re-used on urban lands
26	Net Return Flow	Net return flow of applied water used for urban indoors and outdoors usage (after re-use)
27	Beginning Storage (+)	Root zone moisture at the beginning of time step
28	Net Gain from Land Expansion (+)	The net moisture gained from other land use areas as the area of urban lands increase (a negative value represents loss of moisture due to the decrease of urban area)
29	Infiltration (+)	Total infiltration on the urban lands computed as the summation of precipitation, prime applied water and inflow as surface runoff less runoff and net return flow
30	Other Inflow (+)	Moisture inflow from other generic moisture sources such as lateral seepage
31	Actual ET (–)	Actual evapotranspiration in urban lands
32	Percolation (–)	Percolation from the root zone which is the vertical moisture outflow from the bottom of the root zone in urban areas
33	Ending Storage (–)	Root zone moisture in urban lands at the end of the time step computed as the summation of the beginning storage and the net inflow into the root zone
34	Discrepancy (=)	Mass balance error check for the moisture storage in the root zone of urban lands
Native and Riparian Vegetation Area		
35	Area	Native and riparian vegetation area
36	Potential ET	Potential evapotranspiration for native and riparian vegetation
37	Precipitation	Precipitation that falls on areas with native and riparian vegetation
38	Inflow as Surface Runoff	Surface runoff (sum of rainfall runoff and return flow from agricultural and urban lands) from upstream elements and subregions that flows into the lands with native and riparian vegetation
39	Runoff	Direct runoff of precipitation that falls on areas with native and riparian vegetation
40	Beginning Storage (+)	Root zone moisture in areas with native and riparian vegetation at the beginning of time step
41	Net Gain from Land Expansion (+)	The net moisture gained from other land use areas as the area of native and riparian vegetation increase (a negative value represents loss of moisture due to the decrease of native and riparian vegetation area)
42	Infiltration (+)	Total infiltration on areas with native and riparian vegetation; computed as the sum of precipitation and inflow as surface runoff less runoff

43	Other Inflow (+)	Moisture inflow from other generic moisture sources such as lateral seepage
44	Actual ET (–)	Actual evapotranspiration in areas with native and riparian vegetation
45	Percolation (–)	Percolation from the root zone which is the vertical moisture outflow from the bottom of the root zone in areas with native and riparian vegetation
46	Ending Storage (+)	Root zone moisture in areas with native and riparian vegetation at the end of the time step; computed as the summation of the beginning storage and the net moisture inflow
47	Discrepancy (=)	Mass balance error check for the moisture storage in the root zone of lands with native and riparian vegetation

If a DSS file is used for print-out, the following pathnames are used:

Part A:

IWFM_ROOTZN_BUD

Part B:

TTT (SR*XXX*) where *TTT* is the name of the subregion and *XXX* is the subregion number

Part C:

One of the following, depending on the output data:

i. *AREA*
ii. *VOLUME*

Part D:

Start date of the time series depending on the values of the BDT and EDT variables (starting and ending date and time of budget print-out)

Part E:

Print-out interval for the subregional root zone moisture budget as specified in the Budget Main Input File

Part F:

One of the following, depending on the output data (refer to the table above for further details):

i. *AG_AREA* (corresponds to column 2 in text output file)
ii. *AG_POT_ET* (corresponds to column 3 in text output file)
iii. *AG_PRECIP* (corresponds to column 4 in text output file)
iv. *AG_RUNOFF* (corresponds to column 5 in text output file)
v. *AG_PRM_H2O* (corresponds to column 6 in text output file)

vi. *AG_SR_INFLOW* (corresponds to column 7 in text output file)
vii. *AG_RE-USE* (corresponds to column 8 in text output file)
viii. *AG_NT_RTRN_FLOW* (corresponds to column 9 in text output file)
ix. *AG_BEGIN_STOR* (corresponds to column 10 in text output file)
x. *AG_GAIN_EXP* (corresponds to column 11 in text output file)
xi. *AG_INFILTR* (corresponds to column 12 in text output file)
xii. *AG_OTHER_INFLOW* (corresponds to column 13 in text output file)
xiii. *AG_DRAIN* (corresponds to column 14 in text output file)
xiv. *AG_ET* (corresponds to column 15 in text output file)
xv. *AG_PERC* (corresponds to column 16 in text output file)
xvi. *AG_END_STOR* (corresponds to column 17 in text output file)
xvii. *AG_DISCREPANCY* (corresponds to column 18 in text output file)
xviii. *URB_AREA* (corresponds to column 19 in text output file)
xix. *URB_POT_ET* (corresponds to column 20 in text output file)
xx. *URB_PRECIP* (corresponds to column 21 in text output file)
xxi. *URB_RUNOFF* (corresponds to column 22 in text output file)
xxii. *URB_PRM_H2O* (corresponds to column 23 in text output file)
xxiii. *URB_SR_INFLOW* (corresponds to column 24 in text output file)
xxiv. *URB_RE-USE* (corresponds to column 25 in text output file)
xxv. *URB_NT_RTRN_FLOW* (corresponds to column 26 in text output file)
xxvi. *URB_BEGIN_STOR* (corresponds to column 27 in text output file)
xxvii. *URB_GAIN_EXP* (corresponds to column 28 in text output file)
xxviii. *URB_INFILTR* (corresponds to column 29 in text output file)
xxix. *URB_OTHER_INFLOW* (corresponds to column 30 in text output file)
xxx. *URB_ET* (corresponds to column 31 in text output file)
xxxi. *URB_PERC* (corresponds to column 32 in text output file)
xxxii. *URB_END_STOR* (corresponds to column 33 in text output file)
xxxiii. *URB_DISCREPANCY* (corresponds to column 34 in text output file)

xxxiv. *NRV_AREA* (corresponds to column 35 in text output file)
xxxv. *NRV_POT_ET* (corresponds to column 36 in text output file)
xxxvi. *NRV_PRECIP* (corresponds to column 37 in text output file)
xxxvii. *NRV_SR_INFLOW* (corresponds to column 38 in text output file)
xxxviii. *NRV_RUNOFF* (corresponds to column 39 in text output file)
xxxix. *NRV_BEGIN_STOR* (corresponds to column 40 in text output file)
xl. *NRV_GAIN_EXP* (corresponds to column 41 in text output file)
xli. *NRV_INFILTR* (corresponds to column 42 in text output file)
xlii. *NRV_OTHER_INFLOW* (corresponds to column 43 in text output file)
xliii. *NRV_ET* (corresponds to column 44 in text output file)
xliv. *NRV_PERC* (corresponds to column 45 in text output file)
xlv. *NRV_END_STOR* (corresponds to column 46 in text output file)
xlvi. *NRV_DISCREPANCY* (corresponds to column 47 in text output file)

8.4.1.4. Crop-Specific Root Zone Moisture Budget

The crop-specific root zone moisture budget HDF5 files are generated by specifying the individual crops and proper filenames in the non-ponded and ponded crops section of the Root Zone Component Main File.

A budget table is produced for each subregion and crop combination listed for the LPRNT variable in the Budget Main Input File. The indices for subregion and crop combinations are arranged in the Root Zone Component such that crops are listed first and subregions second. For instance, if 5 non-ponded crops are specified for crop-specific root zone moisture budget HDF5 output in a model with 2 subregions, indices 1 through 5 represent crops 1 through 5 in subregion 1, indices 6 through 10 represent crops 1 through 5 in subregion 2, and indices 11 through 15 represent crops 1 through 5 in the entire model domain. So, if LPRNT variable is set to {1, 7, 9}, budget tables for crop 1 in subregion 1 (index 1), crop 2 in subregion 2 (index 7) and crop 4 in subregion 2 (index 9) will be printed.

The generated budget table is similar to that generated for the subregional root zone moisture budget except that there is no information for urban lands, and areas with native and riparian vegetation. The title printed for each crop-specific root zone moisture budget includes root zone component version number, subregion name given by the user, the crop code, the unit of data columns and the area of the subregion.

The following table describes the columns in the crop-specific root zone moisture budget when printed out to a text file:

CROP-SPECIFIC ROOT ZONE MOISTURE BUDGET		
Column No.	Column Name	Description
1	Time	Simulation date and time
2	Area	Crop area
3	Potential ET	Potential evapotranspiration for the specified crop
4	Precipitation	Precipitation that falls on areas with the specified crop
5	Runoff	Direct runoff of precipitation that falls on areas with the specified crop
6	Prime Applied Water	Amount of water applied as a summation of surface water deliveries and pumping for irrigation purposes
7	Inflow as Surface Runoff	Surface runoff (sum of rainfall runoff and return flow from agricultural and urban lands) from upstream elements and subregions that is captured and used for irrigation purposes
8	Reused Water	Amount of return flow that is captured and re-used for irrigation
9	Net Return Flow	Net return flow of irrigation on areas with the specified crop (after re-use)
10	Beginning Storage (+)	Root zone moisture in areas with the specified crop at the beginning of time step
11	Net Gain from Land Expansion (+)	The net moisture gained from other land use areas as the area of the specified crop increases (a negative value represents loss of moisture due to the decrease of the crop area)
12	Infiltration (+)	Total infiltration on areas with the specified crop; computed as the summation of precipitation, prime applied water and inflow as surface runoff less runoff and net return flow
13	Other Inflow (+)	Moisture inflow from other generic moisture sources such as lateral seepage
14	Pond Drain (–)	Drainage of rice and refuge ponds; this column is non-zero only if the specified crop is a ponded crop
15	Actual ET (–)	Actual evapotranspiration of the specified crop

16	Percolation (–)	Percolation from the root zone which is the vertical moisture outflow from the bottom of the crop root zone
17	Ending Storage (–)	Root zone moisture in areas with the specified crop at the end of the time step computed as the summation of the beginning storage and the net inflow into the root zone
18	Discrepancy (=)	Mass balance error check for the moisture storage in the root zone of the specified crop

If a DSS file is used for print-out, the following pathnames are used:

Part A:

IWFM_ROOTZN_BUD

Part B:

TTT (SR*XXX*)_*YY* where *TTT* is the name of the subregion, *XXX* is the subregion number and *YY* is the crop code specified by the user

Part C:

One of the following, depending on the output data:

i. *AREA*
ii. *VOLUME*

Part D:

Start date of the time series depending on the values of the BDT and EDT variables (starting and ending date and time of budget print-out)

Part E:

Print-out interval for the crop-specific root zone moisture budget as specified in the Budget Main Input File

Part F:

One of the following, depending on the output data (refer to the table above for further details):

i. *AREA* (corresponds to column 2 in text output file)
ii. *POT_ET* (corresponds to column 3 in text output file)
iii. *PRECIP* (corresponds to column 4 in text output file)
iv. *RUNOFF* (corresponds to column 5 in text output file)
v. *PRM_H2O* (corresponds to column 6 in text output file)
vi. *SR_INFLOW* (corresponds to column 7 in text output file)
vii. *RE-USE* (corresponds to column 8 in text output file)
viii. *NET_RTRN_FLOW* (corresponds to column 9 in text output file)

ix. *BEGIN_STOR* (corresponds to column 10 in text output file)
x. *GAIN_EXP* (corresponds to column 11 in text output file)
xi. *INFILTR* (corresponds to column 12 in text output file)
xii. *OTHER_INFLOW* (corresponds to column 13 in text output file)
xiii. *DRAIN* (corresponds to column 14 in text output file)
xiv. *ET* (corresponds to column 15 in text output file)
xv. *PERC* (corresponds to column 16 in text output file)
xvi. *END_STOR* (corresponds to column 17 in text output file)
xvii. *DISCREPANCY* (corresponds to column 18 in text output file)

8.4.2. Output Files for Root Zone Component Version 4.01

Root zone component version 4.01 can generate the same output files as version 4.0. Refer to section 8.4.1 for a description of these files. Additionally it can generate the land and water use as well as the root zone Z-Budget output files for element-level budgets which can then be aggregated for groups of elements, called zones, using the Z-Budget post-processing tool.

8.4.2.1. Land and Water Use Z-Budget

The Z-Budget tool allows printing of the land and water use budget tables to either an ASCII text file or to a DSS file for each of the zones defined by the user. The budget table for each zone includes a title that lists the version of the root zone component that was used in the IDC run, the units of the budget flow terms as well as the name and area of the zone.

The land and water use budget for each zone provides water demand and supply information for non-ponded crops, rice, refuges and urban areas. The portions of the evapotranspiration that are met by irrigation, source of water that meets the evapotranspiration are also listed.

The following table defines each column in the land and water use budget table printed out to a text file:

LAND AND WATER USE Z-BUDGET		
Column No.	Column Name	Description
1	Time	Simulation date and time
Non-Ponded Agricultural Area		
2	Area	Non-ponded agricultural area
3	Potential CUAW	Applied water needed to increase the soil moisture to irrigation target moisture for non-ponded crops before taking into account the net return flow
4	Agricultural Supply Requirement	If non-ponded crop water demands are computed internally, this is the total amount of applied water needed to increase the soil moisture to irrigation target moisture plus the net return flow for non-ponded crops. If non-ponded water demands are specified, then this term equals the pre-specified water demand.
5	Pumping (–)	Portion of groundwater pumping that is used to meet the non-ponded agricultural supply requirement
6	Deliveries (–)	Portion of the stream diversions that is used to meet the non-ponded agricultural supply requirement
7	Inflow as Srfc. Runoff (–)	Surface runoff (combination of rainfall runoff, and agricultural and urban return flow) from upstream elements and subregions that is captured and used to meet part of the non-ponded agricultural supply requirement
8	Shortage (=)	Resulting water balance with respect to the non-ponded agricultural supply requirements and actual water supply specified in preceding columns
9	ETAW	Amount of non-ponded crop evapotranspiration that is met by applied water (summation of pumping, deliveries and captured surface runoff from upstream elements) through current and previous irrigation events
10	Effective Precip	Amount of non-ponded crop evapotranspiration that is met by current and previous precipitation events
11	ET from Other Sources	Amount of non-ponded crop evapotranspiration that is met by generic water sources (e.g. lateral seepage, fog)
Rice Area		
12	Area	Total rice area
13	Potential CUAW	Applied water needed to increase the soil moisture to irrigation target moisture before taking into account the net return flow
14	Agricultural Supply Requirement	If rice water demands are computed internally, this is the total amount of applied water needed to increase the soil moisture to irrigation target moisture plus the net return flow. If rice water demands are specified,

		then this term equals the pre-specified water demand.
15	Pumping (–)	Portion of groundwater pumping that is used to meet the rice water supply requirement
16	Deliveries (–)	Portion of the stream diversions that is used to meet the rice water supply requirement
17	Inflow as Srfc. Runoff (–)	Surface runoff (combination of rainfall runoff, and agricultural and urban return flow) from upstream elements and subregions that is captured and used to meet part of the rice water supply requirement
18	Shortage (=)	Resulting water balance with respect to the rice water supply requirements and actual water supply specified in preceding columns
19	ETAW	Amount of rice evapotranspiration that is met by applied water (summation of pumping, deliveries and captured surface runoff from upstream elements) through current and previous irrigation events
20	Effective Precip	Amount of rice evapotranspiration that is met by current and previous precipitation events
21	ET from Other Sources	Amount of rice evapotranspiration that is met by generic water sources (e.g. lateral seepage, fog)
Refuge Area		
22	Area	Total refuge area
23	Potential CUAW	Applied water needed to increase the soil moisture to irrigation target moisture in refuges before taking into account the net return flow
24	Agricultural Supply Requirement	If refuge water demands are computed internally, this is the total amount of applied water needed to increase the soil moisture to irrigation target moisture plus the net return flow. If refuge water demands are specified, then this term equals the pre-specified water demand.
25	Pumping (–)	Portion of groundwater pumping that is used to meet the refuge water supply requirement
26	Deliveries (–)	Portion of the stream diversions that is used to meet the refuge water supply requirement
27	Inflow as Srfc. Runoff (–)	Surface runoff (combination of rainfall runoff, and agricultural and urban return flow) from upstream elements and subregions that is captured and used to meet part of the refuge water supply requirement
28	Shortage (=)	Resulting water balance with respect to the refuge water supply requirements and actual water supply specified in preceding columns
29	ETAW	Amount of refuge evapotranspiration that is met by applied water (summation of pumping, deliveries and captured surface runoff from upstream elements) through current and previous irrigation events

30	Effective Precip	Amount of refuge evapotranspiration that is met by current and previous precipitation events
31	ET from Other Sources	Amount of refuge evapotranspiration that is met by generic water sources (e.g. lateral seepage, fog)
Urban Area		
32	Area	Urban area
33	Urban Supply Requirement	Sum of indoor and outdoor urban water demand
34	Pumping (–)	Portion of groundwater pumping that is used to meet the urban supply requirement
35	Deliveries (–)	Portion of stream diversions that is used to meet the urban supply requirement
36	Inflow as Srfc. Runoff (–)	Surface runoff (combination of rainfall runoff, and agricultural and urban return flow) from upstream elements and subregions that is captured and used to meet part of the urban supply requirement
37	Shortage (=)	Resulting water balance with respect to the urban supply requirements and actual water supply specified in preceding columns

If a DSS file is used for print-out, the following pathnames are used:

Part A:

IWFM_ZBUD

Part B:

ZONE:*XXX* where *XXX* is the zone number

Part C:

One of the following, depending on the output data:

i. *AREA*
ii. *VOLUME*

Part D:

Start date of the time series depending on the values of the BDT and EDT variables (starting and ending date and time of budget print-out)

Part E:

Print-out interval for the zonal land and water use budget as specified in the Z-Budget Main Input File

Part F:

One of the following, depending on the output data (refer to the table above for further details):

i. *NP_AG_AREA* (corresponds to column 2 in text output file)

ii. *NP_AG_POTNL_CUAW* (corresponds to column 3 in text output file)
iii. *NP_AG_SUP_REQ* (corresponds to column 4 in text output file)
iv. *NP_AG_PUMPING* (corresponds to column 5 in text output file)
v. *NP_AG_DELIVERY* (corresponds to column 6 in text output file)
vi. *NP_AG_SR_INFLOW* (corresponds to column 7 in text output file)
vii. *NP_AG_SHORTAGE* (corresponds to column 8 in text output file)
viii. *NP_AG_ETAW* (corresponds to column 9 in text output file)
ix. *NP_AG_EFF_PRECIP* (corresponds to column 10 in text output file)
x. *NP_AG_ET_OTH* (corresponds to column 11 in text output file)
xi. *RICE_AREA* (corresponds to column 12 in text output file)
xii. *RICE_POTNL_CUAW* (corresponds to column 13 in text output file)
xiii. *RICE_SUP_REQ* (corresponds to column 14 in text output file)
xiv. *RICE_PUMPING* (corresponds to column 15 in text output file)
xv. *RICE_DELIVERY* (corresponds to column 16 in text output file)
xvi. *RICE_SR_INFLOW* (corresponds to column 17 in text output file)
xvii. *RICE_SHORTAGE* (corresponds to column 18 in text output file)
xviii. *RICE_ETAW* (corresponds to column 19 in text output file)
xix. *RICE_EFF_PRECIP* (corresponds to column 20 in text output file)
xx. *RICE_ET_OTH* (corresponds to column 21 in text output file)
xxi. *REFUGE_AREA* (corresponds to column 22 in text output file)
xxii. *REFUGE_POTNL_CUAW* (corresponds to column 23 in text output file)
xxiii. *REFUGE_SUP_REQ* (corresponds to column 24 in text output file)
xxiv. *REFUGE_PUMPING* (corresponds to column 25 in text output file)
xxv. *REFUGE_DELIVERY* (corresponds to column 26 in text output file)
xxvi. *REFUGE_SR_INFLOW* (corresponds to column 27 in text output file)

xxvii. *REFUGE_SHORTAGE* (corresponds to column 28 in text output file)
xxviii. *REFUGE_ETAW* (corresponds to column 29 in text output file)
xxix. *REFUGE_EFF_PRECIP* (corresponds to column 30 in text output file)
xxx. *REFUGE_ET_OTH* (corresponds to column 31 in text output file)
xxxi. *URB_AREA* (corresponds to column 32 in text output file)
xxxii. *URB_SUP_REQ* (corresponds to column 33 in text output file)
xxxiii. *URB_PUMPING* (corresponds to column 34 in text output file)
xxxiv. *URB_DELIVERY* (corresponds to column 35 in text output file)
xxxv. *URB_SR_INFLOW* (corresponds to column 36 in text output file)
xxxvi. *URB_SHORTAGE* (corresponds to column 37 in text output file)

8.4.2.2. Root Zone Moisture Z-Budget

The Z-Budget tool allows printing of the root zone budget tables to either an ASCII text file or to a DSS file for each of the zones defined by the user. The budget table for each zone includes a title that lists the version of the root zone component that was used in the IDC run, the units of the budget flow terms as well as the name and area of the zone.

The root zone moisture budget for each zone provides detailed inflow and outflow terms to and from the root zone for non-ponded crops, rice, refuges and urban areas as well as native and riparian vegetation araes. It also includes precipitation, rainfall runoff, applied water and return flow for each zone.

The following table defines each column in the land and water use budget table printed out to a text file:

ROOT ZONE MOISTURE Z-BUDGET		
Column No.	Column Name	Description
1	Time	Simulation date and time
Non-Ponded Agricultural Area		
2	Area	Agricultural area
3	Potential ET	Potential evapotranspiration for non-ponded crops
4	Precipitation	Precipitation that falls on non-ponded agricultural lands

5	Runoff	Direct runoff of precipitation that falls on non-ponded agricultural lands
6	Prime Applied Water	Amount of water applied as a summation of surface water deliveries and pumping for irrigation purposes
7	Inflow as Surface Runoff	Surface runoff (sum of rainfall runoff and return flow from agricultural and urban lands) from upstream elements and subregions that is captured and used for irrigation purposes
8	Reused Water	Amount of return flow that is captured and re-used for irrigation
9	Net Return Flow	Net return flow of irrigation on non-ponded agricultural lands (after re-use)
10	Beginning Storage (+)	Root zone moisture in non-ponded agricultural lands at the beginning of time step
11	Net Gain from Land Expansion (+)	The net moisture gained from other land use areas as the area of non-ponded agricultural lands increase (a negative value represents loss of moisture due to the decrease of non-ponded agricultural area)
12	Infiltration (+)	Total infiltration on the non-ponded agricultural lands; computed as the summation of precipitation, prime applied water and inflow as surface runoff less runoff and net return flow
13	Other Inflow (+)	Moisture inflow from other generic moisture sources such as lateral seepage
14	Actual ET (–)	Actual non-ponded crop evapotranspiration
15	Percolation (–)	Percolation from the root zone which is the vertical moisture outflow from the bottom of the root zone in non-ponded agricultural areas
16	Ending Storage (–)	Root zone moisture in non-ponded agricultural lands at the end of the time step computed as the summation of the beginning storage and the net inflow into the root zone
17	Discrepancy (=)	Mass balance error check for the moisture storage in the root zone of non-ponded agricultural lands
Rice Area		
18	Area	Rice area
19	Potential ET	Potential evapotranspiration for rice
20	Precipitation	Precipitation that falls on rice lands
21	Runoff	Direct runoff of precipitation that falls on rice lands
22	Prime Applied Water	Amount of water applied as a summation of surface water deliveries and pumping for irrigation purposes
23	Inflow as Surface Runoff	Surface runoff (sum of rainfall runoff and return flow from agricultural and urban lands) from upstream elements and subregions that is captured and used for irrigation purposes

24	Reused Water	Amount of return flow that is captured and re-used for irrigation
25	Net Return Flow	Net return flow of irrigation on rice lands (after re-use)
26	Beginning Storage (+)	Root zone moisture in rice lands at the beginning of time step
27	Net Gain from Land Expansion (+)	The net moisture gained from other land use areas as the area of rice lands increase (a negative value represents loss of moisture due to the decrease of rice area)
28	Infiltration (+)	Total infiltration on the rice lands; computed as the summation of precipitation, prime applied water and inflow as surface runoff less runoff and net return flow
29	Other Inflow (+)	Moisture inflow from other generic moisture sources such as lateral seepage
30	Pond Drain (–)	Drainage of rice ponds
31	Actual ET (–)	Actual rice evapotranspiration
32	Percolation (–)	Percolation from the root zone which is the vertical moisture outflow from the bottom of the root zone in rice lands
33	Ending Storage (–)	Root zone moisture in rice lands at the end of the time step computed as the summation of the beginning storage and the net inflow into the root zone
34	Discrepancy (=)	Mass balance error check for the moisture storage in the root zone of rice lands
Refuge Area		
35	Area	Refuge area
36	Potential ET	Potential evapotranspiration for refuges
37	Precipitation	Precipitation that falls on refuges
38	Runoff	Direct runoff of precipitation that falls on refuges
39	Prime Applied Water	Amount of water applied as a summation of surface water deliveries and pumping for irrigation purposes
40	Inflow as Surface Runoff	Surface runoff (sum of rainfall runoff and return flow from agricultural and urban lands) from upstream elements and subregions that is captured and used for irrigation purposes
41	Reused Water	Amount of return flow that is captured and re-used for irrigation
42	Net Return Flow	Net return flow of irrigation on refuges (after re-use)
43	Beginning Storage (+)	Root zone moisture in refuges at the beginning of time step

44	Net Gain from Land Expansion (+)	The net moisture gained from other land use areas as the area of refuges increase (a negative value represents loss of moisture due to the decrease of refuge area)
45	Infiltration (+)	Total infiltration in the refuges; computed as the summation of precipitation, prime applied water and inflow as surface runoff less runoff and net return flow
46	Other Inflow (+)	Moisture inflow from other generic moisture sources such as lateral seepage
47	Pond Drain (–)	Drainage of refuge ponds
48	Actual ET (–)	Actual refuge evapotranspiration
49	Percolation (–)	Percolation from the root zone which is the vertical moisture outflow from the bottom of the root zone in refuges
50	Ending Storage (–)	Root zone moisture in refuges at the end of the time step computed as the summation of the beginning storage and the net inflow into the root zone
51	Discrepancy (=)	Mass balance error check for the moisture storage in the root zone of refuges
Urban Area		
52	Area	Urban area
53	Potential ET	Potential evapotranspiration for urban lands
54	Precipitation	Precipitation that falls on urban lands
55	Runoff	Direct runoff of precipitation that falls on urban lands
56	Prime Applied Water	Total amount of pumping and surface water deliveries that is used to meet urban indoors and outdoors water demand
57	Inflow as Surface Runoff	Surface runoff (sum of rainfall runoff and return flow from agricultural and urban lands) from upstream elements and subregions that is captured and used to meet urban water demand
58	Reused Water	The amount of return flow that is captured and re-used on urban lands
59	Net Return Flow	Net return flow of applied water used for urban indoors and outdoors usage (after re-use)
60	Beginning Storage (+)	Root zone moisture at the beginning of time step
61	Net Gain from Land Expansion (+)	The net moisture gained from other land use areas as the area of urban lands increase (a negative value represents loss of moisture due to the decrease of urban area)
62	Infiltration (+)	Total infiltration on the urban lands computed as the summation of precipitation, prime applied water and inflow as surface runoff less runoff and net return flow

63	Other Inflow (+)	Moisture inflow from other generic moisture sources such as lateral seepage
64	Actual ET (–)	Actual evapotranspiration in urban lands
65	Percolation (–)	Percolation from the root zone which is the vertical moisture outflow from the bottom of the root zone in urban areas
66	Ending Storage (–)	Root zone moisture in urban lands at the end of the time step computed as the summation of the beginning storage and the net inflow into the root zone
67	Discrepancy (=)	Mass balance error check for the moisture storage in the root zone of urban lands
Native and Riparian Vegetation Area		
68	Area	Native and riparian vegetation area
69	Potential ET	Potential evapotranspiration for native and riparian vegetation
70	Precipitation	Precipitation that falls on areas with native and riparian vegetation
71	Inflow as Surface Runoff	Surface runoff (sum of rainfall runoff and return flow from agricultural and urban lands) from upstream elements and subregions that flows into the lands with native and riparian vegetation
72	Runoff	Direct runoff of precipitation that falls on areas with native and riparian vegetation
73	Beginning Storage (+)	Root zone moisture in areas with native and riparian vegetation at the beginning of time step
74	Net Gain from Land Expansion (+)	The net moisture gained from other land use areas as the area of native and riparian vegetation increase (a negative value represents loss of moisture due to the decrease of native and riparian vegetation area)
75	Infiltration (+)	Total infiltration on areas with native and riparian vegetation; computed as the sum of precipitation and inflow as surface runoff less runoff
76	Other Inflow (+)	Moisture inflow from other generic moisture sources such as lateral seepage
77	Actual ET (–)	Actual evapotranspiration in areas with native and riparian vegetation
78	Percolation (–)	Percolation from the root zone which is the vertical moisture outflow from the bottom of the root zone in areas with native and riparian vegetation
79	Ending Storage (+)	Root zone moisture in areas with native and riparian vegetation at the end of the time step; computed as the summation of the beginning storage and the net moisture inflow
80	Discrepancy (=)	Mass balance error check for the moisture storage in the root zone of lands with native and riparian vegetation

If a DSS file is used for print-out, the following pathnames are used:

Part A:

IWFM_ZBUD

Part B:

ZONE:*XXX* where *XXX* is the zone number

Part C:

One of the following, depending on the output data:

i. *AREA*
ii. *VOLUME*

Part D:

Start date of the time series depending on the values of the BDT and EDT variables (starting and ending date and time of budget print-out)

Part E:

Print-out interval for the zonal root zone budget as specified in the Z-Budget Main Input File

Part F:

One of the following, depending on the output data (refer to the table above for further details):

i. *NP_AG_AREA* (corresponds to column 2 in text output file)
ii. *NP_AG_POT_ET* (corresponds to column 3 in text output file)
iii. *NP_AG_PRECIP* (corresponds to column 4 in text output file)
iv. *NP_AG_RUNOFF* (corresponds to column 5 in text output file)
v. *NP_AG_PRM_H2O* (corresponds to column 6 in text output file)
vi. *NP_AG_SR_INFLOW* (corresponds to column 7 in text output file)
vii. *NP_AG_RE-USE* (corresponds to column 8 in text output file)
viii. *NP_AG_NT_RTRN_FLOW* (corresponds to column 9 in text output file)
ix. *NP_AG_BEGIN_STOR* (corresponds to column 10 in text output file)
x. *NP_AG_GAIN_EXP* (corresponds to column 11 in text output file)
xi. *NP_AG_INFILTR* (corresponds to column 12 in text output file)

xii. *NP_AG_OTHER_INFLOW* (corresponds to column 13 in text output file)
xiii. *NP_AG_ET* (corresponds to column 14 in text output file)
xiv. *NP_AG_PERC* (corresponds to column 15 in text output file)
xv. *NP_AG_END_STOR* (corresponds to column 16 in text output file)
xvi. *NP_AG_DISCREPANCY* (corresponds to column 17 in text output file)
xvii. *RICE_AREA* (corresponds to column 18 in text output file)
xviii. *RICE_POT_ET* (corresponds to column 19 in text output file)
xix. *RICE_PRECIP* (corresponds to column 20 in text output file)
xx. *RICE_RUNOFF* (corresponds to column 21 in text output file)
xxi. *RICE_PRM_H2O* (corresponds to column 22 in text output file)
xxii. *RICE_SR_INFLOW* (corresponds to column 23 in text output file)
xxiii. *RICE_RE-USE* (corresponds to column 24 in text output file)
xxiv. *RICE_NT_RTRN_FLOW* (corresponds to column 25 in text output file)
xxv. *RICE_BEGIN_STOR* (corresponds to column 26 in text output file)
xxvi. *RICE_GAIN_EXP* (corresponds to column 27 in text output file)
xxvii. *RICE_INFILTR* (corresponds to column 28 in text output file)
xxviii. *RICE_OTHER_INFLOW* (corresponds to column 29 in text output file)
xxix. *RICE_DRAIN* (corresponds to column 30 in text output file)
xxx. *RICE_ET* (corresponds to column 31 in text output file)
xxxi. *RICE_PERC* (corresponds to column 32 in text output file)
xxxii. *RICE_END_STOR* (corresponds to column 33 in text output file)
xxxiii. *RICE_DISCREPANCY* (corresponds to column 34 in text output file)
xxxiv. *REFUGE_AREA* (corresponds to column 35 in text output file)
xxxv. *REFUGE_POT_ET* (corresponds to column 36 in text output file)
xxxvi. *REFUGE_PRECIP* (corresponds to column 37 in text output file)
xxxvii. *REFUGE_RUNOFF* (corresponds to column 38 in text output file)

xxxviii. *REFUGE_PRM_H2O* (corresponds to column 39 in text output file)
xxxix. *REFUGE_SR_INFLOW* (corresponds to column 40 in text output file)
xl. *REFUGE_RE-USE* (corresponds to column 41 in text output file)
xli. *REFUGE_NT_RTRN_FLOW* (corresponds to column 42 in text output file)
xlii. *REFUGE_BEGIN_STOR* (corresponds to column 43 in text output file)
xliii. *REFUGE_GAIN_EXP* (corresponds to column 44 in text output file)
xliv. *REFUGE_INFILTR* (corresponds to column 45 in text output file)
xlv. *REFUGE_OTHER_INFLOW* (corresponds to column 46 in text output file)
xlvi. *REFUGE_DRAIN* (corresponds to column 47 in text output file)
xlvii. *REFUGE_ET* (corresponds to column 48 in text output file)
xlviii. *REFUGE_PERC* (corresponds to column 49 in text output file)
xlix. *REFUGE_END_STOR* (corresponds to column 50 in text output file)
l. *REFUGE_DISCREPANCY* (corresponds to column 51 in text output file)
li. *URB_AREA* (corresponds to column 52 in text output file)
lii. *URB_POT_ET* (corresponds to column 53 in text output file)
liii. *URB_PRECIP* (corresponds to column 54 in text output file)
liv. *URB_RUNOFF* (corresponds to column 55 in text output file)
lv. *URB_PRM_H2O* (corresponds to column 56 in text output file)
lvi. *URB_SR_INFLOW* (corresponds to column 57 in text output file)
lvii. *URB_RE-USE* (corresponds to column 58 in text output file)
lviii. *URB_NT_RTRN_FLOW* (corresponds to column 59 in text output file)
lix. *URB_BEGIN_STOR* (corresponds to column 60 in text output file)
lx. *URB_GAIN_EXP* (corresponds to column 61 in text output file)
lxi. *URB_INFILTR* (corresponds to column 62 in text output file)

lxii. *URB_OTHER_INFLOW* (corresponds to column 63 in text output file)
lxiii. *URB_ET* (corresponds to column 64 in text output file)
lxiv. *URB_PERC* (corresponds to column 65 in text output file)
lxv. *URB_END_STOR* (corresponds to column 66 in text output file)
lxvi. *URB_DISCREPANCY* (corresponds to column 67 in text output file)
lxvii. *NRV_AREA* (corresponds to column 68 in text output file)
lxviii. *NRV_POT_ET* (corresponds to column 69 in text output file)
lxix. *NRV_PRECIP* (corresponds to column 70 in text output file)
lxx. *NRV_SR_INFLOW* (corresponds to column 71 in text output file)
lxxi. *NRV_RUNOFF* (corresponds to column 72 in text output file)
lxxii. *NRV_BEGIN_STOR* (corresponds to column 73 in text output file)
lxxiii. *NRV_GAIN_EXP* (corresponds to column 74 in text output file)
lxxiv. *NRV_INFILTR* (corresponds to column 75 in text output file)
lxxv. *NRV_OTHER_INFLOW* (corresponds to column 76 in text output file)
lxxvi. *NRV_ET* (corresponds to column 77 in text output file)
lxxvii. *NRV_PERC* (corresponds to column 78 in text output file)
lxxviii. *NRV_END_STOR* (corresponds to column 79 in text output file)
lxxix. *NRV_DISCREPANCY* (corresponds to column 80 in text output file)

8.4.3. Output Files for Root Zone Component Version 4.1

Since root zone component version 4.1 simulates root water uptake from groundwater and riparian vegetation access to stream flows in addition to other flow processes simulated in version 4.1, budget output files for version 4.1 have several additional data columns. Other data columns are the same as those in version 4.0 and are already explained in detail in section 8.4.1. Therefore, only the additional data columns that appear in version 4.1 will be explained in the following sections.

8.4.3.1. Subregional Land and Water Use Budget

In root zone component version 4.1, groundwater can meet all or a portion of the plant evapotranspirative demand. For agricultural areas, the portion of the total evapotranspiration that is met by groundwater is listed along with the other possible moisture sources; namely, irrigation, precipitation and generic moisture source.

The following table defines each column in the subregional land and water use budget table for root zone component version 4.1 when printed out to a text file:

SUBREGIONAL LAND AND WATER USE BUDGET		
Column No.	Column Name	Description
1	Time	Simulation date and time
Agricultural Area		
2	Area	Agricultural area
3	Potential CUAW	Applied water needed to increase the soil moisture to irrigation target moisture before taking into account the net return flow
4	Agricultural Supply Requirement	If agricultural water demands are computed internally, this is the total amount of applied water needed to increase the soil moisture to irrigation target moisture plus the net return flow. If agricultural water demands are specified, then this term equals the pre-specified water demand.
5	Pumping (–)	Portion of groundwater pumping that is used to meet the agricultural supply requirement
6	Deliveries (–)	Portion of the stream diversions that is used to meet the agricultural supply requirement
7	Inflow as Srfc. Runoff (–)	Surface runoff (combination of rainfall runoff, and agricultural and urban return flow) from upstream elements and subregions that is captured and used to meet part of the agricultural supply requirement
8	Shortage (=)	Resulting water balance with respect to the agricultural supply requirements and actual water supply specified in preceding columns
9	ETAW	Amount of crop evapotranspiration that is met by applied water (summation of pumping, deliveries and captured surface runoff from upstream elements) through current and previous irrigation events
10	Effective Precip	Amount of crop evapotranspiration that is met by current and previous precipitation events
11	ET from Groundwater	Amount of crop evapotranspiration that is met by groundwater

12	ET from Other Sources	Amount of crop evapotranspiration that is met by generic water sources (e.g. lateral seepage, fog)
Urban Area		
13	Area	Urban area
14	Urban Supply Requirement	Sum of indoor and outdoor urban water demand
15	Pumping (–)	Portion of groundwater pumping that is used to meet the urban supply requirement
16	Deliveries (–)	Portion of stream diversions that is used to meet the urban supply requirement
17	Inflow as Srfc. Runoff (–)	Surface runoff (combination of rainfall runoff, and agricultural and urban return flow) from upstream elements and subregions that is captured and used to meet part of the urban supply requirement
18	Shortage (=)	Resulting water balance with respect to the urban supply requirements and actual water supply specified in preceding columns

If a DSS file is used for print-out, the following pathnames are used:

Part A:

IWFM_L&W_USE_BUD

Part B:

TTT (SR*XXX*) where *TTT* is the name of the subregion and *XXX* is the subregion number

Part C:

One of the following, depending on the output data:

i. *AREA*
ii. *VOLUME*

Part D:

Start date of the time series depending on the values of the BDT and EDT variables (starting and ending date and time of budget print-out)

Part E:

Print-out interval for the subregional land and water use budget as specified in the Budget Main Input File

Part F:

One of the following, depending on the output data (refer to the table above for further details):

i. *AG_AREA* (corresponds to column 2 in text output file)
ii. *AG_POTNL_CUAW* (corresponds to column 3 in text output file)

iii. *AG_SUP_REQ* (corresponds to column 4 in text output file)
iv. *AG_PUMPING* (corresponds to column 5 in text output file)
v. *AG_DELIVERY* (corresponds to column 6 in text output file)
vi. *AG_SR_INFLOW* (corresponds to column 7 in text output file)
vii. *AG_SHORTAGE* (corresponds to column 8 in text output file)
viii. *AG_ETAW* (corresponds to column 19 in text output file)
ix. *AG_EFF_PRECIP* (corresponds to column 10 in text output file)
x. *AG_ET_GW* (corresponds to column 11 in text output file)
xi. *AG_ET_OTH* (corresponds to column 12 in text output file)
xii. *URB_AREA* (corresponds to column 13 in text output file)
xiii. *URB_SUP_REQ* (corresponds to column 14 in text output file)
xiv. *URB_PUMPING* (corresponds to column 15 in text output file)
xv. *URB_DELIVERY* (corresponds to column 16 in text output file)
xvi. *URB_SR_INFLOW* (corresponds to column 17 in text output file)
xvii. *URB_SHORTAGE* (corresponds to column 18 in text output file)

8.4.3.2. Crop-Specific Land and Water Use Budget

In addition to the output columns listed and explained for root zone component version 4.0 in section 8.4.1.2, the portion of plant evapotranspirative demand that is met by groundwater is listed for user-specified ponded and non-ponded crops. The following table defines each column in the crop-specific land and water use budget table printed out to a text file:

CROP-SPECIFIC LAND AND WATER USE BUDGET		
Column No.	Column Name	Description
1	Time	Simulation date and time
2	Area	Crop area
3	Potential CUAW	Applied water needed to increase the soil moisture to irrigation target moisture before taking into account the net return flow
4	Agricultural Supply Requirement	If crop water demand is computed internally, this is the total amount of applied water needed to increase the soil moisture to irrigation target moisture plus the net return flow. If crop water demand is specified, then this term equals the pre-specified crop water demand.
5	Pumping (–)	Portion of groundwater pumping that is used to meet the crop water supply requirement
6	Deliveries (–)	Portion of the stream diversions that is used to meet the crop water supply requirement
7	Inflow as Srfc. Runoff (–)	Surface runoff (combination of rainfall runoff, and agricultural and urban return flow) from upstream elements and subregions that is captured and used to meet part of the crop water supply requirement
8	Shortage (=)	Resulting water balance with respect to the crop water supply requirement and actual water supply specified in preceding columns
9	ETAW	Amount of crop evapotranspiration that is met by applied water (summation of pumping, deliveries and captured surface runoff from upstream elements) through current and previous irrigation events
10	Effective Precip	Amount of crop evapotranspiration that is met by current and previous precipitation events
11	ET from Groundwater	Amount of crop evapotranspiration that is met by groundwater
12	ET from Other Sources	Amount of crop evapotranspiration that is met by generic water sources (e.g. lateral seepage, fog)

If a DSS file is used for print-out, the following pathnames are used:

Part A:

IWFM_L&W_USE_BUD

Part B:

TTT (SR*XXX*)_*YY* where *TTT* is the name of the subregion, *XXX* is the subregion number and *YY* is the user-specified crop code

Part C:

One of the following, depending on the output data:

i. *AREA*
ii. *VOLUME*

Part D:

Start date of the time series depending on the values of the BDT and EDT variables (starting and ending date and time of budget print-out)

Part E:

Print-out interval for the crop-specific land and water use budget as specified in the Budget Main Input File

Part F:

One of the following, depending on the output data (refer to the table above for further details):

i. *AREA* (corresponds to column 2 in text output file)
ii. *POTNL_CUAW* (corresponds to column 3 in text output file)
iii. *SUP_REQ* (corresponds to column 4 in text output file)
iv. *PUMPING* (corresponds to column 5 in text output file)
v. *DELIVERY* (corresponds to column 6 in text output file)
vi. *SR_INFLOW* (corresponds to column 7 in text output file)
vii. *SHORTAGE* (corresponds to column 8 in text output file)
viii. *ETAW* (corresponds to column 9 in text output file)
ix. *EFF_PRECIP* (corresponds to column 10 in text output file)
x. *ET_GW* (corresponds to column 11 in text output file)
xi. *ET_OTHER* (corresponds to column 12 in text output file)

8.4.3.3. Subregional Root Zone Moisture Budget

In addition to the output columns listed in section 8.4.1.3, several additional data columns appear in the budget output tables for root zone component version 4.1 to account for the effects of root water uptake from groundwater and riparian vegetation access to stream flow to meet part or all of the riparian evapotranspirative demand. The following table describes the columns in the subregional root zone moisture budget when printed out to a text file:

SUBREGIONAL ROOT ZONE MOISTURE BUDGET		
Column No.	Column Name	Description
1	Time	Simulation date and time
Agricultural Area		
2	Area	Agricultural area
3	Potential ET	Potential evapotranspiration for agricultural lands
4	Precipitation	Precipitation that falls on agricultural lands
5	Runoff	Direct runoff of precipitation that falls on agricultural lands
6	Prime Applied Water	Amount of water applied as a summation of surface water deliveries and pumping for irrigation purposes
7	Inflow as Surface Runoff	Surface runoff (sum of rainfall runoff and return flow from agricultural and urban lands) from upstream elements and subregions that is captured and used for irrigation purposes
8	Reused Water	Amount of return flow that is captured and re-used for irrigation
9	Net Return Flow	Net return flow of irrigation on agricultural lands (after re-use)
10	Beginning Storage (+)	Root zone moisture in agricultural lands at the beginning of time step
11	Net Gain from Land Expansion (+)	The net moisture gained from other land use areas as the area of agricultural lands increase (a negative value represents loss of moisture due to the decrease of agricultural area)
12	Infiltration (+)	Total infiltration on the agricultural lands; computed as the summation of precipitation, prime applied water and inflow as surface runoff less runoff and net return flow
13	Groundwater Inflow (+)	Portion of the actual agricultural evapotranspiration that is met by groundwater
14	Other Inflow (+)	Moisture inflow from other generic moisture sources such as lateral seepage
15	Pond Drain (–)	Drainage of rice and refuge ponds
16	Actual ET (–)	Actual evapotranspiration in agricultural lands
17	Percolation (–)	Percolation from the root zone which is the vertical moisture outflow from the bottom of the root zone in agricultural areas
18	Ending Storage (–)	Root zone moisture in agricultural lands at the end of the time step computed as the summation of the beginning storage and the net inflow into the root zone
19	Discrepancy (=)	Mass balance error check for the moisture storage in the root zone of agricultural lands

Urban Area		
20	Area	Urban area
21	Potential ET	Potential evapotranspiration for urban lands
22	Precipitation	Precipitation that falls on urban lands
23	Runoff	Direct runoff of precipitation that falls on urban lands
24	Prime Applied Water	Total amount of pumping and surface water deliveries that is used to meet urban indoors and outdoors water demand
25	Inflow as Surface Runoff	Surface runoff (sum of rainfall runoff and return flow from agricultural and urban lands) from upstream elements and subregions that is captured and used to meet urban water demand
26	Reused Water	The amount of return flow that is captured and re-used on urban lands
27	Net Return Flow	Net return flow of applied water used for urban indoors and outdoors usage (after re-use)
28	Beginning Storage (+)	Root zone moisture at the beginning of time step
29	Net Gain from Land Expansion (+)	The net moisture gained from other land use areas as the area of urban lands increase (a negative value represents loss of moisture due to the decrease of urban area)
30	Infiltration (+)	Total infiltration on the urban lands computed as the summation of precipitation, prime applied water and inflow as surface runoff less runoff and net return flow
31	Groundwater Inflow (+)	Portion of the actual urban evapotranspiration that is met by groundwater
32	Other Inflow (+)	Moisture inflow from other generic moisture sources such as lateral seepage
33	Actual ET (–)	Actual evapotranspiration in urban lands
34	Percolation (–)	Percolation from the root zone which is the vertical moisture outflow from the bottom of the root zone in urban areas
35	Ending Storage (–)	Root zone moisture in urban lands at the end of the time step computed as the summation of the beginning storage and the net inflow into the root zone
36	Discrepancy (=)	Mass balance error check for the moisture storage in the root zone of urban lands
Native & Riparian Vegetation Area		
37	Area	Native and riparian vegetation area
38	Potential ET	Total potential evapotranspiration for native and riparian vegetation

39	Precipitation	Precipitation that falls on areas with native and riparian vegetation
40	Inflow as Surface Runoff	Surface runoff (sum of rainfall runoff and return flow from agricultural and urban lands) from upstream elements and subregions that flows into the lands with native and riparian vegetation
41	Runoff	Direct runoff of precipitation that falls on areas with native and riparian vegetation
42	Beginning Storage (+)	Root zone moisture in areas with native and riparian vegetation at the beginning of time step
43	Net Gain from Land Expansion (+)	The net moisture gained from other land use areas as the area of native and riparian vegetation increase (a negative value represents loss of moisture due to the decrease of native and riparian vegetation area)
44	Infiltration (+)	Total infiltration on areas with native and riparian vegetation; computed as the sum of precipitation and inflow as surface runoff less runoff
45	Groundwater Inflow (+)	Portion of the actual native and riparian vegetation evapotranspiration that is met by groundwater
46	Other Inflow (+)	Moisture inflow from other generic moisture sources such as lateral seepage
47	Stream Inflow for ET (+)	Portion of the actual riparian vegetation evapotranspiration that is met by stream flows
48	Actual ET (–)	Actual evapotranspiration in areas with native and riparian vegetation
49	Percolation (–)	Percolation from the root zone which is the vertical moisture outflow from the bottom of the root zone in areas with native and riparian vegetation
50	Ending Storage (–)	Root zone moisture in areas with native and riparian vegetation at the end of the time step; computed as the summation of the beginning storage and the net moisture inflow
51	Discrepancy (=)	Mass balance error check for the moisture storage in the root zone of lands with native and riparian vegetation

If a DSS file is used for print-out, the following pathnames are used:

Part A:

IWFM_ROOTZN_BUD

Part B:

TTT (SR*XXX*) where *TTT* is the name of the subregion and *XXX* is the subregion number

Part C:

One of the following, depending on the output data:

i. *AREA*
ii. *VOLUME*

Part D:

Start date of the time series depending on the values of the BDT and EDT variables (starting and ending date and time of budget print-out)

Part E:

Print-out interval for the subregional root zone moisture budget as specified in the Budget Main Input File

Part F:

One of the following, depending on the output data (refer to the table above for further details):

i. *AG_AREA* (corresponds to column 2 in text output file)
ii. *AG_POT_ET* (corresponds to column 3 in text output file)
iii. *AG_PRECIP* (corresponds to column 4 in text output file)
iv. *AG_RUNOFF* (corresponds to column 5 in text output file)
v. *AG_PRM_H2O* (corresponds to column 6 in text output file)
vi. *AG_SR_INFLOW* (corresponds to column 7 in text output file)
vii. *AG_RE-USE* (corresponds to column 8 in text output file)
viii. *AG_NT_RTRN_FLOW* (corresponds to column 9 in text output file)
ix. *AG_BEGIN_STOR* (corresponds to column 10 in text output file)
x. *AG_GAIN_EXP* (corresponds to column 11 in text output file)
xi. *AG_INFILTR* (corresponds to column 12 in text output file)
xii. *AG_GW_INFLOW* (corresponds to column 13 in text output file)
xiii. *AG_OTHER_INFLOW* (corresponds to column 14 in text output file)
xiv. *AG_DRAIN* (corresponds to column 15 in text output file)
xv. *AG_ET* (corresponds to column 16 in text output file)
xvi. *AG_PERC* (corresponds to column 17 in text output file)
xvii. *AG_END_STOR* (corresponds to column 18 in text output file)
xviii. *AG_DISCREPANCY* (corresponds to column 19 in text output file)
xix. *URB_AREA* (corresponds to column 20 in text output file)

xx. *URB_POT_ET* (corresponds to column 21 in text output file)
xxi. *URB_PRECIP* (corresponds to column 22 in text output file)
xxii. *URB_RUNOFF* (corresponds to column 23 in text output file)
xxiii. *URB_PRM_H2O* (corresponds to column 24 in text output file)
xxiv. *URB_SR_INFLOW* (corresponds to column 25 in text output file)
xxv. *URB_RE-USE* (corresponds to column 26 in text output file)
xxvi. *URB_NT_RTRN_FLOW* (corresponds to column 27 in text output file)
xxvii. *URB_BEGIN_STOR* (corresponds to column 28 in text output file)
xxviii. *URB_GAIN_EXP* (corresponds to column 29 in text output file)
xxix. *URB_INFILTR* (corresponds to column 30 in text output file)
xxx. *URB_GW_INFLOW* (corresponds to column 31 in text output file)
xxxi. *URB_OTHER_INFLOW* (corresponds to column 32 in text output file)
xxxii. *URB_ET* (corresponds to column 33 in text output file)
xxxiii. *URB_PERC* (corresponds to column 34 in text output file)
xxxiv. *URB_END_STOR* (corresponds to column 35 in text output file)
xxxv. *URB_DISCREPANCY* (corresponds to column 36 in text output file)
xxxvi. *NRV_AREA* (corresponds to column 37 in text output file)
xxxvii. *NRV_POT_ET* (corresponds to column 38 in text output file)
xxxviii. *NRV_PRECIP* (corresponds to column 39 in text output file)
xxxix. *NRV_SR_INFLOW* (corresponds to column 40 in text output file)
xl. *NRV_RUNOFF* (corresponds to column 41 in text output file)
xli. *NRV_BEGIN_STOR* (corresponds to column 42 in text output file)
xlii. *NRV_GAIN_EXP* (corresponds to column 43 in text output file)
xliii. *NRV_INFILTR* (corresponds to column 44 in text output file)
xliv. *NRV_GW_INFLOW* (corresponds to column 45 in text output file)

xlv. *NRV_OTHER_INFLOW* (corresponds to column 46 in text output file)
xlvi. *NRV_STRM_ET* (corresponds to column 47 in text output file)
xlvii. *NRV_ET* (corresponds to column 48 in text output file)
xlviii. *NRV_PERC* (corresponds to column 49 in text output file)
xlix. *NRV_END_STOR* (corresponds to column 50 in text output file)
l. *NRV_DISCREPANCY* (corresponds to column 51 in text output file)

8.4.3.4. Crop-Specific Root Zone Moisture Budget

Contribution of groundwater to the evapotranspiration for user-specified ponded and non-ponded crops is listed in addition to the data columns listed for root zone component version 4.0 in section 8.4.1.4. The following table describes the columns in the crop-specific root zone moisture budget when printed out to a text file:

CROP-SPECIFIC ROOT ZONE MOISTURE BUDGET		
Column No.	Column Name	Description
1	Time	Simulation date and time
2	Area	Crop area
3	Potential ET	Potential evapotranspiration for the specified crop
4	Precipitation	Precipitation that falls on areas with the specified crop
5	Runoff	Direct runoff of precipitation that falls on areas with the specified crop
6	Prime Applied Water	Amount of water applied as a summation of surface water deliveries and pumping for irrigation purposes
7	Inflow as Surface Runoff	Surface runoff (sum of rainfall runoff and return flow from agricultural and urban lands) from upstream elements and subregions that is captured and used for irrigation purposes
8	Reused Water	Amount of return flow that is captured and re-used for irrigation
9	Net Return Flow	Net return flow of irrigation on areas with the specified crop (after re-use)
10	Beginning Storage (+)	Root zone moisture in areas with the specified crop at the beginning of time step

11	Net Gain from Land Expansion (+)	The net moisture gained from other land use areas as the area of the specified crop increases (a negative value represents loss of moisture due to the decrease of the crop area)
12	Groundwater Inflow (+)	Portion of the actual evapotranspiration for the user-specified crop that is met by groundwater
13	Infiltration (+)	Total infiltration on areas with the specified crop; computed as the summation of precipitation, prime applied water and inflow as surface runoff less runoff and net return flow
14	Other Inflow (+)	Moisture inflow from other generic moisture sources such as lateral seepage
15	Pond Drain (–)	Drainage of rice and refuge ponds; this column is non-zero only if the specified crop is a ponded crop
16	Actual ET (–)	Actual evapotranspiration of the specified crop
17	Percolation (–)	Percolation from the root zone which is the vertical moisture outflow from the bottom of the crop root zone
18	Ending Storage (–)	Root zone moisture in areas with the specified crop at the end of the time step computed as the summation of the beginning storage and the net inflow into the root zone
19	Discrepancy (=)	Mass balance error check for the moisture storage in the root zone of the specified crop

If a DSS file is used for print-out, the following pathnames are used:

Part A:

IWFM_ROOTZN_BUD

Part B:

TTT (SR*XXX*)_*YY* where *TTT* is the name of the subregion, *XXX* is the subregion number and *YY* is the crop code specified by the user

Part C:

One of the following, depending on the output data:

i. *AREA*
ii. *VOLUME*

Part D:

Start date of the time series depending on the values of the BDT and EDT variables (starting and ending date and time of budget print-out)

Part E:

Print-out interval for the crop-specific root zone moisture budget as specified in the Budget Main Input File

Part F:

One of the following, depending on the output data (refer to the table above for further details):

i. *AREA* (corresponds to column 2 in text output file)
ii. *POT_ET* (corresponds to column 3 in text output file)
iii. *PRECIP* (corresponds to column 4 in text output file)
iv. *RUNOFF* (corresponds to column 5 in text output file)
v. *PRM_H2O* (corresponds to column 6 in text output file)
vi. *SR_INFLOW* (corresponds to column 7 in text output file)
vii. *RE-USE* (corresponds to column 8 in text output file)
viii. *NET_RTRN_FLOW* (corresponds to column 9 in text output file)
ix. *BEGIN_STOR* (corresponds to column 10 in text output file)
x. *GAIN_EXP* (corresponds to column 11 in text output file)
xi. *INFILTR* (corresponds to column 12 in text output file)
xii. *GW_INFLOW* (corresponds to column 13 in text output file)
xiii. *OTHER_INFLOW* (corresponds to column 14 in text output file)
xiv. *DRAIN* (corresponds to column 15 in text output file)
xv. *ET* (corresponds to column 16 in text output file)
xvi. *PERC* (corresponds to column 17 in text output file)
xvii. *END_STOR* (corresponds to column 18 in text output file)
xviii. *DISCREPANCY* (corresponds to column 19 in text output file)

8.4.4. Output Files for Root Zone Component Version 4.11

Root zone component version 4.11 can generate the same output files as version 4.1. Refer to section 8.4.3 for a description of these files. Additionally it can generate the land and water use as well as the root zone Z-Budget output files for element-level budgets which can then be aggregated for groups of elements, called zones, using the Z-Budget post-processing tool.

8.4.4.1. Land and Water Use Z-Budget

The Z-Budget tool allows printing of the land and water use budget tables to either an ASCII text file or to a DSS file for each of the zones defined by the user. The budget table for each zone includes a title that lists the version of the root zone component that was used in the IDC run, the units of the budget flow terms as well as the name and area of the zone.

The land and water use budget for each zone provides water demand and supply information for non-ponded crops, rice, refuges and urban areas. The portions of the evapotranspiration that are met by irrigation, source of water that meets the evapotranspiration are also listed.

The following table defines each column in the land and water use budget table printed out to a text file:

LAND AND WATER USE Z-BUDGET		
Column No.	Column Name	Description
1	Time	Simulation date and time
Non-Ponded Agricultural Area		
2	Area	Non-ponded agricultural area
3	Potential CUAW	Applied water needed to increase the soil moisture to irrigation target moisture for non-ponded crops before taking into account the net return flow
4	Agricultural Supply Requirement	If non-ponded crop water demands are computed internally, this is the total amount of applied water needed to increase the soil moisture to irrigation target moisture plus the net return flow for non-ponded crops. If non-ponded water demands are specified, then this term equals the pre-specified water demand.
5	Pumping (–)	Portion of groundwater pumping that is used to meet the non-ponded agricultural supply requirement
6	Deliveries (–)	Portion of the stream diversions that is used to meet the non-ponded agricultural supply requirement
7	Inflow as Srfc. Runoff (–)	Surface runoff (combination of rainfall runoff, and agricultural and urban return flow) from upstream elements and subregions that is captured and used to meet part of the non-ponded agricultural supply requirement
8	Shortage (=)	Resulting water balance with respect to the non-ponded agricultural supply requirements and actual water supply specified in preceding columns
9	ETAW	Amount of non-ponded crop evapotranspiration that is met by applied water (summation of pumping, deliveries and captured surface runoff from upstream elements) through current and previous irrigation events

10	Effective Precip	Amount of non-ponded crop evapotranspiration that is met by current and previous precipitation events
11	ET from Groundwater	Amount of non-ponded crop evapotranspiration that is met by groundwater
12	ET from Other Sources	Amount of non-ponded crop evapotranspiration that is met by generic water sources (e.g. lateral seepage, fog)
Rice Area		
13	Area	Total rice area
14	Potential CUAW	Applied water needed to increase the soil moisture to irrigation target moisture before taking into account the net return flow
15	Agricultural Supply Requirement	If rice water demands are computed internally, this is the total amount of applied water needed to increase the soil moisture to irrigation target moisture plus the net return flow. If rice water demands are specified, then this term equals the pre-specified water demand.
16	Pumping (–)	Portion of groundwater pumping that is used to meet the rice water supply requirement
17	Deliveries (–)	Portion of the stream diversions that is used to meet the rice water supply requirement
18	Inflow as Srfc. Runoff (–)	Surface runoff (combination of rainfall runoff, and agricultural and urban return flow) from upstream elements and subregions that is captured and used to meet part of the rice water supply requirement
19	Shortage (=)	Resulting water balance with respect to the rice water supply requirements and actual water supply specified in preceding columns
20	ETAW	Amount of rice evapotranspiration that is met by applied water (summation of pumping, deliveries and captured surface runoff from upstream elements) through current and previous irrigation events
21	Effective Precip	Amount of rice evapotranspiration that is met by current and previous precipitation events
22	ET from Groundwater	Amount of rice evapotranspiration that is met by groundwater
23	ET from Other Sources	Amount of rice evapotranspiration that is met by generic water sources (e.g. lateral seepage, fog)
Refuge Area		
24	Area	Total refuge area
25	Potential CUAW	Applied water needed to increase the soil moisture to irrigation target moisture in refuges before taking into account the net return flow
26	Agricultural Supply Requirement	If refuge water demands are computed internally, this is the total amount of applied water needed to increase the soil moisture to irrigation target moisture plus the net return flow. If refuge water

		demands are specified, then this term equals the pre-specified water demand.
27	Pumping (–)	Portion of groundwater pumping that is used to meet the refuge water supply requirement
28	Deliveries (–)	Portion of the stream diversions that is used to meet the refuge water supply requirement
29	Inflow as Srfc. Runoff (–)	Surface runoff (combination of rainfall runoff, and agricultural and urban return flow) from upstream elements and subregions that is captured and used to meet part of the refuge water supply requirement
30	Shortage (=)	Resulting water balance with respect to the refuge water supply requirements and actual water supply specified in preceding columns
31	ETAW	Amount of refuge evapotranspiration that is met by applied water (summation of pumping, deliveries and captured surface runoff from upstream elements) through current and previous irrigation events
32	Effective Precip	Amount of refuge evapotranspiration that is met by current and previous precipitation events
33	ET from Groundwater	Amount of refuge evapotranspiration that is met by groundwater
34	ET from Other Sources	Amount of refuge evapotranspiration that is met by generic water sources (e.g. lateral seepage, fog)
Urban Area		
35	Area	Urban area
36	Urban Supply Requirement	Sum of indoor and outdoor urban water demand
37	Pumping (–)	Portion of groundwater pumping that is used to meet the urban supply requirement
38	Deliveries (–)	Portion of stream diversions that is used to meet the urban supply requirement
39	Inflow as Srfc. Runoff (–)	Surface runoff (combination of rainfall runoff, and agricultural and urban return flow) from upstream elements and subregions that is captured and used to meet part of the urban supply requirement
40	Shortage (=)	Resulting water balance with respect to the urban supply requirements and actual water supply specified in preceding columns

If a DSS file is used for print-out, the following pathnames are used:

Part A:

IWFM_ZBUD

Part B:

ZONE:*XXX* where *XXX* is the zone number

Part C:

One of the following, depending on the output data:

i. *AREA*
ii. *VOLUME*

Part D:

Start date of the time series depending on the values of the BDT and EDT variables (starting and ending date and time of budget print-out)

Part E:

Print-out interval for the zonal land and water use budget as specified in the Z-Budget Main Input File

Part F:

One of the following, depending on the output data (refer to the table above for further details):

i. *NP_AG_AREA* (corresponds to column 2 in text output file)
ii. *NP_AG_POTNL_CUAW* (corresponds to column 3 in text output file)
iii. *NP_AG_SUP_REQ* (corresponds to column 4 in text output file)
iv. *NP_AG_PUMPING* (corresponds to column 5 in text output file)
v. *NP_AG_DELIVERY* (corresponds to column 6 in text output file)
vi. *NP_AG_SR_INFLOW* (corresponds to column 7 in text output file)
vii. *NP_AG_SHORTAGE* (corresponds to column 8 in text output file)
viii. *NP_AG_ETAW* (corresponds to column 9 in text output file)
ix. *NP_AG_EFF_PRECIP* (corresponds to column 10 in text output file)
x. *NP_AG_ET_GW* (corresponds to column 11 in text output file)
xi. *NP_AG_ET_OTH* (corresponds to column 12 in text output file)
xii. *RICE_AREA* (corresponds to column 13 in text output file)
xiii. *RICE_POTNL_CUAW* (corresponds to column 14 in text output file)
xiv. *RICE_SUP_REQ* (corresponds to column 15 in text output file)
xv. *RICE_PUMPING* (corresponds to column 16 in text output file)
xvi. *RICE_DELIVERY* (corresponds to column 17 in text output file)
xvii. *RICE_SR_INFLOW* (corresponds to column 18 in text output file)

xviii. *RICE_SHORTAGE* (corresponds to column 19 in text output file)
xix. *RICE_ETAW* (corresponds to column 20 in text output file)
xx. *RICE_EFF_PRECIP* (corresponds to column 21 in text output file)
xxi. *RICE_ET_GW* (corresponds to column 22 in text output file)
xxii. *RICE_ET_OTH* (corresponds to column 23 in text output file)
xxiii. *REFUGE_AREA* (corresponds to column 24 in text output file)
xxiv. *REFUGE_POTNL_CUAW* (corresponds to column 25 in text output file)
xxv. *REFUGE_SUP_REQ* (corresponds to column 26 in text output file)
xxvi. *REFUGE_PUMPING* (corresponds to column 27 in text output file)
xxvii. *REFUGE_DELIVERY* (corresponds to column 28 in text output file)
xxviii. *REFUGE_SR_INFLOW* (corresponds to column 29 in text output file)
xxix. *REFUGE_SHORTAGE* (corresponds to column 30 in text output file)
xxx. *REFUGE_ETAW* (corresponds to column 31 in text output file)
xxxi. *REFUGE_EFF_PRECIP* (corresponds to column 32 in text output file)
xxxii. *REFUGE_ET_GW* (corresponds to column 33 in text output file)
xxxiii. *REFUGE_ET_OTH* (corresponds to column 34 in text output file)
xxxiv. *URB_AREA* (corresponds to column 35 in text output file)
xxxv. *URB_SUP_REQ* (corresponds to column 36 in text output file)
xxxvi. *URB_PUMPING* (corresponds to column 37 in text output file)
xxxvii. *URB_DELIVERY* (corresponds to column 38 in text output file)
xxxviii. *URB_SR_INFLOW* (corresponds to column 39 in text output file)
xxxix. *URB_SHORTAGE* (corresponds to column 40 in text output file)

8.4.4.2. Root Zone Moisture Z-Budget

The Z-Budget tool allows printing of the root zone budget tables to either an ASCII text file or to a DSS file for each of the zones defined by the user. The budget table for each zone includes a title that lists the version of the root zone component that was used in the IDC run, the units of the budget flow terms as well as the name and area of the zone.

The root zone moisture budget for each zone provides detailed inflow and outflow terms to and from the root zone for non-ponded crops, rice, refuges and urban areas as well native and riparian vegetation areas. It also includes precipitation, rainfall runoff, applied water and return flow for each zone.

The following table defines each column in the land and water use budget table printed out to a text file:

ROOT ZONE MOISTURE Z-BUDGET		
Column No.	Column Name	Description
1	Time	Simulation date and time
Non-Ponded Agricultural Area		
2	Area	Agricultural area
3	Potential ET	Potential evapotranspiration for non-ponded crops
4	Precipitation	Precipitation that falls on non-ponded agricultural lands
5	Runoff	Direct runoff of precipitation that falls on non-ponded agricultural lands
6	Prime Applied Water	Amount of water applied as a summation of surface water deliveries and pumping for irrigation purposes
7	Inflow as Surface Runoff	Surface runoff (sum of rainfall runoff and return flow from agricultural and urban lands) from upstream elements and subregions that is captured and used for irrigation purposes
8	Reused Water	Amount of return flow that is captured and re-used for irrigation
9	Net Return Flow	Net return flow of irrigation on non-ponded agricultural lands (after re-use)
10	Beginning Storage (+)	Root zone moisture in non-ponded agricultural lands at the beginning of time step
11	Net Gain from Land Expansion (+)	The net moisture gained from other land use areas as the area of non-ponded agricultural lands increase (a negative value represents loss of moisture due to the decrease of non-ponded agricultural area)

12	Infiltration (+)	Total infiltration on the non-ponded agricultural lands; computed as the summation of precipitation, prime applied water and inflow as surface runoff less runoff and net return flow
13	Groundwater Inflow (+)	Portion of the actual non-ponded crops evapotranspiration that is met by groundwater
14	Other Inflow (+)	Moisture inflow from other generic moisture sources such as lateral seepage
15	Actual ET (–)	Actual non-ponded crop evapotranspiration
16	Percolation (–)	Percolation from the root zone which is the vertical moisture outflow from the bottom of the root zone in non-ponded agricultural areas
17	Ending Storage (–)	Root zone moisture in non-ponded agricultural lands at the end of the time step computed as the summation of the beginning storage and the net inflow into the root zone
18	Discrepancy (=)	Mass balance error check for the moisture storage in the root zone of non-ponded agricultural lands
Rice Area		
19	Area	Rice area
20	Potential ET	Potential evapotranspiration for rice
21	Precipitation	Precipitation that falls on rice lands
22	Runoff	Direct runoff of precipitation that falls on rice lands
23	Prime Applied Water	Amount of water applied as a summation of surface water deliveries and pumping for irrigation purposes
24	Inflow as Surface Runoff	Surface runoff (sum of rainfall runoff and return flow from agricultural and urban lands) from upstream elements and subregions that is captured and used for irrigation purposes
25	Reused Water	Amount of return flow that is captured and re-used for irrigation
26	Net Return Flow	Net return flow of irrigation on rice lands (after re-use)
27	Beginning Storage (+)	Root zone moisture in rice lands at the beginning of time step
28	Net Gain from Land Expansion (+)	The net moisture gained from other land use areas as the area of rice lands increase (a negative value represents loss of moisture due to the decrease of rice area)
29	Infiltration (+)	Total infiltration on the rice lands; computed as the summation of precipitation, prime applied water and inflow as surface runoff less runoff and net return flow
30	Groundwater Inflow (+)	Portion of the actual rice evapotranspiration that is met by groundwater

31	Other Inflow (+)	Moisture inflow from other generic moisture sources such as lateral seepage
32	Pond Drain (–)	Drainage of rice ponds
33	Actual ET (–)	Actual rice evapotranspiration
34	Percolation (–)	Percolation from the root zone which is the vertical moisture outflow from the bottom of the root zone in rice lands
35	Ending Storage (–)	Root zone moisture in rice lands at the end of the time step computed as the summation of the beginning storage and the net inflow into the root zone
36	Discrepancy (=)	Mass balance error check for the moisture storage in the root zone of rice lands
Refuge Area		
37	Area	Refuge area
38	Potential ET	Potential evapotranspiration for refuges
39	Precipitation	Precipitation that falls on refuges
40	Runoff	Direct runoff of precipitation that falls on refuges
41	Prime Applied Water	Amount of water applied as a summation of surface water deliveries and pumping for irrigation purposes
42	Inflow as Surface Runoff	Surface runoff (sum of rainfall runoff and return flow from agricultural and urban lands) from upstream elements and subregions that is captured and used for irrigation purposes
43	Reused Water	Amount of return flow that is captured and re-used for irrigation
44	Net Return Flow	Net return flow of irrigation on refuges (after re-use)
45	Beginning Storage (+)	Root zone moisture in refuges at the beginning of time step
46	Net Gain from Land Expansion (+)	The net moisture gained from other land use areas as the area of refuges increase (a negative value represents loss of moisture due to the decrease of refuge area)
47	Infiltration (+)	Total infiltration in the refuges; computed as the summation of precipitation, prime applied water and inflow as surface runoff less runoff and net return flow
48	Groundwater Inflow (+)	Portion of the actual refuge evapotranspiration that is met by groundwater
49	Other Inflow (+)	Moisture inflow from other generic moisture sources such as lateral seepage
50	Pond Drain (–)	Drainage of refuge ponds
51	Actual ET (–)	Actual refuge evapotranspiration

52	Percolation (–)	Percolation from the root zone which is the vertical moisture outflow from the bottom of the root zone in refuges
53	Ending Storage (–)	Root zone moisture in refuges at the end of the time step computed as the summation of the beginning storage and the net inflow into the root zone
54	Discrepancy (=)	Mass balance error check for the moisture storage in the root zone of refuges
Urban Area		
55	Area	Urban area
56	Potential ET	Potential evapotranspiration for urban lands
57	Precipitation	Precipitation that falls on urban lands
58	Runoff	Direct runoff of precipitation that falls on urban lands
59	Prime Applied Water	Total amount of pumping and surface water deliveries that is used to meet urban indoors and outdoors water demand
60	Inflow as Surface Runoff	Surface runoff (sum of rainfall runoff and return flow from agricultural and urban lands) from upstream elements and subregions that is captured and used to meet urban water demand
61	Reused Water	The amount of return flow that is captured and re-used on urban lands
62	Net Return Flow	Net return flow of applied water used for urban indoors and outdoors usage (after re-use)
63	Beginning Storage (+)	Root zone moisture at the beginning of time step
64	Net Gain from Land Expansion (+)	The net moisture gained from other land use areas as the area of urban lands increase (a negative value represents loss of moisture due to the decrease of urban area)
65	Infiltration (+)	Total infiltration on the urban lands computed as the summation of precipitation, prime applied water and inflow as surface runoff less runoff and net return flow
66	Groundwater Inflow (+)	Portion of the actual urban evapotranspiration that is met by groundwater
67	Other Inflow (+)	Moisture inflow from other generic moisture sources such as lateral seepage
68	Actual ET (–)	Actual evapotranspiration in urban lands
69	Percolation (–)	Percolation from the root zone which is the vertical moisture outflow from the bottom of the root zone in urban areas
70	Ending Storage (–)	Root zone moisture in urban lands at the end of the time step computed as the summation of the beginning storage and the net inflow into the root zone

71	Discrepancy (=)	Mass balance error check for the moisture storage in the root zone of urban lands
Native and Riparian Vegetation Area		
72	Area	Native and riparian vegetation area
73	Potential ET	Potential evapotranspiration for native and riparian vegetation
74	Precipitation	Precipitation that falls on areas with native and riparian vegetation
75	Inflow as Surface Runoff	Surface runoff (sum of rainfall runoff and return flow from agricultural and urban lands) from upstream elements and subregions that flows into the lands with native and riparian vegetation
76	Runoff	Direct runoff of precipitation that falls on areas with native and riparian vegetation
77	Beginning Storage (+)	Root zone moisture in areas with native and riparian vegetation at the beginning of time step
78	Net Gain from Land Expansion (+)	The net moisture gained from other land use areas as the area of native and riparian vegetation increase (a negative value represents loss of moisture due to the decrease of native and riparian vegetation area)
79	Infiltration (+)	Total infiltration on areas with native and riparian vegetation; computed as the sum of precipitation and inflow as surface runoff less runoff
80	Groundwater Inflow (+)	Portion of the actual evapotranspiration of native and riparian vegetation that is met by groundwater
81	Other Inflow (+)	Moisture inflow from other generic moisture sources such as lateral seepage
82	Stream Inflow for ET (+)	Portion of the actual riparian vegetation evapotranspiration that is met by stream flows
83	Actual ET (–)	Actual evapotranspiration in areas with native and riparian vegetation
84	Percolation (–)	Percolation from the root zone which is the vertical moisture outflow from the bottom of the root zone in areas with native and riparian vegetation
85	Ending Storage (+)	Root zone moisture in areas with native and riparian vegetation at the end of the time step; computed as the summation of the beginning storage and the net moisture inflow
86	Discrepancy (=)	Mass balance error check for the moisture storage in the root zone of lands with native and riparian vegetation

If a DSS file is used for print-out, the following pathnames are used:

Part A:

IWFM_ZBUD

Part B:

ZONE:*XXX* where *XXX* is the zone number

Part C:

One of the following, depending on the output data:

i. *AREA*
ii. *VOLUME*

Part D:

Start date of the time series depending on the values of the BDT and EDT variables (starting and ending date and time of budget print-out)

Part E:

Print-out interval for the zonal root zone budget as specified in the Z-Budget Main Input File

Part F:

One of the following, depending on the output data (refer to the table above for further details):

i. *NP_AG_AREA* (corresponds to column 2 in text output file)
ii. *NP_AG_POT_ET* (corresponds to column 3 in text output file)
iii. *NP_AG_PRECIP* (corresponds to column 4 in text output file)
iv. *NP_AG_RUNOFF* (corresponds to column 5 in text output file)
v. *NP_AG_PRM_H2O* (corresponds to column 6 in text output file)
vi. *NP_AG_SR_INFLOW* (corresponds to column 7 in text output file)
vii. *NP_AG_RE-USE* (corresponds to column 8 in text output file)
viii. *NP_AG_NT_RTRN_FLOW* (corresponds to column 9 in text output file)
ix. *NP_AG_BEGIN_STOR* (corresponds to column 10 in text output file)
x. *NP_AG_GAIN_EXP* (corresponds to column 11 in text output file)
xi. *NP_AG_INFILTR* (corresponds to column 12 in text output file)
xii. *NP_AG_GW_INFLOW* (corresponds to column 13 in text output file)
xiii. *NP_AG_OTHER_INFLOW* (corresponds to column 14 in text output file)

xiv. *NP_AG_ET* (corresponds to column 15 in text output file)
xv. *NP_AG_PERC* (corresponds to column 16 in text output file)
xvi. *NP_AG_END_STOR* (corresponds to column 17 in text output file)
xvii. *NP_AG_DISCREPANCY* (corresponds to column 18 in text output file)
xviii. *RICE_AREA* (corresponds to column 19 in text output file)
xix. *RICE_POT_ET* (corresponds to column 20 in text output file)
xx. *RICE_PRECIP* (corresponds to column 21 in text output file)
xxi. *RICE_RUNOFF* (corresponds to column 22 in text output file)
xxii. *RICE_PRM_H2O* (corresponds to column 23 in text output file)
xxiii. *RICE_SR_INFLOW* (corresponds to column 24 in text output file)
xxiv. *RICE_RE-USE* (corresponds to column 25 in text output file)
xxv. *RICE_NT_RTRN_FLOW* (corresponds to column 26 in text output file)
xxvi. *RICE_BEGIN_STOR* (corresponds to column 27 in text output file)
xxvii. *RICE_GAIN_EXP* (corresponds to column 28 in text output file)
xxviii. *RICE_INFILTR* (corresponds to column 29 in text output file)
xxix. *RICE_GW_INFLOW* (corresponds to column 30 in text output file)
xxx. *RICE_OTHER_INFLOW* (corresponds to column 31 in text output file)
xxxi. *RICE_DRAIN* (corresponds to column 32 in text output file)
xxxii. *RICE_ET* (corresponds to column 33 in text output file)
xxxiii. *RICE_PERC* (corresponds to column 34 in text output file)
xxxiv. *RICE_END_STOR* (corresponds to column 35 in text output file)
xxxv. *RICE_DISCREPANCY* (corresponds to column 36 in text output file)
xxxvi. *REFUGE_AREA* (corresponds to column 37 in text output file)
xxxvii. *REFUGE_POT_ET* (corresponds to column 38 in text output file)
xxxviii. *REFUGE_PRECIP* (corresponds to column 39 in text output file)
xxxix. *REFUGE_RUNOFF* (corresponds to column 40 in text output file)

xl. *REFUGE_PRM_H2O* (corresponds to column 41 in text output file)
xli. *REFUGE_SR_INFLOW* (corresponds to column 42 in text output file)
xlii. *REFUGE_RE-USE* (corresponds to column 43 in text output file)
xliii. *REFUGE_NT_RTRN_FLOW* (corresponds to column 44 in text output file)
xliv. *REFUGE_BEGIN_STOR* (corresponds to column 45 in text output file)
xlv. *REFUGE_GAIN_EXP* (corresponds to column 46 in text output file)
xlvi. *REFUGE_INFILTR* (corresponds to column 47 in text output file)
xlvii. *REFUGE_GW_INFLOW* (corresponds to column 48 in text output file)
xlviii. *REFUGE_OTHER_INFLOW* (corresponds to column 49 in text output file)
xlix. *REFUGE_DRAIN* (corresponds to column 50 in text output file)
l. *REFUGE_ET* (corresponds to column 51 in text output file)
li. *REFUGE_PERC* (corresponds to column 52 in text output file)
lii. *REFUGE_END_STOR* (corresponds to column 53 in text output file)
liii. *REFUGE_DISCREPANCY* (corresponds to column 54 in text output file)
liv. *URB_AREA* (corresponds to column 55 in text output file)
lv. *URB_POT_ET* (corresponds to column 56 in text output file)
lvi. *URB_PRECIP* (corresponds to column 57 in text output file)
lvii. *URB_RUNOFF* (corresponds to column 58 in text output file)
lviii. *URB_PRM_H2O* (corresponds to column 59 in text output file)
lix. *URB_SR_INFLOW* (corresponds to column 60 in text output file)
lx. *URB_RE-USE* (corresponds to column 61 in text output file)
lxi. *URB_NT_RTRN_FLOW* (corresponds to column 62 in text output file)
lxii. *URB_BEGIN_STOR* (corresponds to column 63 in text output file)
lxiii. *URB_GAIN_EXP* (corresponds to column 64 in text output file)

lxiv. *URB_INFILTR* (corresponds to column 65 in text output file)
lxv. *URB_GW_INFLOW* (corresponds to column 66 in text output file)
lxvi. *URB_OTHER_INFLOW* (corresponds to column 67 in text output file)
lxvii. *URB_ET* (corresponds to column 68 in text output file)
lxviii. *URB_PERC* (corresponds to column 69 in text output file)
lxix. *URB_END_STOR* (corresponds to column 70 in text output file)
lxx. *URB_DISCREPANCY* (corresponds to column 71 in text output file)
lxxi. *NRV_AREA* (corresponds to column 72 in text output file)
lxxii. *NRV_POT_ET* (corresponds to column 73 in text output file)
lxxiii. *NRV_PRECIP* (corresponds to column 74 in text output file)
lxxiv. *NRV_SR_INFLOW* (corresponds to column 75 in text output file)
lxxv. *NRV_RUNOFF* (corresponds to column 76 in text output file)
lxxvi. *NRV_BEGIN_STOR* (corresponds to column 77 in text output file)
lxxvii. *NRV_GAIN_EXP* (corresponds to column 78 in text output file)
lxxviii. *NRV_INFILTR* (corresponds to column 79 in text output file)
lxxix. *NRV_GW_INFLOW* (corresponds to column 80 in text output file)
lxxx. *NRV_OTHER_INFLOW* (corresponds to column 81 in text output file)
lxxxi. *NRV_STRM_ET* (corresponds to column 82 in text output file)
lxxxii. *NRV_ET* (corresponds to column 83 in text output file)
lxxxiii. *NRV_PERC* (corresponds to column 84 in text output file)
lxxxiv. *NRV_END_STOR* (corresponds to column 85 in text output file)
lxxxv. *NRV_DISCREPANCY* (corresponds to column 86 in text output file)

8.4.5. Output Files for Root Zone Component Version 5.0

Output files for root zone component version 5.0 are similar to those of versions 4.01 and 4.11 except that there are no budget output files for crop-specific land and water use and root zone data. This is because root zone version 5.0 computes the water demands, and land surface and root zone flow processes for an agricultural crop with average parameters based on crop areas in each subregion. Additionally, element-level Z-Budget output does not distinguish information between non-ponded crops, rice and refuge lands.

8.4.5.1. Subregional Land and Water Use Budget

The subregional land and water use budget HDF5 file is generated by specifying a proper filename in the Root Zone Component Main File. A budget table is produced for each subregion listed for the LPRNT variable in the Budget Main Input File. The title printed for each subregional land and water use budget includes root zone component version number, subregion name given by the user, the unit of data columns and the area of the subregion. All land and water use budget columns are in volumetric units except *Time*, *Agricultural Area* and *Urban Area*. The output units and conversion factors for area (UNITAROU and FACTAROU) and volume (UNITVLOU and FACTVLOU) are specified by the user in the Budget Main Input File.

The total agricultural and urban areas, as well as the agricultural potential consumptive use of applied water and the water supply requirements are reported in the output, followed by the components that the land and water use budget is comprised of. For agricultural lands, potential consumptive use is the amount of water needed to bring the soil moisture up to the irrigation target moisture (field capacity, by default) after the effects of precipitation and generic moisture sources, excluding the net return flow, are taken into account. The agricultural supply requirement is the potential consumptive use of applied water plus the net return flow.

A positive or negative sign is given for each column that is a component of the subregional land and water use. The *Shortage* column is the resulting balance, based on water use components. A value of zero in this column indicates that the available water supply (surface water deliveries, groundwater pumping and surface runoff from upstream elements) meets the agricultural or urban supply requirements. A positive value indicates that the supply is not a large enough quantity to satisfy water requirements. Conversely, a negative value in the *Shortage* column signifies a water supply surplus. The last three columns for agricultural areas are informational and show the sources of water that are used in meeting the crop evapotranspirative requirement.

The following table defines each column in the subregional land and water use budget table printed out to a text file:

SUBREGIONAL LAND AND WATER USE BUDGET		
Column No.	Column Name	Description
1	Time	Simulation date and time
Agricultural Area		
2	Area	Agricultural area
3	Potential CUAW	Applied water needed to increase the soil moisture to irrigation target moisture before taking into account the net return flow
4	Agricultural Supply Requirement	If agricultural water demands are computed internally, this is the total amount of applied water needed to increase the soil moisture to irrigation target moisture plus the net return flow. If agricultural water demands are specified, then this term equals the pre-specified water demand.
5	Pumping (–)	Portion of groundwater pumping that is used to meet the agricultural supply requirement
6	Deliveries (–)	Portion of the stream diversions that is used to meet the agricultural supply requirement
7	Inflow as Srfc. Runoff (–)	Surface runoff (combination of rainfall runoff, and agricultural and urban return flow) from upstream elements and subregions that is captured and used to meet part of the agricultural supply requirement
8	Shortage (=)	Resulting water balance with respect to the agricultural supply requirements and actual water supply specified in preceding columns
9	ETAW	Amount of crop evapotranspiration that is met by applied water (summation of pumping, deliveries and captured surface runoff from upstream elements) through current and previous irrigation events
10	Effective Precip	Amount of crop evapotranspiration that is met by current and previous precipitation events
11	ET from Other Sources	Amount of crop evapotranspiration that is met by generic water sources (e.g. lateral seepage, fog)
Urban Area		
12	Area	Urban area
13	Urban Supply Requirement	Sum of indoor and outdoor urban water demand
14	Pumping (–)	Portion of groundwater pumping that is used to meet the urban supply requirement

15	Deliveries (–)	Portion of stream diversions that is used to meet the urban supply requirement
16	Inflow as Srfc. Runoff (–)	Surface runoff (combination of rainfall runoff, and agricultural and urban return flow) from upstream elements and subregions that is captured and used to meet part of the urban supply requirement
17	Shortage (=)	Resulting water balance with respect to the urban supply requirements and actual water supply specified in preceding columns

If a DSS file is used for print-out, the following pathnames are used:

Part A:

IWFM_L&W_USE_BUD

Part B:

TTT (SR*XXX*) where *TTT* is the name of the subregion and *XXX* is the subregion number

Part C:

One of the following, depending on the output data:

i. *AREA*
ii. *VOLUME*

Part D:

Start date of the time series depending on the values of the BDT and EDT variables (starting and ending date and time of budget print-out)

Part E:

Print-out interval for the subregional land and water use budget as specified in the Budget Main Input File

Part F:

One of the following, depending on the output data (refer to the table above for further details):

i. *AG_AREA* (corresponds to column 2 in text output file)
ii. *AG_POTNL_CUAW* (corresponds to column 3 in text output file)
iii. *AG_SUP_REQ* (corresponds to column 4 in text output file)
iv. *AG_PUMPING* (corresponds to column 5 in text output file)
v. *AG_DELIVERY* (corresponds to column 6 in text output file)
vi. *AG_SR_INFLOW* (corresponds to column 7 in text output file)
vii. *AG_SHORTAGE* (corresponds to column 8 in text output file)
viii. *AG_ETAW* (corresponds to column 9 in text output file)

ix. *AG_EFF_PRECIP* (corresponds to column 10 in text output file)
x. *AG_ET_OTH* (corresponds to column 11 in text output file)
xi. *URB_AREA* (corresponds to column 12 in text output file)
xii. *URB_SUP_REQ* (corresponds to column 13 in text output file)
xiii. *URB_PUMPING* (corresponds to column 14 in text output file)
xiv. *URB_DELIVERY* (corresponds to column 15 in text output file)
xv. *URB_SR_INFLOW* (corresponds to column 16 in text output file)
xvi. *URB_SHORTAGE* (corresponds to column 17 in text output file)

8.4.5.2. Subregional Root Zone Moisture Budget

The subregional root zone moisture budget is produced for each subregion listed for processing in the Budget Main Input File. The title printed for each subregional root zone moisture budget includes root zone component version number, subregion name given by the user, the unit of data columns and the area of the subregion. The output units are specified by the user in the Budget Main Input File.

The root zone moisture budget provides information on processes that are used to compute soil moisture in the root zone. Agricultural areas represent the areas where crops are located. Urban area includes indoor and outdoor urban areas and the native and riparian lands represent the undeveloped area in the subregion. For each area type (agricultural, urban, and native and riparian vegetation) precipitation and irrigation (except for native and riparian vegetation areas) along with direct runoff and return flows are listed. The *Infiltration* column is computed by adding the *Precipitation*, *Prime Applied Water* and *Inflow as Surface Runoff* columns and subtracting the *Runoff* and *Net Return Flow* columns. The following table describes the columns in the subregional root zone moisture budget when printed out to a text file:

SUBREGIONAL ROOT ZONE MOISTURE BUDGET		
Column No.	Column Name	Description
1	Time	Simulation date and time
Agricultural Area		
2	Area	Agricultural area
3	Potential ET	Potential evapotranspiration for agricultural lands
4	Precipitation	Precipitation that falls on agricultural lands

5	Runoff	Direct runoff of precipitation that falls on agricultural lands
6	Prime Applied Water	Amount of water applied as a summation of surface water deliveries and pumping for irrigation purposes
7	Inflow as Surface Runoff	Surface runoff (sum of rainfall runoff and return flow from agricultural and urban lands) from upstream elements and subregions that is captured and used for irrigation purposes
8	Reused Water	Amount of return flow that is captured and re-used for irrigation
9	Net Return Flow	Net return flow of irrigation on agricultural lands (after re-use)
10	Beginning Storage (+)	Root zone moisture in agricultural lands at the beginning of time step
11	Net Gain from Land Expansion (+)	The net moisture gained from other land use areas as the area of agricultural lands increase (a negative value represents loss of moisture due to the decrease of agricultural area)
12	Infiltration (+)	Total infiltration on the agricultural lands; computed as the summation of precipitation, prime applied water and inflow as surface runoff less runoff and net return flow
13	Other Inflow (+)	Moisture inflow from other generic moisture sources such as lateral seepage
14	Actual ET (–)	Actual evapotranspiration in agricultural lands
15	Percolation (–)	Percolation from the root zone which is the vertical moisture outflow from the bottom of the root zone in agricultural areas
16	Ending Storage (–)	Root zone moisture in agricultural lands at the end of the time step computed as the summation of the beginning storage and the net inflow into the root zone
17	Discrepancy (=)	Mass balance error check for the moisture storage in the root zone of agricultural lands
Urban Area		
18	Area	Urban area
19	Potential ET	Potential evapotranspiration for urban lands
20	Precipitation	Precipitation that falls on urban lands
21	Runoff	Direct runoff of precipitation that falls on urban lands
22	Prime Applied Water	Total amount of pumping and surface water deliveries that is used to meet urban indoors and outdoors water demand
23	Inflow as Surface Runoff	Surface runoff (sum of rainfall runoff and return flow from agricultural and urban lands) from upstream elements and subregions that is captured and used to meet urban water demand

24	Reused Water	The amount of return flow that is captured and re-used on urban lands
25	Net Return Flow	Net return flow of applied water used for urban indoors and outdoors usage (after re-use)
26	Beginning Storage (+)	Root zone moisture at the beginning of time step
27	Net Gain from Land Expansion (+)	The net moisture gained from other land use areas as the area of urban lands increase (a negative value represents loss of moisture due to the decrease of urban area)
28	Infiltration (+)	Total infiltration on the urban lands computed as the summation of precipitation, prime applied water and inflow as surface runoff less runoff and net return flow
29	Other Inflow (+)	Moisture inflow from other generic moisture sources such as lateral seepage
30	Actual ET (–)	Actual evapotranspiration in urban lands
31	Percolation (–)	Percolation from the root zone which is the vertical moisture outflow from the bottom of the root zone in urban areas
32	Ending Storage (–)	Root zone moisture in urban lands at the end of the time step computed as the summation of the beginning storage and the net inflow into the root zone
33	Discrepancy (=)	Mass balance error check for the moisture storage in the root zone of urban lands
Native and Riparian Vegetation Area		
34	Area	Native and riparian vegetation area
35	Potential ET	Potential evapotranspiration for native and riparian vegetation
36	Precipitation	Precipitation that falls on areas with native and riparian vegetation
37	Inflow as Surface Runoff	Surface runoff (sum of rainfall runoff and return flow from agricultural and urban lands) from upstream elements and subregions that flows into the lands with native and riparian vegetation
38	Runoff	Direct runoff of precipitation that falls on areas with native and riparian vegetation
39	Beginning Storage (+)	Root zone moisture in areas with native and riparian vegetation at the beginning of time step
40	Net Gain from Land Expansion (+)	The net moisture gained from other land use areas as the area of native and riparian vegetation increase (a negative value represents loss of moisture due to the decrease of native and riparian vegetation area)
41	Infiltration (+)	Total infiltration on areas with native and riparian vegetation; computed as the sum of precipitation and inflow as surface runoff less runoff

42	Other Inflow (+)	Moisture inflow from other generic moisture sources such as lateral seepage
43	Actual ET (–)	Actual evapotranspiration in areas with native and riparian vegetation
44	Percolation (–)	Percolation from the root zone which is the vertical moisture outflow from the bottom of the root zone in areas with native and riparian vegetation
45	Ending Storage (+)	Root zone moisture in areas with native and riparian vegetation at the end of the time step; computed as the summation of the beginning storage and the net moisture inflow
46	Discrepancy (=)	Mass balance error check for the moisture storage in the root zone of lands with native and riparian vegetation

If a DSS file is used for print-out, the following pathnames are used:

Part A:

IWFM_ROOTZN_BUD

Part B:

TTT (SR*XXX*) where *TTT* is the name of the subregion and *XXX* is the subregion number

Part C:

One of the following, depending on the output data:

i. *AREA*
ii. *VOLUME*

Part D:

Start date of the time series depending on the values of the BDT and EDT variables (starting and ending date and time of budget print-out)

Part E:

Print-out interval for the subregional root zone moisture budget as specified in the Budget Main Input File

Part F:

One of the following, depending on the output data (refer to the table above for further details):

i. *AG_AREA* (corresponds to column 2 in text output file)
ii. *AG_POT_ET* (corresponds to column 3 in text output file)
iii. *AG_PRECIP* (corresponds to column 4 in text output file)
iv. *AG_RUNOFF* (corresponds to column 5 in text output file)
v. *AG_PRM_H2O* (corresponds to column 6 in text output file)

vi. *AG_SR_INFLOW* (corresponds to column 7 in text output file)
vii. *AG_RE-USE* (corresponds to column 8 in text output file)
viii. *AG_NT_RTRN_FLOW* (corresponds to column 9 in text output file)
ix. *AG_BEGIN_STOR* (corresponds to column 10 in text output file)
x. *AG_GAIN_EXP* (corresponds to column 11 in text output file)
xi. *AG_INFILTR* (corresponds to column 12 in text output file)
xii. *AG_OTHER_INFLOW* (corresponds to column 13 in text output file)
xiii. *AG_ET* (corresponds to column 14 in text output file)
xiv. *AG_PERC* (corresponds to column 15 in text output file)
xv. *AG_END_STOR* (corresponds to column 16 in text output file)
xvi. *AG_DISCREPANCY* (corresponds to column 17 in text output file)
xvii. *URB_AREA* (corresponds to column 18 in text output file)
xviii. *URB_POT_ET* (corresponds to column 19 in text output file)
xix. *URB_PRECIP* (corresponds to column 20 in text output file)
xx. *URB_RUNOFF* (corresponds to column 21 in text output file)
xxi. *URB_PRM_H2O* (corresponds to column 22 in text output file)
xxii. *URB_SR_INFLOW* (corresponds to column 23 in text output file)
xxiii. *URB_RE-USE* (corresponds to column 24 in text output file)
xxiv. *URB_NT_RTRN_FLOW* (corresponds to column 25 in text output file)
xxv. *URB_BEGIN_STOR* (corresponds to column 26 in text output file)
xxvi. *URB_GAIN_EXP* (corresponds to column 27 in text output file)
xxvii. *URB_INFILTR* (corresponds to column 28 in text output file)
xxviii. *URB_OTHER_INFLOW* (corresponds to column 29 in text output file)
xxix. *URB_ET* (corresponds to column 30 in text output file)
xxx. *URB_PERC* (corresponds to column 31 in text output file)
xxxi. *URB_END_STOR* (corresponds to column 32 in text output file)
xxxii. *URB_DISCREPANCY* (corresponds to column 33 in text output file)
xxxiii. *NRV_AREA* (corresponds to column 34 in text output file)

xxxiv. *NRV_POT_ET* (corresponds to column 35 in text output file)
xxxv. *NRV_PRECIP* (corresponds to column 36 in text output file)
xxxvi. *NRV_SR_INFLOW* (corresponds to column 37 in text output file)
xxxvii. *NRV_RUNOFF* (corresponds to column 38 in text output file)
xxxviii. *NRV_BEGIN_STOR* (corresponds to column 39 in text output file)
xxxix. *NRV_GAIN_EXP* (corresponds to column 40 in text output file)
xl. *NRV_INFILTR* (corresponds to column 41 in text output file)
xli. *NRV_OTHER_INFLOW* (corresponds to column 42 in text output file)
xlii. *NRV_ET* (corresponds to column 43 in text output file)
xliii. *NRV_PERC* (corresponds to column 44 in text output file)
xliv. *NRV_END_STOR* (corresponds to column 45 in text output file)
xlv. *NRV_DISCREPANCY* (corresponds to column 46 in text output file)

8.4.5.3. Land and Water Use Z-Budget

The Z-Budget tool allows printing of the land and water use budget tables to either an ASCII text file or to a DSS file for each of the zones defined by the user. The budget table for each zone includes a title that lists the version of the root zone component that was used in the IDC run, the units of the budget flow terms as well as the name and area of the zone.

The land and water use budget for each zone provides water demand and supply information for agricultural and urban areas. The portions of the evapotranspiration that are met by irrigation, source of water that meets the evapotranspiration are also listed.

The following table defines each column in the land and water use budget table printed out to a text file:

LAND AND WATER USE Z-BUDGET		
Column No.	Column Name	Description
1	Time	Simulation date and time
Agricultural Area		
2	Area	Agricultural area

3	Potential CUAW	Applied water needed to increase the soil moisture to irrigation target moisture for agricultural crops before taking into account the net return flow
4	Agricultural Supply Requirement	If agricultural water demands are computed internally, this is the total amount of applied water needed to increase the soil moisture to irrigation target moisture plus the net return flow for non-ponded crops. If non-ponded water demands are specified, then this term equals the pre-specified water demand.
5	Pumping (–)	Portion of groundwater pumping that is used to meet the agricultural supply requirement
6	Deliveries (–)	Portion of the stream diversions that is used to meet the agricultural supply requirement
7	Inflow as Srfc. Runoff (–)	Surface runoff (combination of rainfall runoff, and agricultural and urban return flow) from upstream elements and subregions that is captured and used to meet part of the agricultural supply requirement
8	Shortage (=)	Resulting water balance with respect to the agricultural supply requirements and actual water supply specified in preceding columns
9	ETAW	Amount of agricultural evapotranspiration that is met by applied water (summation of pumping, deliveries and captured surface runoff from upstream elements) through current and previous irrigation events
10	Effective Precip	Amount of agricultural evapotranspiration that is met by current and previous precipitation events
11	ET from Other Sources	Amount of agricultural evapotranspiration that is met by generic water sources (e.g. lateral seepage, fog)
Urban Area		
12	Area	Urban area
13	Urban Supply Requirement	Sum of indoor and outdoor urban water demand
14	Pumping (–)	Portion of groundwater pumping that is used to meet the urban supply requirement
15	Deliveries (–)	Portion of stream diversions that is used to meet the urban supply requirement
16	Inflow as Srfc. Runoff (–)	Surface runoff (combination of rainfall runoff, and agricultural and urban return flow) from upstream elements and subregions that is captured and used to meet part of the urban supply requirement
17	Shortage (=)	Resulting water balance with respect to the urban supply requirements and actual water supply specified in preceding columns

If a DSS file is used for print-out, the following pathnames are used:

Part A:

IWFM_ZBUD

Part B:

ZONE:*XXX* where *XXX* is the zone number

Part C:

One of the following, depending on the output data:

i. *AREA*
ii. *VOLUME*

Part D:

Start date of the time series depending on the values of the BDT and EDT variables (starting and ending date and time of budget print-out)

Part E:

Print-out interval for the zonal land and water use budget as specified in the Z-Budget Main Input File

Part F:

One of the following, depending on the output data (refer to the table above for further details):

i. *AG_AREA* (corresponds to column 2 in text output file)
ii. *AG_POTNL_CUAW* (corresponds to column 3 in text output file)
iii. *AG_SUP_REQ* (corresponds to column 4 in text output file)
iv. *AG_PUMPING* (corresponds to column 5 in text output file)
v. *AG_DELIVERY* (corresponds to column 6 in text output file)
vi. *AG_SR_INFLOW* (corresponds to column 7 in text output file)
vii. *AG_SHORTAGE* (corresponds to column 8 in text output file)
viii. *AG_ETAW* (corresponds to column 9 in text output file)
ix. *AG_EFF_PRECIP* (corresponds to column 10 in text output file)
x. *AG_ET_OTH* (corresponds to column 11 in text output file)
xi. *URB_AREA* (corresponds to column 12 in text output file)
xii. *URB_SUP_REQ* (corresponds to column 13 in text output file)
xiii. *URB_PUMPING* (corresponds to column 14 in text output file)
xiv. *URB_DELIVERY* (corresponds to column 15 in text output file)
xv. *URB_SR_INFLOW* (corresponds to column 16 in text output file)
xvi. *URB_SHORTAGE* (corresponds to column 17 in text output file)

8.4.5.4. Root Zone Moisture Z-Budget

The Z-Budget tool allows printing of the root zone budget tables to either an ASCII text file or to a DSS file for each of the zones defined by the user. The budget table for each zone includes a title that lists the version of the root zone component that was used in the IDC run, the units of the budget flow terms as well as the name and area of the zone.

The root zone moisture budget for each zone provides detailed inflow and outflow terms to and from the root zone for agricultural, urban and natural (native and riparian vegetation) areas. It also includes precipitation, rainfall runoff, applied water and return flow for each zone.

The following table defines each column in the land and water use budget table printed out to a text file:

ROOT ZONE MOISTURE Z-BUDGET		
Column No.	Column Name	Description
1	Time	Simulation date and time
Agricultural Area		
2	Area	Agricultural area
3	Potential ET	Potential evapotranspiration for agricultural lands
4	Precipitation	Precipitation that falls on agricultural lands
5	Runoff	Direct runoff of precipitation that falls on agricultural lands
6	Prime Applied Water	Amount of water applied as a summation of surface water deliveries and pumping for irrigation purposes
7	Inflow as Surface Runoff	Surface runoff (sum of rainfall runoff and return flow from agricultural and urban lands) from upstream elements and subregions that is captured and used for irrigation purposes
8	Reused Water	Amount of return flow that is captured and re-used for irrigation
9	Net Return Flow	Net return flow of irrigation on agricultural lands (after re-use)
10	Beginning Storage (+)	Root zone moisture in agricultural lands at the beginning of time step
11	Net Gain from Land Expansion (+)	The net moisture gained from other land use areas as the area of agricultural lands increase (a negative value represents loss of moisture due to the decrease of agricultural area)

12	Infiltration (+)	Total infiltration on the agricultural lands; computed as the summation of precipitation, prime applied water and inflow as surface runoff less runoff and net return flow
13	Other Inflow (+)	Moisture inflow from other generic moisture sources such as lateral seepage
14	Actual ET (–)	Actual evapotranspiration in agricultural lands
15	Percolation (–)	Percolation from the root zone which is the vertical moisture outflow from the bottom of the root zone in agricultural areas
16	Ending Storage (–)	Root zone moisture in agricultural lands at the end of the time step computed as the summation of the beginning storage and the net inflow into the root zone
17	Discrepancy (=)	Mass balance error check for the moisture storage in the root zone of agricultural lands
Urban Area		
18	Area	Urban area
19	Potential ET	Potential evapotranspiration for urban lands
20	Precipitation	Precipitation that falls on urban lands
21	Runoff	Direct runoff of precipitation that falls on urban lands
22	Prime Applied Water	Total amount of pumping and surface water deliveries that is used to meet urban indoors and outdoors water demand
23	Inflow as Surface Runoff	Surface runoff (sum of rainfall runoff and return flow from agricultural and urban lands) from upstream elements and subregions that is captured and used to meet urban water demand
24	Reused Water	The amount of return flow that is captured and re-used on urban lands
25	Net Return Flow	Net return flow of applied water used for urban indoors and outdoors usage (after re-use)
26	Beginning Storage (+)	Root zone moisture at the beginning of time step
27	Net Gain from Land Expansion (+)	The net moisture gained from other land use areas as the area of urban lands increase (a negative value represents loss of moisture due to the decrease of urban area)
28	Infiltration (+)	Total infiltration on the urban lands computed as the summation of precipitation, prime applied water and inflow as surface runoff less runoff and net return flow
29	Other Inflow (+)	Moisture inflow from other generic moisture sources such as lateral seepage
30	Actual ET (–)	Actual evapotranspiration in urban lands

31	Percolation (–)	Percolation from the root zone which is the vertical moisture outflow from the bottom of the root zone in urban areas
32	Ending Storage (–)	Root zone moisture in urban lands at the end of the time step computed as the summation of the beginning storage and the net inflow into the root zone
33	Discrepancy (=)	Mass balance error check for the moisture storage in the root zone of urban lands
Native and Riparian Vegetation Area		
34	Area	Native and riparian vegetation area
35	Potential ET	Potential evapotranspiration for native and riparian vegetation
36	Precipitation	Precipitation that falls on areas with native and riparian vegetation
37	Inflow as Surface Runoff	Surface runoff (sum of rainfall runoff and return flow from agricultural and urban lands) from upstream elements and subregions that flows into the lands with native and riparian vegetation
38	Runoff	Direct runoff of precipitation that falls on areas with native and riparian vegetation
39	Beginning Storage (+)	Root zone moisture in areas with native and riparian vegetation at the beginning of time step
40	Net Gain from Land Expansion (+)	The net moisture gained from other land use areas as the area of native and riparian vegetation increase (a negative value represents loss of moisture due to the decrease of native and riparian vegetation area)
41	Infiltration (+)	Total infiltration on areas with native and riparian vegetation; computed as the sum of precipitation and inflow as surface runoff less runoff
42	Other Inflow (+)	Moisture inflow from other generic moisture sources such as lateral seepage
43	Actual ET (–)	Actual evapotranspiration in areas with native and riparian vegetation
44	Percolation (–)	Percolation from the root zone which is the vertical moisture outflow from the bottom of the root zone in areas with native and riparian vegetation
45	Ending Storage (+)	Root zone moisture in areas with native and riparian vegetation at the end of the time step; computed as the summation of the beginning storage and the net moisture inflow
46	Discrepancy (=)	Mass balance error check for the moisture storage in the root zone of lands with native and riparian vegetation

If a DSS file is used for print-out, the following pathnames are used:

Part A:

IWFM_ZBUD

Part B:

ZONE:*XXX* where *XXX* is the zone number

Part C:

One of the following, depending on the output data:

i. *AREA*
ii. *VOLUME*

Part D:

Start date of the time series depending on the values of the BDT and EDT variables (starting and ending date and time of budget print-out)

Part E:

Print-out interval for the zonal root zone budget as specified in the Z-Budget Main Input File

Part F:

One of the following, depending on the output data (refer to the table above for further details):

i. *AG_AREA* (corresponds to column 2 in text output file)
ii. *AG_POT_ET* (corresponds to column 3 in text output file)
iii. *AG_PRECIP* (corresponds to column 4 in text output file)
iv. *AG_RUNOFF* (corresponds to column 5 in text output file)
v. *AG_PRM_H2O* (corresponds to column 6 in text output file)
vi. *AG_SR_INFLOW* (corresponds to column 7 in text output file)
vii. *AG_RE-USE* (corresponds to column 8 in text output file)
viii. *AG_NT_RTRN_FLOW* (corresponds to column 9 in text output file)
ix. *AG_BEGIN_STOR* (corresponds to column 10 in text output file)
x. *AG_GAIN_EXP* (corresponds to column 11 in text output file)
xi. *AG_INFILTR* (corresponds to column 12 in text output file)
xii. *AG_OTHER_INFLOW* (corresponds to column 13 in text output file)
xiii. *AG_ET* (corresponds to column 14 in text output file)
xiv. *AG_PERC* (corresponds to column 15 in text output file)
xv. *AG_END_STOR* (corresponds to column 16 in text output file)

xvi. *AG_DISCREPANCY* (corresponds to column 17 in text output file)
xvii. *URB_AREA* (corresponds to column 18 in text output file)
xviii. *URB_POT_ET* (corresponds to column 19 in text output file)
xix. *URB_PRECIP* (corresponds to column 20 in text output file)
xx. *URB_RUNOFF* (corresponds to column 21 in text output file)
xxi. *URB_PRM_H2O* (corresponds to column 22 in text output file)
xxii. *URB_SR_INFLOW* (corresponds to column 23 in text output file)
xxiii. *URB_RE-USE* (corresponds to column 24 in text output file)
xxiv. *URB_NT_RTRN_FLOW* (corresponds to column 25 in text output file)
xxv. *URB_BEGIN_STOR* (corresponds to column 26 in text output file)
xxvi. *URB_GAIN_EXP* (corresponds to column 27 in text output file)
xxvii. *URB_INFILTR* (corresponds to column 28 in text output file)
xxviii. *URB_OTHER_INFLOW* (corresponds to column 29 in text output file)
xxix. *URB_ET* (corresponds to column 30 in text output file)
xxx. *URB_PERC* (corresponds to column 31 in text output file)
xxxi. *URB_END_STOR* (corresponds to column 32 in text output file)
xxxii. *URB_DISCREPANCY* (corresponds to column 33 in text output file)
xxxiii. *NRV_AREA* (corresponds to column 34 in text output file)
xxxiv. *NRV_POT_ET* (corresponds to column 35 in text output file)
xxxv. *NRV_PRECIP* (corresponds to column 36 in text output file)
xxxvi. *NRV_SR_INFLOW* (corresponds to column 37 in text output file)
xxxvii. *NRV_RUNOFF* (corresponds to column 38 in text output file)
xxxviii. *NRV_BEGIN_STOR* (corresponds to column 39 in text output file)
xxxix. *NRV_GAIN_EXP* (corresponds to column 40 in text output file)
xl. *NRV_INFILTR* (corresponds to column 41 in text output file)
xli. *NRV_OTHER_INFLOW* (corresponds to column 42 in text output file)
xlii. *NRV_ET* (corresponds to column 43 in text output file)
xliii. *NRV_PERC* (corresponds to column 44 in text output file)

xliv. *NRV_END_STOR* (corresponds to column 45 in text output file)

xlv. *NRV_DISCREPANCY* (corresponds to column 46 in text output file)

9. Budget Post-Processor

IDC prints out its results into HDF5 files to decrease the computer run times as well as the size of the output files. The information in these HDF5 files need to be processed to generate understandable information in a table format. The Budget post-processor is created for this purpose and it is available for download from the IDC's web site at https://water.ca.gov/Library/Modeling-and-Analysis/Modeling-Platforms/Integrated-Water-Flow-Model-Demand-Calculator.

Budget post-processor can process multiple HDF5 files at the same time. The user specifies the number of HDF5 files to be processed, the names of these files and the output files where the processed results will be printed out.

For each HDF5 file to be processed the user can choose the "locations" for which the IDC results will be listed in a tabulated form. A location can either be a subregion or a set of specified land-uses at a subregion. For instance, the user can specify names for root zone moisture, and land and water use budget files in the Root Zone Parameter File. For these files, a location is a subregion. If the model has 20 subregions, then the user can choose in the Budget post-processor to process these two HDF5 files and generate tabulated data for all or some of the subregions.

Similar output file names can also be specified for non-ponded and ponded crops as well as urban, native vegetation and riparian vegetation lands. In this case, a location will be a land-use and subregion combination. For instance, if the user chooses to generate HDF5 soil moisture budget file for 4 crops (e.g. grain, alfalfa, corn and sugar beets), the first location for the processed and tabulated data will be grain in the first subregion, second location will be alfalfa in the first subregion, third location will be corn in the first subregion, etc. Fifth location will be grain in the second subregion.

By using the output features of IDC and Budget post-processor the user can obtain detailed land and water use as well as soil moisture budgets for total agriculture, urban, and native and riparian vegetation lands as well as for specific crops in each subregion.

When executed, Budget post-processor asks for the name of the Budget Main Input File which is described below.

9.1. Budget Main Input File

The Budget Main Input File contains output unit controls, beginning and ending simulation times for the budget print-out, names of the HDF5 files to be processed, budget print-out locations and the print-out interval of the budget data.

The values stored in the HDF5 files have units used in the IDC run. The output unit control information allows the user to print out the budget data in a different set of units. The user is required to enter the beginning date and time, BDT, and the ending date and time, EDT for the budget outputs. The user can process as many budget files as needed. A single HDF5 file can be processed multiple times with different output intervals. For each HDF5 file to be processed, the user is required to enter the name of the HDF5 file, the name of the output file, output interval, number of *locations* for budget print-out and a list of the location indices. If the output interval is greater than the simulation time step, the budget flow terms will be accumulated over the output interval.

The meaning of *location* depends on the type of the budget file being processed. For instance, for subregional root zone budget, *location* represents a subregion. For crop specific root zone budget a *location* represents agricultural lands occupied by a specific crop at a subregion. When location is specified as −1, Budget post-processor prints out budget tables for all locations in that particular budget class. If a value of 0 is specified for the location, then Budget suppresses the processing of the budget tables.

The following is a list of variables that need to be defined in this file:

FACTLTOU	Factor to convert simulation unit of length to output unit of length
UNITLTOU	Output unit of length (maximum of 8 characters)
FACTAROU	Factor to convert simulation unit of area to output unit of area
UNITAROU	Output unit of area (maximum of 8 characters)
FACTVLOU	Factor to convert simulation unit of volume to output unit of volume
UNITVLOU	Output unit of volume (maximum of 8 characters)
CACHE	Cache size in terms of number of output values stored in the memory before being printed to the output file; a large CACHE value (e.g. 50000 or more depending on the memory resources of the computer where Budget runs are taking

	place) can drastically decrease the program run-time especially when the budget tables are printed out to a DSS file.
TBEGIN	Beginning time step for the budget tables; used only for non-time-tracking simulations (note that IDC only performs time-tracking simulations)
TLAST	Ending time step for the budget tables; used only for non-time-tracking simulations (note that IDC only performs time-tracking simulations)
BDT	Beginning date and time for the budget tables; used only for time-tracking simulations
EDT	Ending date and time for the budget tables; used only for time-tracking simulations
NBUDGET	Number of budget files to be processed

NBUDGET, described above, informs the Budget post-processor about the number of budget files that will be processed. For each of the budget files to be processed the following variables need to be set:

HDFFILE	Name of the HDF5 budget file (maximum 1000 characters)
OUTFILE	Name of the budget output file (maximum 1000 characters); the filename extension dictates if the output file will be text file or a DSS file (see section 8.2 for file types and corresponding filename extensions)
INTPRNT	Interval for budget print-out (budget flow terms will be accumulated over the output interval); this should be one of the units recognized by HEC-DSS that are listed in the IDC Main Input File. If left blank, the print-out interval will be the same as the simulation time step.
NLPRNT	Number of *locations* for budget table print-out; a *location* corresponds to different spatial attributes depending on the type of the budget table being processed (e.g. a subregion for subregional root zone budgets, lands that are occupied by a specific crop in a subregion for crop specific root zone budget, etc.)
LPRNT	Index for locations for which a budget table will be generated; for budget tables at subregions, the index for the entire

domain is the number of subregions plus 1 (−1 = print budget tables for all locations, 0 = suppress printing of all budget tables)

```
C*******************************************************************************
C
C                   INTEGRATED WATER FLOW MODEL (IWFM)
C                          *** Version ### ***
C
C*******************************************************************************
C
C                            BUDGET INPUT FILE
C                        for IWFM Post-Processing
C
C
C             Project:  IDC Version ### Release
C                       California Department of Water Resources
C             Filename: Budget.in
C
C*******************************************************************************
c
C                             File Description
C
C    This file contains the names of all HDF5 input files,
C    conversion factors and output control options for running the post-processor.
C
C*******************************************************************************
C                    Output Unit Control
C
C    FACTLTOU; Factor to convert simulation unit of length to output unit of length
C    UNITLTOU; Output unit of length (8 characters max.)
C    FACTAROU; Factor to convert simulation unit of area to output unit of area
C    UNITAROU; Output unit of area (8 characters max.)
C    FACTVLOU; Factor to convert simulation unit of volume to output unit of volume
C    UNITVLOU; Output unit of volume (8 characters max.)
C
C-----------------------------------------------------------------------------
C   VALUE                            DESCRIPTION
C-----------------------------------------------------------------------------
    1.0                              / FACTLTOU
    FT.                              / UNITLTOU
    2.295684114e-5                   / FACTAROU  (sq.ft. -> ac)
    AC.                              / UNITAROU
    2.295684114e-5                   / FACTVLOU  (cu.ft. -> ac.ft.)
    AC.FT.                           / UNITVLOU
C*******************************************************************************
C                    Output Cache Size
C
C    CACHE;   Cache size in terms of number of values stored for time series
C             data output
C
C-----------------------------------------------------------------------------------
C   VALUE                            DESCRIPTION
C-------------------------------------------------------------------------------
    500000                           / CACHE
C*******************************************************************************
C                        Budget Output Control Options
C                    (Simulation Date and Time NOT Tracked)
C
C    If the actual simulation date and time is NOT tracked enter the following
C    variables. Otherwise, comment out the following variables and use the
C    "Simulation Date and Time NOT Tracked" option below.
C
C    TBEGIN ; Beginning time for the budget tables
C              * Use ##.# format
C    TLAST  ; Ending time for the budget tables
C              * Use ##.# format
C
C-------------------------------------------------------------------------------
C   VALUE                          DESCRIPTION
C-------------------------------------------------------------------------------
*                                  / TBEGIN
*                                  / TLAST
C-------------------------------------------------------------------------------
C                        Budget Output Control Options
C                      (Simulation Date and Time Tracked)
C
C    If the actual simulation date and time is tracked enter the following
C    variables. Otherwise, comment out the following variables and use the
C    "Simulation Date and Time NOT Tracked" option above.
C
C    BDT    ; Begining date and time for the budget output
C              * Use MM/DD/YYYY_HH:MM format
C              * Midnight is 24:00
C    EDT    ; Ending date and time for the budget output
C              * Use MM/DD/YYYY_HH:MM format
C              * Midnight is 24:00
C
C-------------------------------------------------------------------------------
C   VALUE                          DESCRIPTION
C-------------------------------------------------------------------------------
    09/30/1980_24:00               / BDT
    09/30/2006_24:00               / EDT
C*******************************************************************************
C                              Budget Output Data
C
C   List below the number of budget classes (i.e. groundwater budget, stream
C   budget, small watershed budget, etc.), and for each budget class list the
C   input file, output file and the locations for which a budget table will
C   be generated.
C
C   NBUDGET ;  Number of budget classes to be printed
C   HDFFILE ;  Name of the input budget file (max. 1000 characters)
C   OUTFILE ;  Name of the budget output file (max. 1000 characters)
C   INTPRNT ;  Interval for budget print out (e.g. 1DAY, 1MONTH, etc.). The interval
C                must be a one of those listed in the Main Input File for the
C                executable that generated the HDF5 input files.
C                * Leave blank to use the same interval as the data.
C                * This interval will only be used for simulation with
C                  date and time tracked
C   NLPRNT  ;  Number of location indices for budget table print-out
C   LPRNT   ;  Index for locations (i.e. subregions, lakes, stream reaches, etc.
C                depending on the budget class) for which a budget table will be
C                generated.  For budget tables at subregions, the index for the
C                entire domain is the number of subregions plus 1.
C                * Enter -1: to print budget tables for all locations
```

```
C                          0: to suppress printing of any budget tables
C
C-------------------------------------------------------------------------------
C   VALUE                          DESCRIPTION
C-------------------------------------------------------------------------------
     4                             / NBUDGET
C*******************************************************************************
C                           Data for Budget Class 1
C
C-------------------------------------------------------------------------------
C   VALUE                          DESCRIPTION
C-------------------------------------------------------------------------------
   LWU.HDF                         / HDFFILE
   LWU.BUD                         / OUTFILE
   1mon                            / INTPRNT
   1                               / NLPRNT
   -1                              / LPRNT[1]
C*******************************************************************************
C                           Data for Budget Class 2
C
C-------------------------------------------------------------------------------
C   VALUE                          DESCRIPTION
C-------------------------------------------------------------------------------
   RZ.HDF                          / HDFFILE
   RZ.BUD                          / OUTFILE
                                   / INTPRNT
   1                               / NLPRNT
   -1                              / LPRNT[1]
C*******************************************************************************
C                           Data for Budget Class 3
C
C-------------------------------------------------------------------------------
C   VALUE                          DESCRIPTION
C-------------------------------------------------------------------------------
    NonPondedAgLWU.hdf             / HDFFILE
    NonPondedAgLWU.bud             / OUTFILE
                                   / INTPRNT
    3                              / NLPRNT
    1                              / LPRNT[1]
    7                              / LPRNT[2]
    14                             / LPRNT[3]
C*******************************************************************************
C                           Data for Budget Class 4
C
C-------------------------------------------------------------------------------
C   VALUE                          DESCRIPTION
C-------------------------------------------------------------------------------
    NonPondedAgLWU.hdf             / HDFFILE
    NonPondedAgLWU_ANNUAL.bud      / OUTFILE
    1year                          / INTPRNT
    1                              / NLPRNT
    -1                             / LPRNT[1]
```

10. Z-Budget Post-Processor

While Budget post-processor tabulates simulation results for predefined subregions, Z-Budget post-processor allows the user to group selected elements into *zones*, and compiles and tabulates water budgets for these zones. This post-processing approach allows the user to zoom in on areas within the model boundary to examine the flow processes in these areas.

All output files the Z-Budget post-processor generates are text files that include tabular data. To perform any analysis, these data are generally needed to be imported into other software such as Microsoft Excel. Alternatively, the user can download and install the IWFM Tools Add-in for Excel 2016 from IWFM's web site (https://water.ca.gov/Library/Modeling-and-Analysis/Modeling-Platforms/Integrated-Water-Flow-Model). This tool allows easy import of the data stored in the HDF5 Z-Budget files into Microsoft Excel.

This chapter describes the input files and provides file samples for the Z-Budget post-processor.

10.1. Z-Budget Main Input File

The Z-Budget Main Input File contains output unit controls, beginning and ending simulation times for the Z-Budget print-out, names of the HDF5 files to be processed, zones for which tabulated data will be generated and the print-out interval of the tabulated data.

The values stored in the HDF5 files have units used in the Simulation. The output unit control information allows the user to print out the tabulated data in a different set of units. Beginning and ending date of the Z-Budget output are required to be specified. The output begin date can be later than the beginning date of the model simulation period and the output end date can be earlier than the ending date of the simulation period, allowing the user to zoom in on short time periods within the simulation period for analysis.

The user can process as many Z-Budget HDF5 files as needed. A single HDF5 file can be processed multiple times with different output intervals or for different zone definitions. For each HDF5 file to be processed, the user is required to enter the name of the HDF5 file, the name of the file that includes the zone definitions, the name of the output file, output interval for time-tracking simulations, number of zones for print-out and a list of the zone indices for the print-out. If the output interval is greater than the simulation time step, the Z-Budget flow terms will be accumulated over the output interval.

The following is a list of variables that need to be defined in this file:

FACTAROU	Factor to convert simulation unit of area to output unit of area
UNITAROU	Output unit of area (maximum of 8 characters)
FACTVLOU	Factor to convert simulation unit of volume to output unit of volume
UNITVLOU	Output unit of volume (maximum of 8 characters)
CACHE	Cache size in terms of number of output values stored in the memory before being printed to the output file; a large CACHE value (e.g. 50000 or more depending on the memory resources of the computer where Z-Budget runs are taking place) can drastically decrease the program run-time especially when the tabulated data are printed out to a DSS file.
BDT	Beginning date and time for the Z-Budget tables
EDT	Ending date and time for the Z-Budget tables
NZBUDGET	Number of Z-Budget HDF5 files to be processed

NZBUDGET, described above, informs the Z-Budget post-processor about the number of HDF5 files that will be processed. For each of the HDF5 files to be processed the following variables need to be set:

ZDEFFILE	Name of the zone definition file (maximum 1000 characters); the contents of this file are described in the next section
HDFFILE	Name of the input HDF5 Z-Budget file (maximum 1000 characters)
OUTFILE	Name of the Z-Budget output file (maximum 1000 characters); the filename extension dictates if the output file will be text file or a DSS file (see section 8.2 for file types and corresponding filename extensions)
INTPRNT	Interval for Z-Budget print-out (flow terms will be accumulated over the output interval); this should be one of the units recognized by HEC-DSS that are listed in the IDC Main Input File. If left blank, the print-out interval will be the same as the IDC model time step.

NZPRNT	Number of zones for which tabulated output is required; enter 1 if ZPRNT is set to −1 or 0 (see below)
ZPRNT	Index for zones for which tabulated data will be generated (−1 = print tabulated data for all zones; 0 = suppress printing of tabulated data for all zones)

```
C*******************************************************************************
C
C                    INTEGRATED WATER FLOW MODEL (IWFM)
C                          *** Version 2015 ***
C
C*******************************************************************************
C
C                          Z-BUDGET MAIN INPUT FILE
C                          for IWFM Post-Processing
C
C
C              Project : IDC Version ### Release
C                        California Department of Water Resources
C              Filename: ZBudget.in
C
C*******************************************************************************
C
C                              File Description
C
C    This file contains the names of all HDF5 Z-Budget input files, conversion
C    factors and output control options for running the post-processor.
C
C*******************************************************************************
C                           Z-Budget Output Control
C
C    FACTAROU; Factor to convert simulation unit of area to output unit of area
C    UNITAROU; Output unit of area (8 characters max.)
C    FACTVLOU; Factor to convert simulation unit of volume to output unit of volume
C    UNITVLOU; Output unit of volume (8 characters max.)
C    CACHE   ; Cache size in terms of number of values stored for time series
C                data output
C
C-----------------------------------------------------------------------------
C   VALUE                        DESCRIPTION
C-----------------------------------------------------------------------------
    0.000022957                  / FACTAROU     (sq.ft. -> ac.)
    AC.                          / UNITAROU
    0.000022957                  / FACTVLOU     (cu.ft. -> ac.ft.)
    AF.                          / UNITVLOU
    500000                       / CACHE
C*******************************************************************************
C                          Z-Budget Output Period
C
C    BDT    ; Begining date and time for the Z-Budget output
C              * Use MM/DD/YYYY_HH:MM format
C              * Midnight is 24:00
C    EDT    ; Ending date and time for the Z-Budget output
C              * Use MM/DD/YYYY_HH:MM format
C              * Midnight is 24:00
C
C-------------------------------------------------------------------------------
C   VALUE                      DESCRIPTION
C-------------------------------------------------------------------------------
    09/30/1921_24:00           / BDT
    09/30/2015_24:00           / EDT
C*******************************************************************************
C                           Z-Budget Output Data
C
C   List below the number of Z-Budget types (i.e. groundwater Z-Budget, root zone
C   Z-Budget, land & water use Z-Budget, etc.), and for each Z-Budget type list the
C   zone definition file, input HDF5 file, output file and the locations for which a
C   Z-Budget table will be generated.
C
C   NZBUDGET;  Number of Z-Budget types to be printed
C   ZDEFFILE;  Name of the zone definition file (max. 1000 characters)
C   HDFFILE ;  Name of the input Z-Budget file (max. 1000 characters)
C   OUTFILE ;  Name of the Z-Budget output file (max. 1000 characters)
C   INTPRNT ;  Interval for Z-Budget print out (e.g. 1DAY, 1MONTH, etc.). The interval
C                must be a one of those listed in the Main Input File for the
C                executable that generated the input HDF5 files.
C                * Leave blank to use the same interval as the data.
C   NZPRNT  ;  Number of zones for Z-Budget print-out (not all the zones listed above
C                need to be processed)
C   ZPRNT   ;  Zone numbers for which a Z-Budget table will be generated
C                * Enter -1: to print Z-Budget tables for all zones
C                         0: to suppress printing of any Z-Budget tables
C
C-------------------------------------------------------------------------------
C   VALUE                      DESCRIPTION
C-------------------------------------------------------------------------------
    4                           / NZBUDGET
C*******************************************************************************
C                          Data for Z-Budget Type 1
C
C-------------------------------------------------------------------------------
C   VALUE                      DESCRIPTION
C-------------------------------------------------------------------------------
    Zones_Subregions.dat       / ZDEFFILE
    LandWater_ZBudget.hdf      / HDFFILE
    LandWater_ZBud_SR.bud      / OUTFILE
                               / INTPRNT
    1                          / NZPRNT
    -1                         / ZPRNT[1]
C*******************************************************************************
C                          Data for Z-Budget Type 2
C
C-------------------------------------------------------------------------------
C   VALUE                      DESCRIPTION
C-------------------------------------------------------------------------------
    Zones_Subregions.dat       / ZDEFFILE
    LandWater_ZBudget.hdf      / HDFFILE
    LandWater_ZBud_SR.bud      / OUTFILE
    1YEAR                      / INTPRNT
    4                          / NZPRNT
    6                          / ZPRNT[1]
    7                          / ZPRNT[2]
    8                          / ZPRNT[3]
    9                          / ZPRNT[4]
C*******************************************************************************
C                          Data for Z-Budget Type 3
C
C-------------------------------------------------------------------------------
```

```
C   VALUE                           DESCRIPTION
C-------------------------------------------------------------------------------
    Zones_DAUs.dat                  / ZDEFFILE
    LandWater_ZBudget.hdf           / HDFFILE
    LandWater_ZBud_DAU.bud          / OUTFILE
                                    / INTPRNT
    1                               / NZPRNT
    -1                              / ZPRNT[1]
C*******************************************************************************
C                          Data for Z-Budget Type 4
C
C-------------------------------------------------------------------------------
C   VALUE                           DESCRIPTION
C-------------------------------------------------------------------------------
    Zones_Elements.dat              / ZDEFFILE
    RootZone_ZBudget.hdf            / HDFFILE
    RootZone_ZBud_Elems.bud         / OUTFILE
    1MON                            / INTPRNT
    7                               / NZPRNT
    567                             / ZPRNT[1]
    1002                            / ZPRNT[2]
    568                             / ZPRNT[3]
    573                             / ZPRNT[4]
    1003                            / ZPRNT[5]
    574                             / ZPRNT[6]
    1006                            / ZPRNT[7]
```

10.2. Zone Definition File

In the Zone Definition File one or more elements are grouped into zones. Each zone is identified with an integer number. Zone numbers don't have to start from 1 and they don't need to be sequential. A single element cannot be associated with more than one zone. Not all elements need to be associated with a zone; by default each element is assigned the *undefined zone number*, –99. However, at least one element must be listed in the Zone Definition File with a zone number that is different than –99. Since –99 is a special zone number for the Z-Budget post-processor, it is not allowed to assign elements with this zone number explicitly.

In theory, zones can be defined both in horizontal and vertical directions. Zone definition in the vertical requires flow processes that operate on three-dimensional space (such as the groundwater or the unsaturated zone processes simulated in IWFM). The root zone process simulated by IDC is only two-dimensional; the root zone flows vary in the horizontal but the system is represented with a single root zone layer in the vertical. Therefore, for Z-Budget outputs produced by IDC zones can only be defined by grouping elements in the horizontal.

Below is a list of the variables that need to be populated in the Zone Definition File:

ZEXTENT	Extent of the zone numbering (1 = zone numbering is defined for horizontal plane and will be used for all layers in the vertical; 0 = different zone numbering is specified for each layer in the vertical); this variable must be set to 1 always to process IDC-generated Z-Budget files
ZID	Zone number for which a name is defined
ZNAME	Name of each zone (maximum 50 characters)
IE	Element number
LAYER	Layer number at which element is located; this variable must always be left blank to process IDC-generated Z-Budget files
ZONE	Zone number; any integer number except –99 is allowed

```
C*******************************************************************************
C
C                   INTEGRATED WATER FLOW MODEL (IWFM)
C                          *** Version 2015 ***
C
C*******************************************************************************
C
C                         ZONE DEFINITION INPUT FILE
C                      for IWFM Z-Budget Post-Processing
C
C
C              Project : IDC Version ### Release
C                        California Department of Water Resources
C              Filename: Zones_DAUs.dat
C
C*******************************************************************************
C
C                             File Description
C
C     This file contains zone definitions to be used with the Z-Budget post-processor.
C
C*******************************************************************************
C                             Zone Information
C
C     The following lists the zone numbers that the elements of the finite element
C     mesh belong to.  Element number, layer number (this information is
C     optional depending on the value of ZEXTENT above) and the zone number that
C     the element belongs to are required information. It is not necessary to list
C     all elements at all layers and assign a zone number to each of them.
C     By default, each element is given a zone number of -99.  Therefore, any elements
C     that are not listed below will constitute zone -99.
C
C     ** Note: If variable ZEXTENT below is set to 1, do not specify LAYER below. If
C              ZEXTENT is set to 0, it is required that LAYER for each element below
C              is specified.
C
C     ZEXTENT ; Extent of the the zone numbering
C                 1 = Zone numbering is defined for horizontal plane and will be
C                      used for all layers
C                 0 = Different zone numbering is specified for each layer
C     ZID     ; Zone number for which a name is defined
C     ZNAME   ; Name of each zone (maximum 50 characters)
C     IE      ; Element number
C     LAYER   ; Layer number at which element is located
C                 *Leave blank if ZEXTENT = 1
C     ZONE    ; Zone number
C
C-------------------------------------------------------------------------------
C     VALUE                    DESCRIPTION
C-------------------------------------------------------------------------------
      1                        / ZEXTENT
C-------------------------------------------------------------------------------
C     ZID       ZNAME
C-------------------------------------------------------------------------------
        1       DAU_41
        2       DAU_139
        3       DAU_141
        .          .
        .          .
        .          .
       57       DAU_259
       58       DAU_260
       59       DAU_261
C-------------------------------------------------------------------------------
C      IE        LAYER        ZONE
C-------------------------------------------------------------------------------
       1                      3
       2                      5
       3                      5
       4                      5
       5                      5
       6                      5
       7                      3
       8                      5
       .                      .
       .                      .
       .                      .
    1385                     56
    1386                     59
    1387                     59
    1388                     56
    1389                     56
    1390                     59
    1391                     56
    1392                     56
```

11. Linking IDC to Other Models

The source code of IDC has been compiled into a dynamic link library (DLL) which is the IDC Application Programing Interface (API). The API exposes the procedures necessary to link IDC to other models.

When IDC is linked to other models it still requires the same input data files that are utilized when IDC is used as a stand-alone model. This means that some information that is used by the linking model may need to be re-structured in a format that IDC expects. For instance, the linking model may already be using precipitation data for other processes it simulates. Since IDC also requires precipitation as input the same or additional precipitation data needs to be re-structured into the format that IDC expects. Another information that needs to be redefined in a format that IDC requires is the configuration of the computational grid. If the linking model utilizes a finite-element grid, it is likely that the format of the grid configuration data for the linking model is in a different format than IDC requires. In this case, the grid configuration needs to be redefined in the format that IDC expects to read. Similarly, if the linking model utilizes a finite-difference grid, the grid configuration should be redefined as if it is a finite-element grid in the format that IDC expects.

To successfully link IDC to other models, the modeler needs to know the interfaces to the exported procedures in the IDC API. Next, the calling convention used in the IDC API, exported procedures and their interfaces are given.

11.1. Calling Conventions

IDC API is written using Fortran 2008 programming language. It is compiled for both 32-bit and 64-bit Microsoft Windows OS. The following approach and data standards are used in the API:

1. *stdcall* calling convention is used to allow the API procedures to be called from code written in Visual Basic for Applications (VBA). For instance, this is the case when the API procedures are called from MS Excel.

2. All procedure arguments are expected to be passed by reference.

3. To avoid possible stack overflows, heap memory is used.

4. All procedure arguments are C data types.

5. All real number arguments that appear in procedure interfaces are defined as C `double` type; i.e. as 64-bit (8-byte) arguments. In this document, a real type is denoted by **`REAL(C_DOUBLE)`**.

6. All integer arguments that appear in procedure interfaces are defined as C `int` type; i.e. as 32-bit (4-byte) arguments. In this document, an integer type is denoted by **`INTEGER(C_INT)`**.

7. The API allows passing arrays of real and integer arguments. This is accomplished by passing a reference to the first element of the array along with its size. Note that Fortran uses 1-based arrays and it uses column-major order (i.e. first array index changes the fastest) when ordering multi-dimensional arrays. Care must be taken when the API is called from languages that use 0-based arrays and row-major ordering.

8. When a scalar string argument is passed to an API procedure, it is received as an array of C `char` data type. Both the name of the argument and the number of characters in the string must be passed. In this document, a character type is denoted by **`CHARACTER(C_CHAR)`**.

11.2. Language-Specific Calling Mechanisms

In this section, mechanisms specific to different programming languages to call IDC API procedures will be explained. For this purpose, the following dummy procedures will be used to demonstrate how arguments with different data types are defined in the client programming language and how the API procedure is called. These procedures are included in the IDC API to test calling mechanisms with other programming languages. Please refer to section 11.4 for the description of these procedures and how to check if the tested calling mechanism works properly.

i. Scalar integer and real numbers (passed to or retrieved from API procedure):

```
SUBROUTINE fooScalar(iArg,dArg)
   INTEGER(C_INT) :: iArg
```

```
    REAL(C_DOUBLE) :: dArg
END SUBROUTINE fooScalar
```

ii. 1-dimensional integer and real arrays (passed to or retrieved from API procedure):

```
SUBROUTINE foo1DArray(iArrayDim,iArray,idArrayDim,dArray)
    INTEGER(C_INT) :: iArrayDim,idArrayDim
    INTEGER(C_INT) :: iArray(iArrayDim)
    REAL(C_DOUBLE) :: dArray(idArrayDim)
END SUBROUTINE foo1DArray
```

iii. 2-dimensional integer and real arrays (passed to or retrieved from API procedure):

```
SUBROUTINE foo2DArray(iDim1,iDim2,iArray,idDim1,idDim2,dArray)
    INTEGER(C_INT) :: iDim1,iDim2,idDim1,idDim2
    INTEGER(C_INT) :: iArray(iDim1,iDim2)
    REAL(C_DOUBLE) :: dArray(idDim1,idDim2)
END SUBROUTINE foo2DArray
```

iv. String scalar passed to API procedure:

```
SUBROUTINE fooStrPassed(iLen,cStrPassed)
    INTEGER(C_INT) :: iLen
    CHARACTER(C_CHAR),INTENT(IN) :: cStrPassed(iLen)
END SUBROUTINE fooStrPassed
```

v. String scalar received from the API procedure:

```
SUBROUTINE fooStrReceived(iLen,cStrRecvd)
    INTEGER(C_INT) :: iLen
    CHARACTER(C_CHAR),INTENT(OUT) :: cStrRecvd(iLen)
END SUBROUTINE fooStrReceived
```

11.2.1. Python

IDC API procedures are called from Python using the `ctypes` foreign function library. `windll` object exposed by `ctypes` is used to gain access to the API procedures using the *stdcall* calling convention.

```
import ctypes
IWFM_dll = ctypes.windll.LoadLibrary("D:\\IDC\\Bin\\IDC2015_x64.dll")
```

i. Scalar integer and real numbers:

```
iArg = ctypes.c_int(5)
dArg = ctypes.c_double(3.2)
```

```
IWFM_dll.fooScalar(ctypes.byref(iArg), ctypes.byref(dArg))
```

ii. 1-dimensional integer and real arrays:

```
iArrayDim = ctypes.c_int(10)
idArrayDim = ctypes.c_int(15)
iArray = (ctypes.c_int*iArrayDim.value)()
dArray = (ctypes.c_double*idArrayDim.value)()
IWFM_dll.foo1DArray(ctypes.byref(iArrayDim), iArray,  \
    ctypes.byref(idArrayDim), dArray)
```

iii. 2-dimensional integer and real arrays:

```
iDim1 = ctypes.c_int(5)
iDim2 = ctypes.c_int(10)
idDim1 = iDim1
idDim2 = iDim2
i2DArray = ((ctypes.c_int*iDim1.value)*iDim2.value)()
d2DArray = ((ctypes.c_double*idDim1.value)*idDim2.value)()
IWFM_dll.foo2DArray(ctypes.byref(iDim1), ctypes.byref(iDim2),  \
    i2DArray, ctypes.byref(idDim1), ctypes.byref(idDim2), d2DArray)
```

iv. String scalar passed to API procedure:

```
sString = ctypes.create_string_buffer(b"This is a test!")
iLen = ctypes.c_int(ctypes.sizeof(sString))
IWFM_dll.fooStrPassed(ctypes.byref(iLen), sString)
```

v. String scalar received from the API procedure:

```
iLen = ctypes.c_int(50)
sString = ctypes.create_string_buffer(iLen.value)
IWFM_dll.fooStrReceived(ctypes.byref(iLen), sString)
print(sString.value)
```

11.2.2. Java

IDC API procedures are accessed from Java using the Java Native Access (JNA) API. JNA provides two types of library mapping: direct and interface mapping. For efficiency, direct mapping is suggested. Individual procedures from the IDC API are accessed by mapping their signatures directly to a Java native method:

```
import com.sun.jna.Native;
import com.sun.jna.ptr.IntByReference;

public class IDC {

    static {
```

```
        Native.register("IDC2015_x64.dll");
    }

    public static native void fooScalar(IntByReference iArg,
                                        DoubleByReference dArg);
}
```

i. Scalar integer and real numbers (`IntByReference` and `DoubleByReference` classes from the JNA API are used):

```
public static native void fooScalar(IntByReference iArg,
                DoubleByReference dArg);

IntByReference iArg = new IntByReference(5);
DoubleByReference dArg = new DoubleByReference(3.2);
IWFM.fooScalar(iArg, dArg);
```

ii. 1-dimensional integer and real arrays (`IntByReference` class from the JNA API is used):

```
public static native void foo1DArray(IntByReference iArrayDim,
                                     int[] iArray,
                                     IntByReference idArrayDim,
                                     double[] dArray);

int[] iArray = new int[10];
double[] dArray = new double[15];
IntByReference iArrayDim = new IntByReference(iArray.length);
IntByReference idArrayDim = new IntByReference(dArray.length);
IWFM.foo1DArray(iArrayDim, iArray, idArrayDim, dArray);
```

iii. 2-dimensional integer and real arrays (the easiest way to pass a 2-dimensional array from Java to Fortran is to flatten it to a 1-dimensional array, keeping in mind that Fortran stores the arrays in column-major order; similarly, a 2-dimensional array can be received from Fortran as a 1-dimensional array and mapped to a 2-dimensional array):

```
public static native void foo2DArray(IntByReference iDim1,
                IntByReference iDim2,
                int[] iArray,
                IntByRference idDim1,
                IntByReference idDim2,
                double[] dArray);

int iDim1 = 5;
int iDim2 = 10;
int idDim1 = iDim1;
```

```
int idDim2 = iDim2;

IntByReference iRefDim1 = new IntByReference(iDim1);
IntByReference iRefDim2 = new IntByReference(iDim2);
IntByReference idRefDim1 = new IntByReference(idDim1);
IntByReference idRefDim2 = new IntByReference(idDim2);
int[] iArray = new int[iDim1*iDim2];
double[] dArray = new double[idDim1*idDim2];
IWFM.foo2DArray(iRefDim1, iRefDim2, iArray,
                idRefDim1, idRefDim2,dArray);

int iRow, iCol, indx;
int[][] i2DArray=new int[iDim1][iDim2];
indx = 0;
for (iCol=0; iCol < iDim2; iCol++)
     for (iRow=0; iRow < iDim1; iRow++) {
          i2DArray[iRow][iCol]=iArray[indx];
          indx++;
}

double[][] d2DArray =  new double[idDim1][idDim2];
indx = 0;
for (iCol=0; iCol < idDim2; iCol++)
     for (iRow=0; iRow < idDim1; iRow++) {
          d2DArray[iRow][iCol]=dArray[indx];
          indx++;
}
```

iv. String scalar passed to API procedure (`IntByReference` class from the JNA API is used):

```
public static native void fooStrPassed(IntByReference iLen,
                String sString);

String sString = "This is a test!";
IntByReference iLen = new IntByReference(sString.length());
IWFM.fooStrPassed(iLen, sString);
```

v. String scalar received from the API procedure (`IntByReference` class from the JNA API is used, the string is received as an array of **`byte`** and converted to Java String; make sure the string length parameter, `iLen`, is large enough to hold all the characters received):

```
public static native void fooStrReceived(IntByReference iLen,
                byte[] bStrRecvd);

IntByReference iLen = new IntByReference(50);
byte[] bss = new byte[iLen.getValue()];
IWFM.fooStrReceived(iLen, bss);
String ss = Native.toString(bss);
```

11.2.3. C#

IDC API procedures are accessed from C# using the `DllImportAttribute` class from the `System.Runtime.InteropServices` namespace.

```
using System.Runtime.InteropServices;
```

An example declaration of an IDC API procedure to be called from C# code is as follows:

```
const string cIDC2015_DLL = "D:\\IDC\\Bin\\IDC2015_x64.dll";
[DllImport(cIDC2015_DLL,
    CallingConvention = CallingConvention.StdCall,
    EntryPoint = "fooScalar",
    CharSet = CharSet.Ansi,
    SetLastError = true,
    ExactSpelling = true)]
public static extern void fooScalar(ref int iArg, ref double dArg);
```

i. Scalar integer and real numbers:

```
[DllImport(cIDC2015_DLL,
    CallingConvention = CallingConvention.StdCall,
    EntryPoint = "fooScalar",
    CharSet = CharSet.Ansi,
    SetLastError = true,
    ExactSpelling = true)]
public static extern void fooScalar(ref int iArg, ref double dArg);

int iArg = 5;
double dArg = 3.2;
fooScalar(ref iArg, ref dArg);
```

ii. 1-dimensional integer and real arrays (note that only the reference to the first item of each array is passed to the API procedure):

```
[DllImport(cIDC2015_DLL,
    CallingConvention = CallingConvention.StdCall,
    EntryPoint = "foo1DArray",
    CharSet = CharSet.Ansi,
    SetLastError = true,
    ExactSpelling = true)]
public static extern void foo1DArray(ref int iArrayDim, ref int iArray,
    ref int idArrayDim, ref double dArray);

int iArrayDim = 10;
int idArrayDim = 15;
int[] iArray = new int[iArrayDim];
double[] dArray = new double[idArrayDim];
```

```
foo1DArray(ref iArrayDim, ref iArray[0], ref idArrayDim, ref dArray[0]);
```

iii. 2-dimensional integer and real arrays (note that only the reference to the first item of each array is passed to the API procedure. Additionally, since the 2-dimensional arrays below are defined in row-major order, the dimensions must be reversed for proper operation with the IDCAPI; i.e. a 10×5 array in C# is transposed and represented as a 5×10 array in IDC API):

```
[DllImport(cIDC2015_DLL,
    CallingConvention = CallingConvention.StdCall,
    EntryPoint = "foo2DArray",
    CharSet = CharSet.Ansi,
    SetLastError = true,
    ExactSpelling = true)]
public static extern void foo2DArray(ref int iDim2, ref int iDim1,
    ref int i2DArray, ref int idDim2, ref int idDim1,
    ref double d2DArray);

int iDim1 = 5;
int iDim2 = 10;
int idDim1 = iDim1;
int idDim2 = iDim2;
int[,] i2DArray = new int[iDim2, iDim1];
double[,] d2DArray = new double[idDim2, idDim1];
foo2DArray(ref iDim1, ref iDim2, ref i2DArray[0,0], ref idDim1,
    ref idDim2, ref d2DArray[0,0]);
```

iv. String scalar passed to API procedure (note that when a `StringBuilder` argument that is already assigned a value is passed to an API procedure, the `Length` property is used to obtain its length in characters):

```
 [DllImport(cIDC2015_DLL,
    CallingConvention = CallingConvention.StdCall,
    EntryPoint = "fooStrPassed",
    CharSet = CharSet.Ansi,
    SetLastError = true,
    ExactSpelling = true)]
public static extern void fooStrPassed(ref int iLen,
    StringBuilder sString);

StringBuilder sString = new StringBuilder("This is a test!");
int iLen = sString.Length;
fooStrPassed(ref iLen, sString);
```

v. String scalar received from the API procedure (note that when a string argument is received from the API procedure, a `StringBuilder` variable with a long enough capacity is created and the `Capacity` property is used to define its length in characters):

```
[DllImport(cIDC2015_DLL,
    CallingConvention = CallingConvention.StdCall,
    EntryPoint = "fooStrReceived",
    CharSet = CharSet.Ansi,
    SetLastError = true,
    ExactSpelling = true)]
public static extern void fooStrReceived(ref int iLen,
    StringBuilder sString);

StringBuilder sString = new StringBuilder(50)
int iLen = sString.Capacity;
fooStrReceived(ref iLen, sString);
```

11.2.4. Visual Basic

IDC API procedures are accessed from Visual Basic using the `DllImportAttribute` class from the `System.Runtime.InteropServices` namespace.

```
Imports System.Runtime.InteropServices
```

An example declaration of an IDC API procedure to be called from Visual Basic code is as follows:

```
Const cIDC2015_DLL As String = "D:\IDC\Bin\IDC2015_x64.dll"
<DllImport(cIDC2015_DLL,
    CallingConvention:=CallingConvention.StdCall,
    EntryPoint:="fooScalar",
    CharSet:=CharSet.Ansi,
    SetLastError:=True,
    ExactSpelling:=True)>
Sub fooScalar(ByRef iArg As Integer, ByRef dArg As Double)
End Sub
```

i. Scalar integer and real numbers:

```
<DllImport(cIDC2015_DLL,
    CallingConvention:=CallingConvention.StdCall,
    EntryPoint:="fooScalar",
    CharSet:=CharSet.Ansi,
    SetLastError:=True,
    ExactSpelling:=True)>
Public Sub fooScalar(ByRef iArg As Integer, ByRef dArg As Double)
End Sub
```

```
Dim iArg As Integer = 5
Dim dArg As Double = 3.2
fooScalar(iArg, dArg)
```

ii. 1-dimensional integer and real arrays (note that only the reference to the first item of each array is passed to the API procedure):

```
<DllImport(cIDC2015_DLL,
    CallingConvention:=CallingConvention.StdCall,
    EntryPoint:="foo1DArray",
    CharSet:=CharSet.Ansi,
    SetLastError:=True,
    ExactSpelling:=True)>
Public Sub foo1DArray(ByRef iArrayDim As Integer,
    ByRef iArray As Integer, ByRef idArrayDim As Integer,
    ByRef dArray As Double)
End Sub

Dim iArrayDim As Integer = 10
Dim idArrayDim As Integer = 15
Dim iArray(iArrayDim - 1) As Integer
Dim dArray(idArrayDim - 1) As Double
foo1DArray(iArrayDim, iArray(0), idArrayDim, dArray(0))
```

iii. 2-dimensional integer and real arrays (note that only the reference to the first item of each array is passed to the API procedure. Additionally, since the 2-dimensional arrays below are defined in row-major order, the dimensions must be reversed for proper operation with the IDC API; i.e. a 10×5 array in Visual Basic is transposed and represented as a 5×10 array in IDC API):

```
<DllImport(cIDC2015_DLL,
    CallingConvention:=CallingConvention.StdCall,
    EntryPoint:="foo2DArray",
    CharSet:=CharSet.Ansi,
    SetLastError:=True,
    ExactSpelling:=True)>
Public Sub foo2DArray(ByRef iDim2 As Integer, ByRef iDim1 As Integer,
    ByRef i2DArray As Integer, ByRef idDim2 As Integer,
    ByRef idDim1 As Integer, ByRef d2DArray As Double)
End Sub

Dim iDim1 As Integer = 5
Dim iDim2 As Integer = 10
Dim idDim1 As Integer = iDim1
Dim idDim2 As Integer = iDim2
Dim i2DArray(iDim2 - 1, iDim1 - 1) As Integer
Dim d2DArray(idDim2 - 1, idDim1 - 1) As Double
foo2DArray(iDim1, iDim2, i2DArray(0, 0), idDim1, idDim2, d2DArray(0, 0))
```

iv. String scalar passed to API procedure (note that when a `StringBuilder` argument that is already assigned a value is passed to an API procedure, the `Length` property is used to obtain its length in characters):

```
<DllImport(cIDC2015_DLL,
    CallingConvention:=CallingConvention.StdCall,
    EntryPoint:="fooStrPassed",
    CharSet:=CharSet.Ansi,
    SetLastError:=True,
    ExactSpelling=True)>
Public Sub fooStrPassed(ByRef iLen As Integer, sString As StringBuilder)
End Sub

Dim sString As New StringBuilder("This is a test!")
Dim iLen As Integer = sString.Length
fooStrPassed(iLen, sString)
```

v. String scalar received from the API procedure (note that when a string argument is received from the API procedure, a `StringBuilder` variable with a long enough capacity is created and the `Capacity` property is used to define its length in characters):

```
<DllImport(cIDC2015_DLL,
    CallingConvention:=CallingConvention.StdCall,
    EntryPoint:="fooStrReceived",
    CharSet:=CharSet.Ansi,
    SetLastError:=True,
    ExactSpelling:=True)>
Public Sub fooStrReceived(ByRef iLen As Integer, sString As StringBuilder)
End Sub

Dim sString As New StringBuilder(50)
Dim iLen As Integer = sString.Capacity
fooStrReceived(iLen, sString)
```

11.2.5. Visual Basic for Applications (VBA)

IDC API procedures are accessed from VBA using the `Declare` statement. An example declaration of an IDC API procedure to be called from VBA code is as follows:

```
Public Declare PtrSafe Sub fooScalar Lib "D:\IDC\Bin\IDC2015_x64.dll" _
    (ByRef iArg As Long, ByRef dArg As Double)
```

i. Scalar integer and real numbers:

```
Public Declare PtrSafe Sub fooScalar Lib "D:\IDC\Bin\IDC2015_x64.dll" _
    (ByRef iArg As Long, ByRef dArg As Double)
```

```
Dim iArg As Long
Dim dArg As Double
iArg = 5
dArg = 3.2
Call fooScalar(iArg, dArg)
```

ii. 1-dimensional integer and real arrays (note that only the reference to the first item of each array is passed to the API procedure):

```
Public Declare PtrSafe Sub foo1DArray Lib "D:\IDC\Bin\IDC2015_x64.dll" _
    (ByRef iArrayDim As Long, ByRef iArray As Long, _
     ByRef idArrayDim As Long, ByRef dArray As Double)

Dim iArrayDim As Long
Dim idArrayDim As Long
Dim iArray() As Long
Dim dArray() As Double
iArrayDim = 10
idArrayDim = 15
ReDim iArray(iArrayDim - 1)
ReDim dArray(idArrayDim - 1)
Call foo1DArray(iArrayDim, iArray(0), idArrayDim, dArray(0))
```

iii. 2-dimensional integer and real arrays (note that only the reference to the first item of each array is passed to the API procedure):

```
Public Declare PtrSafe Sub foo2DArray Lib "D:\IDC\Bin\IDC2015_x64.dll" _
    (ByRef iDim2 As Long, ByRef iDim1 As Long, ByRef i2DArray As Long, _
     ByRef idDim2 As Long, ByRef idDim1 As Long, _
     ByRef d2DArray As Double)

Dim iDim1 As Long
Dim iDim2 As Long
Dim idDim1 As Long
Dim idDim2 As Long
Dim i2DArray() As Long
Dim d2DArray() As Double
iDim1 = 5
iDim2 = 10
idDim1 = iDim1
idDim2 = iDim2
ReDim i2DArray(iDim1 - 1, iDim2 - 1)
ReDim d2DArray(idDim1 - 1, idDim2 - 1)
Call foo2DArray(iDim1, iDim2, i2DArray(0, 0), idDim1, _
                idDim2, d2DArray(0, 0))
```

iv. String scalar passed to API procedure:

```
Public Declare PtrSafe Sub fooStrPassed Lib "D:\IDC\Bin\IDC2015_x64.dll" _
    (ByRef iLen As Long, ByVal sString As String)
```

```
Dim sString As String
Dim iLen As Long
sString = "This is a test!"
iLen = Len(sString)
Call fooStrPassed(iLen, sString)
```

v. String scalar received from the API procedure (note that when a string argument is received from the API procedure, a `String` variable with a long enough capacity is created):

```
Public Declare PtrSafe Sub fooStrReceived Lib "D:\IDC\Bin\IDC2015_x64.dll" _
    (ByRef iLen As Long, ByVal sString As String)

Dim sString As String
Dim iLen As Long
iLen = 50
sString = String(iLen, " ")
Call fooStrReceived(iLen, sString)
```

11.3. Pseudocode to Link a Model to IDC

For IDC to execute properly when linked to other models, it is necessary to invoke the procedures in the IDC API in a specific order. Below is a pseudocode describing the steps to instantiate, run and interact with an IDC model from a generic integrated hydrologic model (IHM) that simulates groundwater, lakes and stream flows. It is assumed that IDC and IHM are linked using an iterative approach until the flows between the two models converge within a given timestep. Although not mentioned in the following pseudocode, it is recommended that the error code returned with each IDC API procedure call is checked and, if the call was unsuccessful, `IDC_GetLastMessage` procedure is called to retrieve the error message.

i) Specify a text log file that IDC will use to print out messages during model execution (call `IDC_SetLogFile` procedure)

ii) Retrieve codes IDC uses to describe different model features (e.g. stream nodes, lakes, outside model domain, etc.) to be used in distributing IDC-computed land surface flows within the linked model domain (call `IDC_GetFlowDestTypeIDs` procedure)

iii) Retrieve codes IDC uses to describe different water supplies (i.e. groundwater pumping and stream diversions) to be used in meeting the computed water demands (call IDC_GetSupplyTypeIDs procedure)

iv) Initialize the IDC model by providing the filename for the IDC Main Input File (call IDC_New procedure)

v) Retrieve destination types and destination indices for land surface flows generated at each grid cell (call IDC_GetSurfaceFlowDestinations procedure)

vi) If needed, adjust the simulation timestep of the IDC model so that it is consistent with the simulation timestep of the calling model (call IDC_SetTimeStep procedure)

vii) Retrieve the number of demand calculation locations (call procedure IDC_GetNDemandLocations) and allocate memory for arrays that will hold agricultural and urban water demand calculated by IDC

viii) Turn the simulation of root water uptake from groundwater on or off (call IDC_SetSimulateGWUptake procedure); note that this procedure will overwrite the setting defined in the IDC model input parameters

ix) If root water uptake from groundwater will be simulated, specify the aquifer specific yield parameters at each IDC model cell (call IDC_SetSpecificYields procedure); note that this procedure will overwrite any specific yield values that are already specified through the IDC model input data files

x) Advance IDC simulation time one timestep forward (call IDC_AdvanceTime procedure)

xi) Read timeseries input data (call IDC_ReadTSData procedure)

xii) If root water uptake from groundwater is simulated, calculate the depth-to-groundwater values at each IDC grid cell and pass them to the IDC model (call IDC_SetDepthToGW procedure); note that this procedure will overwrite any depth-to-groundwater values that are already specified through the IDC model input data files

xiii) Compute agricultural and urban water demand (call IDC_ComputeWaterDemand procedure)

xiv) Retrieve agricultural and urban water demands (call IDC_GetWaterDemand_Ag and IDC_GetWaterDemand_Urb procedures)

xv) Retrieve flows that will affect stream flows in IHM (call IDC_GetFlowsToStreams procedure), lakes (call IDC_GetFlowsToLakes procedure) and the groundwater system (call IDC_GetPercAll and IDC_GetElementGWUptake procedures)

xvi) In IHM, simulate groundwater, stream flows, lakes as well as groundwater pumping and stream diversions that will be used to meet the water demand in the IDC model

xvii) Specify agricultural and urban water supplies for the IDC model based on the simulated groundwater pumping and stream diversions (call IDC_ZeroSupply procedure first, then call IDC_SetSupply_Ag and IDC_SetSupply_Urb procedures as many times as needed)

xviii) Specify the actual riparian evapotranspiration that the stream flows were able to provide (call IDC_SetActualRiparianET_AtStrmNodes procedure)

xix) Simulate land surface and root zone flows (call IDC_Simulate procedure)

xx) Retrieve flows computed by IDC that will affect streams, lakes and groundwater; compare them to those obtained in step *xiv*; if they are close enough (based on a predefined convergence criteria) go to next step, otherwise go to step *xiv*

xxi) Print out IDC simulation results (call IDC_PrintResults procedure)

xxii) Check if the end of the simulation period reached (call IDC_IsEndOfSimulation procedure); if end of simulation period is not reached, advance state of the IDC model in time (call IDC_AdvanceState procedure) and go to step *x*

xxiii) Clear memory and close all IDC-related files (call IDC_Kill and IDC_CloseLogFile procedures)

11.4. Procedure Interfaces

11.4.1. IDC_New

Given the name of the Main Control Data File, this procedure instantiates an IDC model.

```
SUBROUTINE IDC_New(iLenFileName,cMainFileName,iStat)
   INTEGER(C_INT),INTENT(IN) :: iLenFileName
   CHARACTER(C_CHAR),INTENT(IN) :: cMainFileName(iLenFileName)
   INTEGER(C_INT),INTENT(OUT) :: iStat
END SUBROUTINE IDC_New
```

`iLenFileName` : Length of the name for the Main Control Data file.

`cMainFileName` : Name of the Main Control Data File

`iStat` : Error code; returns 0 if the procedure call was successful

11.4.2. IDC_Kill

This subroutine clears the memory associated with IDC and resets all IDC-related parameters.

```
SUBROUTINE IDC_Kill(iStat)
   INTEGER(C_INT),INTENT(OUT) :: iStat
END SUBROUTINE IDC_Kill
```

`iStat` : Error code; returns 0 if the procedure call was successful

11.4.3. IDC_GetSupplyTypeIDs

This procedure returns the codes that IDC uses to define water supply types, pumping or diversions.

```
SUBROUTINE IDC_GetSupplyTypeIDs(iSupplyType_Pump,iSupplyType_Div,iStat)
   INTEGER(C_INT),INTENT(OUT) :: iSupplyType_Pump,iSupplyType_Div,iStat
END SUBROUTINE IDC_GetSupplyTypeIDs
```

`iSupplyType_Pump` : Code that indicates that water supply is from groundwater pumping `iSupplyType_Div` : Code that indicates that water supply is from stream diversions

`iStat` : Error code; returns 0 if the procedure call was successful

11.4.4. IDC_GetFlowDestTypeIDs

This procedure retrieves all the codes that are used to indicate different types of model features as the destination of surface flows computed by IDC.

```
SUBROUTINE IDC_GetFlowDestTypeIDs(iFlowDestTypeID_Outside,            &
                     iFlowDestTypeID_StrmNode,                         &
                     iFlowDestTypeID_Element,iFlowDestTypeID_Lake,     &
                     iFlowDestTypeID_Subregion,iFlowDestTypeID_GWElement, &
                     iFlowDestTypeID_ElementSet,iStat)
   INTEGER(C_INT),INTENT(OUT) :: iFlowDestTypeID_StrmNode,     &
                                 iFlowDestTypeID_Element,      &
                                 iFlowDestTypeID_Lake,         &
                                 iFlowDestTypeID_Subregion,    &
                                 iFlowDestTypeID_GWElement,    &
                                 iFlowDestTypeID_ElementSet,   &
                                 iStat
END SUBROUTINE IDC_GetFlowDestTypeIDs
```

`iFlowDestTypeID_Outside` : Code that indicates outside the model domain as the destination of flow from a hydrologic feature

`iFlowDestTypeID_StrmNode` : Code that indicates a stream node as the destination of flow from a hydrologic feature

`iFlowDestTypeID_Element` : Code that indicates a grid cell as the destination of flow from a hydrologic feature

`iFlowDestTypeID_Lake` : Code that indicates a lake as the destination of flow from a hydrologic feature

`iFlowDestTypeID_Subregion` : Code that indicates a subregion as the destination of flow from a hydrologic feature

`iFlowDestTypeID_GWElement` : Code that indicates groundwater at a grid cell as the destination of flow from a hydrologic feature

`iFlowDestTypeID_ElementSet` : Code that indicates a group of grid cells as the destination of flow from a hydrologic feature

`iStat` : Error code; returns 0 if the procedure call was successful

11.4.5. IDC_GetCurrentDateAndTime

This procedure retrieves the date and time for which land surface and root zone flow processes are being simulated.

```
SUBROUTINE IDC_GetCurrentDateAndTime(iLen,cDateAndTime,iStat)
   INTEGER(C_INT),INTENT(IN) :: iLen
   CHARACTER(C_CHAR),INTENT(OUT) :: cDateAndTime(iLen)
   INTEGER(C_INT),INTENT(OUT) :: iStat
END SUBROUTINE IDC_GetCurrentDateAndTime
```

`iLen` : Character length of the simulation date and time; a value of 16 is appropriate

`cDateAndTime` : Date and time for which land surface and root zone flow processes are being simulated; the format is MM/DD/YYY_hh:mm

`iStat` : Error code; returns 0 if the procedure call was successful

11.4.6. IDC_GetNElements

This procedure returns the number of grid cells in the IDC model.

```
SUBROUTINE IDC_GetNElements(iNElements,iStat)
   INTEGER(C_INT),INTENT(OUT) :: iNElements,iStat
END SUBROUTINE IDC_GetNElements
```

`iNElements` : Number of grid cells in the IDC model

`iStat` : Error code; returns 0 if the procedure call was successful

11.4.7. IDC_GetElementIDs

This procedure returns the grid cell identification numbers in the IDC model.

```
SUBROUTINE IDC_GetElementIDs(iNElements,iElemIDs,iStat)
    INTEGER(C_INT),INTENT(IN) :: iNElements
    INTEGER(C_INT),INTENT(OUT) :: iElemIDs(iNElements),iStat
END SUBROUTINE IDC_GetNElements
```

`iNElements` : Number of grid cells in the IDC model; this value can be obtained by calling procedure `IDC_GetNElements` (see section 11.4.5)

`iElemIDs` : Array of grid cell identification numbers

`iStat` : Error code; returns 0 if the procedure call was successful

11.4.8. IDC_GetRatio_DestSupplyToRegionSupply_Ag

This procedure returns the ratio of the agricultural water demand at each demand location to the total agricultural water demand at the subregion that each demand location belongs to. These ratios can then be used to distribute subregional water supplies to specific demand locations within those subregions.

```
SUBROUTINE IDC_GetRatio_DestSupplyToRegionSupply_Ag(iNLocs,rRatio,iStat)
    INTEGER(C_INT),INTENT(IN) :: iNLocs
    REAL(C_DOUBLE),INTENT(OUT) :: rRatio(iNLocs)
    INTEGER(C_INT),INTENT(OUT) :: iStat
END SUBROUTINE IDC_GetRatio_DestSupplyToRegionSupply_Ag
```

`iNLocs` : Number of demand locations; this number can be obtained by calling `IDC_GetNDemandLocations` procedure (see section 11.4.15)

`rRatio` : Ratio of agricultural water demand at each demand location to the total agricultural water demand at the subregion that the demand location belongs to

`iStat` : Error code; returns 0 if the procedure call was successful

11.4.9. IDC_GetRatio_DestSupplyToRegionSupply_Urb

This procedure returns the ratio of the urban water demand at each demand location to the total urban water demand at the subregion that each demand location belongs to. These ratios can then be used to distribute subregional water supplies to specific demand locations within those subregions.

```
SUBROUTINE IDC_GetRatio_DestSupplyToRegionSupply_Urb(iNLocs,rRatio,iStat)
   INTEGER(C_INT),INTENT(IN) :: iNLocs
   REAL(C_DOUBLE),INTENT(OUT) :: rRatio(iNLocs)
   INTEGER(C_INT),INTENT(OUT) :: iStat
END SUBROUTINE IDC_GetRatio_DestSupplyToRegionSupply_Urb
```

`iNLocs`	:	Number of demand locations; this number can be obtained by calling `IDC_GetNDemandLocations` procedure (see section 11.4.15)
`rRatio`	:	Ratio of urban water demand at each demand location to the total urban water demand at the subregion that the demand location belongs to
`iStat`	:	Error code; returns 0 if the procedure call was successful

11.4.10. IDC_GetFlowsToStreams

This procedure returns the surface flows into each stream node in terms of return flows and rainfall runoff as well as the required outflow (actual amount is limited by the amount of actual flow in the stream) from each stream node due to riparian evapotranspiration at each stream node.

```
SUBROUTINE IDC_GetFlowsToStreams(iNStrmNodes,rRunoff,rReturnFlow, &
              rRipETReq,iStat)
   INTEGER(C_INT),INTENT(IN) :: iNStrmNodes
   REAL(C_DOUBLE),INTENT(OUT) :: rRunoff(iNStrmNodes),     &
                                 rReturnFlow(iNStrmNodes), &
                                 rRipETReq(iNStrmNodes)
   INTEGER(C_INT),INTENT(OUT) :: iStat
END SUBROUTINE IDC_GetFlowsToStreams
```

`iNStrmNodes`	:	Number of stream nodes simulated in the system
`rRunoff`	:	Rainfall runoff into each stream node as calculated by IDC
`rReturnFlow`	:	Sum of agricultural and urban return flow into each stream node as calculated by IDC

`rRipETReq` : Required outflow from each stream node to meet the riparian evapotranspirative demand

`iStat` : Error code; returns 0 if the procedure call was successful

11.4.11. IDC_GetFlowsToLakes

This procedure returns the surface flows into each lake in terms of return flows and rainfall runoff.

```
SUBROUTINE IDC_GetFlowsToLakes(iNLakes,rRunoff,rReturnFlow,iStat)
   INTEGER(C_INT),INTENT(IN) :: iNLakes
   REAL(C_DOUBLE),INTENT(OUT) :: rRunoff(iNLakes),     &
                                 rReturnFlow(iNLakes)
   INTEGER(C_INT),INTENT(OUT) :: iStat
END SUBROUTINE IDC_GetFlowsToLakes
```

`iNLakes` : Number of lakes simulated in the system

`rRunoff` : Rainfall runoff into each lake as calculated by IDC

`rReturnFlow` : Sum of agricultural and urban return flow into each lake as calculated by IDC

`iStat` : Error code; returns 0 if the procedure call was successful

11.4.12. IDC_GetPercElement

This procedure is used to retrieve percolation at a specific cell of the computational grid.

```
SUBROUTINE IDC_GetPercElement(iElem,rPerc,iStat)
   INTEGER(C_INT),INTENT(IN) :: iElem
   REAL(C_DOUBLE),INTENT(OUT) :: rPerc
   INTEGER(C_INT),INTENT(OUT) :: iStat
END SUBROUTINE IDC_GetPercElement
```

`iElem` : Index of the grid cell for which the percolation is retrieved; note that grid cell identification (ID) number defined in an IDC model can be different than the index within the array used by IDC to store grid cell information; procedure `IDC_GetElementIDs` (see section 11.4.7) can be used to retrieve

		the list of cell ID numbers and to convert a cell ID number to its corresponding index
`rPerc`	:	Percolation at grid cell iElem computed by IDC
`iStat`	:	Error code; returns 0 if the procedure call was successful

11.4.13. IDC_GetPercAll

This procedure is used to retrieve the percolation computed at all elements of the computational grid. These values can be used by the calling simulation model as the recharge to the groundwater.

```
SUBROUTINE IDC_GetPercAll(iNElements,rPerc,iStat)
   INTEGER(C_INT),INTENT(IN) :: iNElements
   REAL(C_DOUBLE),INTENT(OUT) :: rPerc(iNElements)
   INTEGER(C_INT),INTENT(OUT) :: iStat
END SUBROUTINE IDC_GetPercAll
```

`iNElements`	:	Number of cells in the computational grid; this value can be obtained by calling procedure `IDC_GetNElements` (see section 11.4.511.4.4)
`rPerc`	:	Percolation at every cell computed by IDC
`iStat`	:	Error code; returns 0 if the procedure call was successful

11.4.14. IDC_GetElementGWUptake

This procedure returns the actual amount of groundwater that is used to meet the plant evapotranspirative demand at each grid cell. These values can be used as sink terms in groundwater simulations.

```
SUBROUTINE IDC_GetElementGWUptake(iNElements,rGWUptake,iStat)
   INTEGER(C_INT),INTENT(IN) :: iNElements
   REAL(C_DOUBLE),INTENT(OUT) :: rGWUptake(iNElements)
   INTEGER(C_INT),INTENT(OUT) :: iStat
END SUBROUTINE IDC_GetElementUptake
```

`iNElements` : Number of cells in the computational grid; this value can be obtained by calling procedure `IDC_GetNElements` (see section 11.4.5)

`rGWUptake` : Actual amount of groundwater that is used to meet the plant evapotranspirative need at each cell

`iStat` : Error code; returns 0 if the procedure call was successful

11.4.15. IDC_GetNDemandLocations

This function returns the number of computational locations where demand is calculated. This procedure will currently return either the number of subregions or the number of finite element cells used in the model, depending on the Root Zone simulation component used.

```
SUBROUTINE IDC_GetNDemandLocations(iNLocs,iStat)
   INTEGER(C_INT),INTENT(OUT) :: iNLocs,iStat
END SUBROUTINE IDC_GetNDemandLocations
```

`iNLocs` : Number of locations (number of cells or subregions) where water demand is computed

`iStat` : Error code; returns 0 if the procedure call was successful

11.4.16. IDC_GetWaterDemand_Ag

This procedure retrieves the agricultural water demand at each demand location (grid cell or subregion, depending on the version of the Root Zone simulation component used). These demands can be used by the linking model to compute diversions and groundwater pumping.

```
SUBROUTINE IDC_GetWaterDemand_Ag(iNLocations,rDemand,iStat)
   INTEGER(C_INT),INTENT(IN) :: iNLocations
   REAL(C_DOUBLE),INTENT(OUT) :: rDemand(iNLocations)
   INTEGER(C_INT),INTENT(OUT) :: iStat
END SUBROUTINE IDC_GetWaterDemand_Ag
```

`iNLocations` : Number of water demand calculation locations; this value can be retreived by calling procedure `IDC_GetNDemandLocations` (see section 11.4.15)

`rDemand` : Agricultural water demand at each demand location computed by IDC

`iStat` : Error code; returns 0 if the procedure call was successful

11.4.17. IDC_GetWaterDemand_Urb

This procedure retrieves the urban water demand at each demand location (grid cell or subregion, depending on the version of the Root Zone simulation component used). These demands can be used by the linking model to compute diversions and groundwater pumping.

```
SUBROUTINE IDC_GetWaterDemand_Urb(iNLocations,rDemand,iStat)
   INTEGER(C_INT),INTENT(IN) :: iNLocations
   REAL(C_DOUBLE),INTENT(OUT) :: rDemand(iNLocations)
   INTEGER(C_INT),INTENT(OUT) :: iStat
END SUBROUTINE IDC_GetWaterDemand_Urb
```

`iNLocations` : Number of water demand calculation locations; this value can be retreived by calling procedure `IDC_GetNDemandLocations` (see section 11.4.15)

`rDemand` : Urban water demand at each demand location computed by IDC

`iStat` : Error code; returns 0 if the procedure call was successful

11.4.18. IDC_GetElementAreas_Ag

This procedure retrieves the agricultural areas at each grid cell.

```
SUBROUTINE IDC_GetElementAreas_Ag(iNElements,rAreas,iStat)
   INTEGER(C_INT),INTENT(IN) :: iNElements
   REAL(C_DOUBLE),INTENT(OUT) :: rAreas(iNElements)
   INTEGER(C_INT),INTENT(OUT) :: iStat
END SUBROUTINE IDC_GetElementAreas_Ag
```

`iNElements` : Number of cells in the computational grid; this value can be obtained by calling procedure `IDC_GetNElements` (see section 11.4.5)

`rAreas` : Agricultural areas at each grid cell

`iStat` : Error code; returns 0 if the procedure call was successful

11.4.19. IDC_GetElementAreas_Urb

This procedure retreives the urban areas at each grid cell.

```
SUBROUTINE IDC_GetElementAreas_Urb(iNElements,rAreas,iStat)
    INTEGER(C_INT),INTENT(IN) :: iNElements
    REAL(C_DOUBLE),INTENT(OUT) :: rAreas(iNElements)
    INTEGER(C_INT),INTENT(OUT) :: iStat
END SUBROUTINE IDC_GetElementAreas_Urb
```

`iNElements` : Number of cells in the computational grid; this value can be obtained by calling procedure `IDC_GetNElements` (see section 11.4.5)

`rAreas` : Urban areas at each grid cell

`iStat` : Error code; returns 0 if the procedure call was successful

11.4.20. IDC_GetSurfaceFlowDestinations

This procedure returns the destination type IDs and the indices for the destination of surface flows generated at each grid cell.

```
SUBROUTINE IDC_GetSurfaceFlowDestinations(iNElements,iDestTypes,iDest,iStat)
    INTEGER(C_INT),INTENT(IN) :: iNElements
    INTEGER(C_INT),INTENT(OUT) :: iDestTypes(iNElements),  &
                                  iDest(iNElements),iStat
END SUBROUTINE IDC_GetSurfaceFlowDestinations
```

`iNElements` : Number of cells in the computational grid; this value can be obtained by calling procedure `IDC_GetNElements` (see section 11.4.5) `iDestTypes` : Codes for the surface flow destinations for each grid cell; codes used by iDC to identify different flow destination types can be obtained by calling `IDC_GetFlowDestTypeIDs` (see section 11.4.4)

`iDest` : Indices for surface flow destinations for each grid cell

`iStat` : Error code; returns 0 if the procedure call was successful

11.4.21. IDC_GetLastMessage

This procedure is used to retrieve the error message in case a procedure call from IDC API returns an error code (`iStat`) other than 0.

```
SUBROUTINE IDC_GetLastMessage(iLen,cErrorMessage,iStat)
   INTEGER(C_INT),INTENT(IN) :: iLen
   CHARACTER(C_CHAR),INTENT(INOUT) :: cErrorMessage(iLen)
   INTEGER(C_INT),INTENT(OUT) :: iStat
END SUBROUTINE IDC_GetLastMessage
```

`iLen` : Character length of the error message; a value of 500 is appropriate

`cErrorMessage` : Error message that is generated by the IDC API procedure that was unsuccessfully called last

`iStat` : Error code; returns 0 if the procedure call was successful

11.4.22. IDC_GetVersion

This subroutine returns the version number of IDC as well as the version numbers all components it is linked to.

```
SUBROUTINE IDC_GetVersion(iLenVersion,cVersion,iStat)
   INTEGER(C_INT),INTENT(IN) :: iLenVersion
   CHARACTER(C_CHAR),INTENT(OUT) :: cVersion(iLenVersion)
   INTEGER(C_INT),INTENT(OUT) :: iStat
END SUBROUTINE IDC_GetVersion
```

`iLenVersion` : Maximum length of the version number in terms of characters; a value of 1000 is recomended `cVersion` : Version number of IDC and all of its components

`iStat` : Error code; returns 0 if the procedure call was successful

11.4.23. IDC_GetActiveRootZoneVersion

This function returns the version number of the active root zone component that is being used in the simulation as an integer (e.g. it returns 40 if root zone component version 4.0 is being used).

```
SUBROUTINE IDC_GetActiveRootZoneVersion(iVersion,iStat)
   INTEGER(C_INT),INTENT(OUT) :: iVersion,iStat
END SUBROUTINE IDC_GetActiveRootZoneVersion
```

`iVersion` : Version number of the active root zone component being used for the simulation

`iStat` : Error code; returns 0 if the procedure call was successful

11.4.24. IDC_SetTimeStep

This subroutine sets the timestep to be used in IDC model and adjusts the time units initially defined for IDC parameters. It can be used when IDC is linked to another model and that model's simulation timestep is different than that of IDC's, which was initially defined in the Main Control Data File. This procedure must be called right after the IDC model is initiated with the `IDC_New` (see section 11.4.1) procedure.

```
SUBROUTINE IDC_SetTimeStep(iLenNewUnit,cNewUnit,iStat)
   INTEGER(C_INT),INTENT(IN) :: iLenNewUnit
   CHARACTER(C_CHAR),INTENT(IN) :: cNewUnit(iLenNewUnit)
   INTEGER(C_INT),INTENT(OUT) :: iStat
END SUBROUTINE IDC_SetTimeStep
```

`iLenNewUnit` : Character length of the simulation timestep; for instance, if simulation timestep is '`1DAY`', then `iLenNewUnit` is 4 (i.e. number of characters in '`1DAY`')

`cNewUnit` : Simulation timestep; allowbale timesteps are

i. "1MIN"

ii. “2MIN”

iii. “3MIN”

iv. “4MIN”

v. “5MIN”

vi. “10MIN”

vii. “15MIN”

viii. “20MIN”

ix. “30MIN”

x. “1HOUR”

xi. “2HOUR”

xii. “3HOUR”

xiii. “4HOUR”

xiv. “6HOUR”

xv. “8HOUR”

xvi. “12HOUR”

xvii. “1DAY”

xviii. “1WEEK”

xix. “1MON”

xx. “1YEAR”

`iStat` : Error code; returns 0 if the procedure call was successful

11.4.25. IDC_SetSimulateGWUptake

This procedure informs the IDC model if groundwater uptake in meeting part or all of the water demand will be simulated or not. If groundwater uptake will be simulated, either the relevant input data (aquifer specific yield, depth-to-groundwater timeseries data, etc.) must be provided as part of the IDC model or must be supplied to the IDC model via relevant procedure calls.

```
SUBROUTINE IDC_SetSimulateGWUptake(iSimGWUptake,iStat)
   INTEGER(C_INT),INTENT(IN) :: iSimGWUptake
   INTEGER(C_INT),INTENT(OUT) :: iStat
END SUBROUTINE IDC_SetSimulateGWUptake
```

`iSimGWUptake`	:	Flag to specify if groundwater uptake will be simulated; 0 = groundwater uptake will not be simulated, 1= groundwater uptake will be simulated
`iStat`	:	Error code; returns 0 if the procedure call was successful

11.4.26. IDC_SetSpecificYields

This procedure sets the value of aquifer specific yield at each model cell to be used in simulating the groundwater uptake. If these values are already supplied through the Depth-to-Groundwater input data file of the IDC model, they will be overwritten by the values provided with this procedure. Note that simulation of groundwater uptake is optional, so this procedure needs to be called only when groundwater uptake is simulated.

```
SUBROUTINE IDC_SetSpecificYields(iNElements,rSys,iStat)
   INTEGER(C_INT),INTENT(IN) :: iNElements
   REAL(C_DOUBLE),INTENT(IN) :: rSys(iNElements)
   INTEGER(C_INT),INTENT(OUT) :: iStat
END SUBROUTINE IDC_SetSimulateGWUptake
```

`iNElements`	:	Number of grid cells in the IDC model; this value can be obtained by calling procedure `IDC_GetNElements` (see section 11.4.5)
`rSys`	:	Specific yield values at each model cell; these values will overwrite those that are specified, if at all, through the Depth-to-Groundwater input data file
`iStat`	:	Error code; returns 0 if the procedure call was successful

11.4.27. IDC_SetDepthToGW

This procedure sets the value of depth-to-groundwater-table at each model cell to be used in simulating the groundwater uptake. If these values are already supplied through the Depth-to-Groundwater input data file of the IDC model, they will be overwritten by the values provided with this procedure. Note that simulation of groundwater uptake is optional, so this procedure needs to be called only when groundwater uptake is simulated.

```
SUBROUTINE IDC_SetDepthToGW(iNElements,rDepthToGW,iStat)
    INTEGER(C_INT),INTENT(IN) :: iNElements
    REAL(C_DOUBLE),INTENT(IN) :: rDepthToGW(iNElements)
    INTEGER(C_INT),INTENT(OUT) :: iStat
END SUBROUTINE IDC_SetDepthToGW
```

`iNElements`	:	Number of grid cells in the IDC model; this value can be obtained by calling procedure `IDC_GetNElements` (see section 11.4.5)
`rDepthToGW`	:	Depth-to-groundwater-table at each model cell; these values will overwrite those that are specified, if at all, through the Depth-to-Groundwater input data file
`iStat`	:	Error code; returns 0 if the procedure call was successful

11.4.28. IDC_SetSupply_Ag

This procedure sets the agricultural water supply to each demand location (element or subregion, based on the version of the Root Zone simulation component used). The source of water supply can be either stream diversions or groundwater pumping. Water supply can be assigned to each element or to each subregion. If the supply is assigned to each subregion than IDC distributes the subregional water supply to individual elements in proportion to the agricultural water demand at each element in the subregion. This procedure can be called multiple times to represent a mixture of pumping and diversions to elements or subregions. When the procedure is called multiple times, IDC accumulates supplies to elements.

```
SUBROUTINE IDC_SetSupply_Ag(iNLocs,rSupply,iSupplyType,iStat)
    INTEGER(C_INT),INTENT(IN) :: iNLocs,iSupplyType
    REAL(C_DOUBLE),INTENT(IN) :: rSupply(iNLocs)
    INTEGER(C_INT),INTENT(OUT) :: iStat
END SUBROUTINE IDC_SetSupply_Ag
```

`iNLocs`	:	Number of demand calculation locations;this value can be obtained by calling procedure `IDC_GetNDemandLocations` (see section 11.4.15)

`rSupply` : Agricultural water supply to each element or subregion

`iSupplyType` : Supply type (pumping or diversions) identification number; supply identification numbers for diversions and pumping used by IDC can be obtained by calling procedure `IDC_GetSupplyTypeIDs` (see section 11.4.3)

`iStat` : Error code; returns 0 if the procedure call was successful

11.4.29. IDC_SetSupply_Urb

This procedure sets the urban water supply to each demand location (element or subregion, based on the version of the Root Zone simulation component used). The source of water supply can be either stream diversions or groundwater pumping. Water supply can be assigned to each element or to each subregion. If the supply is assigned to each subregion, then IDC distributes the subregional water supply to individual elements in proportion to the urban water demand at each element in the subregion. This procedure can be called multiple times to represent a mixture of pumping and diversions to elements or subregions. When the procedure is called multiple times, IDC accumulates supplies to elements.

```
SUBROUTINE IDC_SetSupply_Urb(iNLocs,rSupply,iSupplyType,iStat)
   INTEGER(C_INT),INTENT(IN) :: iNLocs,iSupplyType
   REAL(C_DOUBLE),INTENT(IN) :: rSupply(iNLocs)
   INTEGER(C_INT),INTENT(OUT) :: iStat
END SUBROUTINE IDC_SetSupply_Urb
```

`iNLocs` : Number of demand calculation locations;this value can be obtained by calling procedure `IDC_GetNDemandLocations` (see section 11.4.15)

`rSupply` : Urban water supply to each element or subregion

`iSupplyType` : Supply type (pumping or diversions) identification number; supply identification numbers for diversions and pumping used by IDC can be obtained by calling procedure `IDC_GetSupplyTypeIDs` (see section 11.4.3)

`iStat` : Error code; returns 0 if the procedure call was successful

11.4.30. IDC_SetActualRiparianET_AtStrmNodes

This procedure specifies the actual outflow from each stream node to meet riparian evapotranspirative demand after stream flows are simulated.

```
SUBROUTINE IDC_SetActualRiparianET_AtStrmNodes(iNStrmNodes,rRipETFrac,iStat)
   INTEGER(C_INT),INTENT(IN) :: iNStrmNodes
   REAL(C_DOUBLE),INTENT(IN) :: rRipETFrac(iNStrmNodes)
   INTEGER(C_INT),INTENT(OUT) :: iStat
END SUBROUTINE IDC_SetActualRiparianET_AtStrmNodes
```

`iNStrmNodes`	:	Number of stream nodes simulated in the system
`rRipETFrac`	:	Ratio of the actual riparian evapotranspiration from each stream node to the required riparian evapotranspiration
`iStat`	:	Error code; returns 0 if the procedure call was successful

11.4.31. IDC_SetLogFile

This procedure creates a text log file for IDC API to print out error and warning messages.

```
SUBROUTINE IDC_SetLogFile(iLen,cFileName,iStat)
   INTEGER(C_INT),INTENT(IN) :: iLen
   CHARACTER(C_CHAR),INTENT(IN) :: cFileName(iLen)
   INTEGER(C_INT),INTENT(OUT) :: iStat
END FUNCTION IDC_SetLogFile
```

`iLen`	:	Character length of the log filename
`cFileName`	:	Log filename
`iStat`	:	Error code; returns 0 if the procedure call was successful

11.4.32. IDC_CloseLogFile

This procedure closes the log file opened for IDC API to print out error and warning messages.

```
SUBROUTINE IDC_CloseLogFile(iStat)
   INTEGER(C_INT),INTENT(OUT) :: iStat
```

```
END SUBROUTINE IDC_CloseLogFile
```

iStat : Error code; returns 0 if the procedure call was successful

11.4.33. IDC_AdvanceTime

This procedure advances the time step for IDC and generates the new time stamp using the simulation time interval. The new time stamp is used to locate and read data from the time-series input data files and to decide if end of simulation period has been reached.

```
SUBROUTINE IDC_AdvanceTime(iStat)
   INTEGER(C_INT),INTENT(OUT) :: iStat
END SUBROUTINE IDC_AdvanceTime
```

iStat : Error code; returns 0 if the procedure call was successful

11.4.34. IDC_ReadTSData

This procedure reads data from time-series input files for the corresponding time step in the simulation.

```
SUBROUTINE IDC_ReadTSData(iStat)
   INTEGER(C_INT),INTENT(OUT) :: iStat
END SUBROUTINE IDC_ReadTSData
```

iStat : Error code; returns 0 if the procedure call was successful

11.4.35. IDC_ComputeWaterDemand

This procedure computes applied water demand for ponded and non-ponded agricultural crops as well as for urban areas. It also incorporates the effect of groundwater uptake, if simulated, on the water demand.

```
SUBROUTINE IDC_ComputeWaterDemand(iStat)
   INTEGER(C_INT),INTENT(OUT) :: iStat
END SUBROUTINE IDC_ComputeWaterDemand
```

iStat : Error code; returns 0 if the procedure call was successful

11.4.36. IDC_ZeroSupply

This procedure resets the water supply to each element to zero.

```
SUBROUTINE IDC_ZeroSupply(iStat)
    INTEGER(C_INT),INTENT(OUT) :: iStat
END SUBROUTINE IDC_ZeroSupply
```

`iStat` : Error code; returns 0 if the procedure call was successful

11.4.37. IDC_Simulate

This procedure simulates the root zone and land surface flow processes.

```
SUBROUTINE IDC_Simulate(iStat)
    INTEGER(C_INT),INTENT(OUT) :: iStat
END SUBROUTINE IDC_Simulate
```

`iStat` : Error code; returns 0 if the procedure call was successful

11.4.38. IDC_PrintResults

This procedure prints out the simulation results at the end of each timestep to the ouput files.

```
SUBROUTINE IDC_PrintResults(iStat)
    INTEGER(C_INT),INTENT(OUT) :: iStat
END SUBROUTINE IDC_PrintResults
```

`iStat` : Error code; returns 0 if the procedure call was successful

11.4.39. IDC_AdvanceState

This procedure advances the state of the root zone in time. The flow rates that are computed at the end of the time step are labeled as flow rates at the beginning of the next time step.

```
SUBROUTINE IDC_AdvanceState(iStat)
    INTEGER(C_INT),INTENT(OUT) :: iStat
END SUBROUTINE IDC_AdvanceState
```

`iStat` : Error code; returns 0 if the procedure call was successful

11.4.40. IDC_IsEndOfSimulation

This procedure checks if the end of simulation period has been reached.

```
SUBROUTINE IDC_IsEndOfSimulation(iEndOfSimulation,iStat)
   INTEGER(C_INT),INTENT(OUT) :: iEndOfSimulation,iStat
END SUBROUTINE IDC_IsEndOfSimulation
```

`iEndOfSimulation` : 1 if end of simulation period has been reached; 0 otherwise

`iStat` : Error code; returns 0 if the procedure call was successful

11.4.41. IDC_IsLandUseUpdated

This procedure checks if the land-use areas have already been read from the input data file and updated.

```
SUBROUTINE IDC_IsLandUseUpdated(iUpdated,iStat)
   INTEGER(C_INT),INTENT(OUT) :: iUpdated,iStat
END SUBROUTINE IDC_IsLandUseUpdated
```

`iUpdated` : 1 if the land-use areas are already updated; 0 if they are not yet updated

`iStat` : Error code; returns 0 if the procedure call was successful

11.4.42. IDC_IsRootZoneDefined

This function checks if the root zone component has been instantiated.

```
SUBROUTINE IDC_IsRootZoneDefined(iDefined,iStat)
   INTEGER(C_INT),INTENT(OUT) :: iDefined,iStat
END SUBROUTINE IDC_IsRootZoneDefined
```

`iDefined` : Flag to check if the root zone has been instantiated; a value of 0 means it has not been instantiated and a value of 1 means it has been instantiated

`iStat` : Error code; returns 0 if the procedure call was successful

11.4.43. fooScalar

This procedure can be used to test the calling mechanisms used by a client software in passing or retrieving scalar integer and real numbers to and from the IDC API.

```
SUBROUTINE fooScalar(iArg,dArg)
   INTEGER(C_INT),INTENT(INOUT) :: iArg
   REAL(C_DOUBLE),INTENT(INOUT) :: dArg
END SUBROUTINE fooScalar
```

`iArg` : Integer argument; if calling of this procedure from a client software is successful, `iArg` will be modified by multiplying its original value by 2 (i.e. if passed `iArg` = 2, retrieved `iArg` = 4)

`dArg` : Real argument; if calling of this procedure from a client software is successful, `dArg` will be modified by multiplying its original value by 2 (i.e. if passed `dArg` = 2.0, retrieved `dArg` = 4.0)

11.4.44. foo1DArray

This procedure can be used to test the calling mechanisms used by a client software in passing or retrieving one-dimensional integer and real arrays to and from the IDC API.

```
SUBROUTINE foo1DArray(iArrayDim,iArray,idArrayDim,dArray)
   INTEGER(C_INT),INTENT(IN) :: iArrayDim,idArrayDim
   INTEGER(C_INT),INTENT(INOUT) :: iArray(iArrayDim)
   REAL(C_DOUBLE),INTENT(INOUT) :: dArray(idArrayDim)
END SUBROUTINE foo1DArray
```

`iArrayDim` : Dimension of the integer array, `iArray`

`iArray` : Integer array; if calling of this procedure from a client software is successful, all components of the integer array will have a value of 5 `dArrayDim` : Dimension of the real array, `dArray`

`dArray` : Real array; if calling of this procedure from a client software is successful, all components of the real array will have a value of 3.2

11.4.45. foo2DArray

This procedure can be used to test the calling mechanisms used by a client software in passing or retrieving two-dimensional integer and real arrays to and from the IDC API. When calling this procedure, care must be taken if the client software uses row-major ordering of multi-dimensional arrays (Fortran uses column-major ordering).

```
SUBROUTINE foo2DArray(iDim1,iDim2,iArray,idDim1,idDim2,dArray)
    INTEGER(C_INT),INTENT(IN) :: iDim1,iDim2,idDim1,idDim2
    INTEGER(C_INT),INTENT(INOUT) :: iArray(iDim1,iDim2)
    REAL(C_DOUBLE),INTENT(INOUT) :: dArray(idDim1,idDim2)
END SUBROUTINE foo2DArray
```

`iDim1` : Number of rows of the integer array, `iArray`; i.e. the size of its first dimension

`iDim2` : Number of columns of the integer array, `iArray`; i.e. the size of its second dimension

`iArray` : Integer array; if calling of this procedure from a client software is successful, all columns will have the associated row number (e.g. all columns in the first row will have the value 1, all columns in the second row will have the value 2, etc.)

`idDim1` : Number of rows of the real array, `dArray`; i.e. the size of its first dimension

`idDim2` : Number of columns of the real array, `dArray`; i.e. the size of its second dimension

`dArray` : Real array; if calling of this procedure from a client software is successful, all columns will have the associated row number (e.g. all columns in the first row will have the value 1.0, all columns in the second row will have the value 2.0, etc.)

11.4.46. fooStrPassed

This procedure can be used to test the calling mechanisms used by a client software in passing a string variable to the IDC API. The API does not modify the value of this variable.

```
SUBROUTINE fooStrPassed(iLen,cStrPassed)
   INTEGER(C_INT),INTENT(IN) :: iLen
   INTEGER(C_CHAR),INTENT(IN) :: cStrPassed(iLen)
END SUBROUTINE fooStrPassed
```

`iLen` : Character length of the passed string variable, `cStrPassed`

`cStrPassed` : String variable with a character length of `iLen` that is passed to the API; if calling of this procedure from a client software is successful, the API creates a new text file with the name *IW_API_Test.txt* and prints the value of `cStrPassed` to this file

11.4.47. fooStrReceived

This procedure can be used to test the calling mechanisms used by a client software in retrieving a string variable to the IDC API.

```
SUBROUTINE fooStrReceived(iLen,cStrRecvd)
   INTEGER(C_INT),INTENT(IN) :: iLen
   INTEGER(C_CHAR),INTENT(OUT) :: cStrRecvd(iLen)
END SUBROUTINE fooStrReceived
```

`iLen` : Character length of the string variable, `cStrRecvd`; its value should be 21 or more

`cStrRecvd` : String variable with a character length of `iLen` that is returned to the client software; if calling of this procedure from a client software is successful, this variable will return with a value `'This is another test!'`

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APPENDIX E

GROUNDWATER STORAGE TECHNICAL MEMORANDUM

14 October 2021

TECHNICAL MEMORANDUM

To: Tom Rooze, PG, Zone 7 Water Agency (Zone 7)
Ken Minn, PE, Zone 7
Colleen Winey, PG, Zone 7
Carol Mahoney, PG, Zone 7

From: Anona Dutton, PG, CHg, EKI Environment & Water, Inc. (EKI)
Aaron Lewis, EIT, EKI
Nigel Chen, PhD, EKI

Subject: **Evaluation of Groundwater Storage Depletion Under Water Level Sustainability Criteria** (EKI C00065.00)

EKI Environment & Water, Inc. (EKI) is pleased to provide to Zone 7 Water Agency (Zone 7) with this technical memorandum (TM) presenting: (1) estimates of the total, baseline, and recent (Fall 2015 – Fall 2020) usable groundwater storage in the Livermore Valley Groundwater Basin (Basin); and (2) an evaluation of the protectiveness of Zone 7's proposed Sustainable Management Criteria (SMCs) for the Chronic Lowering of Groundwater Levels Sustainability Indicator (SI) and for use as a proxy for the Reduction of Groundwater Storage SI. The sole purpose of the estimates and evaluation is to verify the effectiveness of use of the groundwater level as the proxy for these SMCs. It should be noted that considering the generalization and included assumptions, these calculated values are meant for relative comparison but not to be considered as absolute values. The most accurate storage values should be calculated using a properly calibrated numerical groundwater flow model.

BACKGROUND AND METHODOLOGY

Pursuant to Title 23, Section 358.2(a) of the California Code of Regulations (23-CCR §358.2(a)), Groundwater Sustainability Agencies (GSAs) with an approved Alternative Groundwater Sustainability Plan (Alt GSP or Plan) must resubmit an updated Plan to the California Department of Water Resources (DWR) every five years. As part of the five-year update process to the 2016 Alt GSP, Zone 7 contracted with EKI to evaluate and develop SMCs for the Reduction of Groundwater Storage SI.

Pursuant to the GSP Emergency Regulations (23 CCR § 354.28(d)) and as further described in the DWR Sustainable Management Criteria Best Management Practices #6[1], Minimum Thresholds (MTs) for the Reduction of Groundwater Storage SI may be set using groundwater levels as a proxy if it is demonstrated

[1] DWR 2017, Sustainable Management Criteria Best Management Practices, dated November 2017, 38 pp.

that a correlation exists between the two metrics and if the MTs for Chronic Lowering of Groundwater Levels are sufficiently protective to ensure prevention of significant and unreasonable occurrences.

To demonstrate that the updated MTs for Chronic Lowering of Groundwater Levels developed by Zone 7 as part of the 2022 Alt GSP are sufficiently protective, a calculation was performed to estimate the volume of groundwater that would be removed from storage in the Principal Aquifer units if groundwater levels were to decline from SGMA Baseline (i.e., Fall 2015) levels to their respective MTs for Chronic Lowering of Groundwater Levels. This volume is then compared to the volume of Total Usable Storage within applicable Management Areas of the Basin, which is defined as the available groundwater storage calculated at historic high water level conditions.[2] Based on the analysis presented herein, the Total Usable Storage in the Basin will not be significantly impacted, even at the MTs, indicating that the MTs for Chronic Lowering of Groundwater Levels are protective for the Reduction of Groundwater Storage SI.

EVALUATION OF TOTAL USABLE GROUNDWATER STORAGE

As described in EKI's TM entitled *Progress Update on Extending Existing Hydrogeologic Framework* (dated 02 April 2021), EKI developed a three-dimensional (3D) representation of the Principal Aquifer units within the Basin using the Rockworks[3] geologic software program. The Principal Aquifer units within the Basin are described in detail in EKI's TM entitled *Geologic Cross-Sections for 2022 Alternative Groundwater Sustainability Plan* (dated 07 June 2021). As described in that TM, the Rockworks model extends to the base of the "usable" aquifer system (i.e., where the deepest wells in the Basin are constructed within the Upper Livermore Formation).

As part of the current effort, EKI extracted a series of rasters delineating the top and bottom elevations of each Principal Aquifer unit mapped in the Rockworks model. The base of each Principal Aquifer unit was compared to surfaces of historic high groundwater elevations previously created by Zone 7 staff to define the maximum saturated aquifer thicknesses historically encountered within the Basin. These saturated aquifer thicknesses were then multiplied by spatially variable storage coefficients previously developed by Zone 7 staff (for the Main Basin)[4] or otherwise estimated based on best available information (for the Fringe Management Area)[5] to support calculations of "Total Usable Storage" volumes within each Management Area of the Basin. Here the Total Usable Storage is defined as the available groundwater storage at historic high water level conditions observed within the Basin. This calculation is shown in the equation below:

$$Total\_Usable\_Storage_{i,j} = \sum_{k=1}^{n} Sat\_Aq\_thickness_{Historic\ High_{i,j,k}} * A_k * S_k$$

---

[2] The Basin is divided into three Management Areas (Main, Fringe, and Upland). The Upland Management area is not considered in this analysis as there are insufficient monitoring wells and groundwater elevation data available to inform comparisons of water level surfaces over time.

[3] RockWorks 2020 Standard Level License from RockWare is downloaded and installed on 15 October 2020: https://www.rockware.com/product/rockworks/

[4] Storage coefficients were provided by Zone 7 at a node level based on the nodes included in DWR's Bulletin 118 groundwater model of the Basin (DWR 1974).

[5] Given the uncertainty in aquifer properties in the Fringe Management Areas, both upper and lower bound storage coefficients were used to present a reasonable range in available groundwater storage.

where:

$Total\_Usable\_Storage_{i,j}$ is the Total Usable Storage (in acre-feet [AF]) for aquifer unit "i" in Management Area "j" based on historic high water level conditions

$Sat\_Aq\_thickness_{Historic\ High_{i,j,k}} = GWE_{Historic\ High_{i,j,k}} - Aq\_bottom_{i,j,k}$

$GWE_{Historic\ High_{i,j,k}}$ is the historic high groundwater elevation in aquifer unit "i" and Management Area "j" at node "k"

$Aq\_bottom_{i,j,k}$ the bottom elevation of aquifer unit "i" in Management Area "j" at node "k"

A_k is the area (acres) of node "k", and

S_k is the storage coefficient (dimensionless) at node "k"

A summary of the Total Usable Storage estimates (in units of thousand acre-feet [TAF]) for each Principal Aquifer unit and applicable Management Area is presented in **Table 1** below. Here the Upper Livermore Formation portion of the Lower Aquifer Principal Aquifer unit is presented distinctly (herein referred to as the "Livermore Aquifer") in order to maintain consistency with the delineation of the Lower Aquifer in the Zone 7's existing storage estimation method (i.e., the "Nodal method", see **Attachments A and B**).

Table 1. Total Usable Groundwater Storage Estimates

Management Area	Principal Aquifer Unit	Total Usable Storage (TAF)
Main Basin	Upper Aquifer[6]	94 - 157 TAF
	Lower Aquifer[7]	102 - 127 TAF
	Livermore Aquifer[8,9]	87 – 174 TAF
North Fringe	Fringe Aquifer[9]	75 – 134 TAF
Northeast Fringe	Fringe Aquifer[9]	24 – 47 TAF
East Fringe	Fringe Aquifer[9]	0.3 – 0.6 TAF
TOTAL		382 – 640 TAF

The raster-based groundwater storage estimation method described above is subject to certain limitations, including: (1) uncertainty in Principal Aquifer unit extents and thicknesses; (2) uncertainty in aquifer storage properties (i.e., specific yield and storativity) and their spatial variability within each Principal Aquifer unit; and (3) lack of ability to calculate groundwater storage reserves in recharge ponds (e.g., the Chain of Lakes mining pits). As such, the estimated groundwater storage volumes are presented as a range that reflects: (1) in the Main Basin, the lower and upper bound estimates of groundwater storage calculated from the Rockworks surfaces versus Zone 7's Nodal method; or (2) in the Fringe

[6] The upper end of the range is based on the Nodal method that has historically been used by Zone 7 to estimate basin storage, see **Attachment A** and **Attachment B.**

[7] The lower end of the range is based on the Nodal method that has historically been used by Zone 7 to estimate basin storage, see **Attachment A** and **Attachment B**.

[8] The range reflects a variability in the specific yield storage coefficient of 0.025 – 0.05.

[9] Here the Upper Livermore Formation portion of the Lower Aquifer unit is presented distinctly (i.e., "Livermore Aquifer") in order to maintain consistency with the delineation of the Lower Aquifer in the Nodal method.

Management Areas, the lower and upper bounds of uncertainty in storage coefficients based on the best available information regarding aquifer lithologies and grain size distributions and applicable methodologies. The resultant volumes are intended to provide a relative comparison of available groundwater storage at different water level conditions and do not represent absolute values. A comparison of this method to other methods historically applied by Zone 7 (i.e., the Nodal method and the Hydrologic Inventory method) is provided as **Attachment A**. The full dataset of historical groundwater storage volumes calculated from Zone 7's Nodal method is provided as **Attachment B**.

EVALUATION OF "SGMA BASELINE" GROUNDWATER STORAGE

As specified in California Water Code (CWC) Section 10727.2(b)(4) a GSP or Alt GSP "may, but is not required to, address undesirable results that occurred before, and have not been corrected by, January 1, 2015". As such, groundwater conditions in 2015 may serve as an effective "SGMA Baseline" to evaluate any further reductions in groundwater storage that would occur at the MTs and MOs defined for Chronic Lowering of Groundwater Levels.

The Rockworks rasters of the top and bottom elevations of the Principal Aquifer units were subsequently compared to Fall 2015 water level surfaces provided by Zone 7 to estimate the "SGMA Baseline" groundwater storage within each Principal Aquifer unit and Management Area. The calculation of SGMA Baseline Storage uses the same equation provided above for Total Usable Storage, except now the saturated aquifer thickness is informed by the Fall 2015 groundwater elevation surfaces as opposed to the historic high surfaces:

$$Current\_Storage_{i,j} = \sum_{k=1}^{n} Sat\_Aq\_thickness_{SGMA\ Baseline_{i,j,k}} * A_k * S_k$$

where:

$$Sat\_Aq\_thickness_{SGMA\ Baseline_{i,j,k}} = GWE_{Fall\ 2015_{i,j,k}} - Aq\_bottom_{i,j,k}$$

A summary of the SGMA Baseline Storage estimates for each Principal Aquifer unit and Management Area is presented in **Table 2** below. Also provided is an estimate of the percentage of storage available in each Principal Aquifer unit at the SGMA Baseline relative to the Total Usable Storage volumes provided in **Table 1**.

Table 2. "SGMA Baseline" (Fall 2015) Available Groundwater Storage Estimates

Management Area	Principal Aquifer Unit	SGMA Baseline Groundwater Storage (TAF)	Percentage Relative to Total Usable Storage[10] (%)
Main Basin	Upper Aquifer[11]	59 – 113 TAF	68%
	Lower Aquifer[12]	102 – 120 TAF	97%
	Livermore Aquifer[13,14]	85 – 170 TAF	98%
North Fringe	Fringe Aquifer[14]	74 – 133 TAF	99%
Northeast Fringe	Fringe Aquifer[14]	23 – 46 TAF	97%
East Fringe	Fringe Aquifer[14]	0.3 – 0.6 TAF	100%
TOTAL		343 – 583 TAF	91%

Based on the above, it appears that approximately 91% of Total Usable Storage is available under the SGMA Baseline (i.e., Fall 2015) condition. As of Fall 2015, Upper Aquifer and Lower Aquifer units of the Main Basin were 68% and 97% full, respectively, relative to historic highs, while the Upper Livermore Formation portion of the Lower Aquifer (i.e., the "Livermore Aquifer") and Fringe Aquifer units remained close to or at historic highs.

EVALUATION OF RECENT GROUNDWATER STORAGE TRENDS

As part of this exercise, EKI also calculated total available groundwater storage volumes for each Principal Aquifer unit and applicable Management Area over the past five years in attempts to conduct relative comparisons of annual changes in groundwater storage observed within the Basin post-SGMA adoption. The same equations used to calculate the Total Usable and SGMA Baseline Storage apply, except now the saturated thickness is informed by recent annual (Fall) water level surfaces previously developed by Zone 7. **Table 3** presents a summary of recent groundwater storage volumes as well as annual and cumulative changes in storage based on water level rasters obtained from Zone 7 for Fall 2015 – Fall 2020.

[10] Percentages are based on the average of the lower and upper bound ranges in Total Usable Storage volumes calculated for each Principal Aquifer unit in **Table 1**.

[11] The upper end of the range is based on the Nodal method that has historically been used by Zone 7 to estimate basin storage, see **Attachment A** and **Attachment B**.

[12] The lower end of the range is based on the Nodal method that has historically been used by Zone 7 to estimate basin storage, see **Attachment A** and **Attachment B**.

[13] The range reflects a variability in the specific yield storage coefficient of 0.025 – 0.05.

[14] Here the Upper Livermore Formation portion of the Lower Aquifer unit is presented distinctly (i.e., the "Livermore Aquifer") in order to maintain consistency with the delineation of the Lower Aquifer in the Nodal method.

Table 3. Recent (Fall 2015 – 2020) Groundwater Storage Estimates

Management Area	Principal Aquifer Unit	Fall 2015 Groundwater Storage (TAF)	Fall 2016 Groundwater Storage (TAF)	Fall 2017 Groundwater Storage (TAF)	Fall 2018 Groundwater Storage (TAF)	Fall 2019 Groundwater Storage (TAF)	Fall 2020 Groundwater Storage (TAF)
Main Basin	Upper Aquifer[15]	59 – 113 TAF	66 - 124 TAF	77 – 143 TAF	76 – 144 TAF	78 – 147 TAF	70 – 129 TAF
	Lower Aquifer[16]	102 - 120 TAF	102 - 122 TAF	102 - 124 TAF	102 - 123 TAF	102 - 123 TAF	102 - 121 TAF
	Livermore Aquifer[17,18]	85 – 170 TAF	85 – 170 TAF	85 – 170 TAF	85 – 170 TAF	85 – 170 TAF	85 – 170 TAF
North Fringe	Fringe Aquifer[18]	74 – 133 TAF	74 – 133 TAF	74 – 133 TAF	74 – 133 TAF	74 – 133 TAF	74 – 133 TAF
Northeast Fringe	Fringe Aquifer[18]	23 – 46 TAF	23 – 46 TAF	23 – 46 TAF	23 – 46 TAF	23 – 46 TAF	23 – 46 TAF
East Fringe	Fringe Aquifer[18]	0.3 – 0.6 TAF	0.3 – 0.5 TAF	0.3 – 0.5 TAF	0.3 – 0.5 TAF	0.3 – 0.5 TAF	0.3 – 0.5 TAF
TOTAL		343 – 583 TAF	350 – 596 TAF	361 – 617 TAF	360 – 617 TAF	362 – 620 TAF	354 – 600 TAF
Average Annual Change in Groundwater Storage		-	+10 TAF	+16 TAF	-1 TAF	+3 TAF	-14 TAF
Cumulative Change in Groundwater Storage		0 TAF	+10 TAF	+26 TAF	+25 TAF	+28 TAF	+14 TAF

Based on the above, it appears that total groundwater storage in the Basin has increased by +14 TAF since the SGMA Baseline period (Fall 2015). Annual changes in groundwater storage ranged from +16 TAF (2016-2017) to -14 TAF (2019 – 2020). All storage changes were observed within the Upper Aquifer and Lower Aquifer units of the Main Basin, while storage in the Upper Livermore Formation portion of the Lower Aquifer (i.e., the "Livermore Aquifer") and remained close to or at historic highs and storage in the Fringe Aquifers remained stable throughout the recent five-year period.

EVALUATION OF AVAILABLE GROUNDWATER STORAGE AT WATER LEVEL MINIMUM THRESHOLDS AND MEASURABLE OBJECTIVES

As mentioned above and described in Section 354.36(b)(1) of the GSP Emergency Regulations (23 CCR § 354.36(b)(1)), "groundwater elevations may be used as a proxy for monitoring [Reduction of Groundwater Storage] if the Agency demonstrates [that] significant correlation exists between groundwater elevations and [Reduction of Groundwater Storage]." In various GSP comment letters submitted to DWR by the State

[15] The upper end of the range is based on the Nodal method that has historically been used by Zone 7 to estimate basin storage, see **Attachment A** and **Attachment B.**

[16] The lower end of the range is based on the Nodal method that has historically been used by Zone 7 to estimate basin storage, see **Attachment A** and **Attachment B**.

[17] The range reflects a variability in the specific yield storage coefficient of 0.025 – 0.05.

[18] Here the Upper Livermore Formation portion of the Lower Aquifer unit is presented distinctly (i.e., the "Livermore Aquifer") in order to maintain consistency with the delineation of the Lower Aquifer in the Nodal method.

Water Resources Control Board (SWRCB)[19], SWRCB consistently identifies the need for Groundwater Sustainability Agencies (GSAs) to "provide technical support for the argument of correlation between groundwater levels and groundwater storage and justifying the use of MTs for Chronic Lowering of Groundwater Levels as a proxy for Reduction of Groundwater Storage, with specific consideration of the metrics associated with the definitions of MTs and Undesirable Results." As such, in order to effectively demonstrate that the use of groundwater elevations can be as a reasonable proxy for Reduction in Groundwater Storage, it is necessary to quantify the estimated groundwater storage depletion that would occur under Chronic Lowering of Groundwater Level MTs and to assess if it would constitute an Undesirable Result for Reduction of Groundwater Storage as defined in the 2022 Alt GSP[20].

As further described in the SMC section of the 2022 Alt GSP, groundwater level MTs and Measurable Objectives (MOs) are defined at specific representative monitoring site (RMS) locations, thus making a comprehensive spatial evaluation of Basin-wide groundwater storage at the MTs/MOs challenging. However, given that water level MOs are generally tied to historic lows in the Basin[21], raster surfaces of historic low groundwater elevations previously created by Zone 7 staff can serve as a reasonable proxy for estimating associated groundwater storage availability at water level MO conditions. Similarly, as water level MTs are generally tied to historic lows with an additional allowable decline informed by seasonal ranges in water levels at the RMSs[22], modified historic low raster surfaces can serve as a reasonable proxy for estimating associated groundwater storage availability at water level MT conditions. The same equations used to calculate the Total Usable, SGMA Baseline, and recent groundwater storage apply, except now the saturated thickness is informed by the historic low water level surface (for MOs) or the modified historic low water level surface (for MTs).

Table 4 and **Table 5** present a summary of estimated available groundwater storage volumes for each Principal Aquifer unit and Management Area at MO and MT water level conditions, respectively, along with their comparative SGMA Baseline Storage volumes (see **Table 2).** Also provided is an estimate of the percentage of storage available in each Principal Aquifer unit at MO and MT water levels relative to the Total Usable and SGMA Baseline Storage volumes provided in **Table 1** and **Table 2**, respectively.

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[19] EKI, 2021. *Key Excerpts from SWRCB's August 2021 GSP Comment Letters in comparison to DWR's 3 June 2021 GSP Determination and Notification Letters, and Suggested Clarifications for the Northern and Central Delta-Mendota Region GSP.*

[20] Zone 7 2022 Alt GSP, Section 13.2.1. *Undesirable Results for Reduction of Groundwater Storage*

[21] Zone 7 2022 Alt GSP, Section 13.1.3 *Measurable Objectives and Interim Milestones for Chronic Lowering of Groundwater Levels*

[22] Zone 7 2022 Alt GSP, Section 13.1.2 *Minimum Thresholds for Chronic Lowering of Groundwater Levels*

Table 4. Available Groundwater Storage Estimates at Measurable Objective Water Levels

Management Area	Principal Aquifer Unit	SGMA Baseline Groundwater Storage (TAF)	Available Groundwater Storage at Measurable Objective (TAF)	Percentage Relative to Total Usable Storage[23] (%)	Percentage Relative to SGMA Baseline Storage[24] (%)
Main Basin	Upper Aquifer[25]	59 – 113 TAF	47 - 67 TAF	45%	67%
	Lower Aquifer[26]	102 - 120 TAF	102 - 110 TAF	93%	95%
	Livermore Aquifer[27,28]	85 – 170 TAF	85 – 170 TAF	98%	100%
North Fringe	Fringe Aquifer[25]	74 – 133 TAF	73 – 131 TAF	98%	99%
Northeast Fringe	Fringe Aquifer[25]	23 – 46 TAF	21 – 43 TAF	90%	91%
East Fringe	Fringe Aquifer[25]	0.3 – 0.6 TAF	0.2 – 0.4 TAF	67%	67%
TOTAL		343 – 583 TAF	328 – 521 TAF	83%	92%

Table 5. Available Groundwater Storage Estimates at Minimum Threshold Water Levels

Management Area	Principal Aquifer Unit	SGMA Baseline Groundwater Storage (TAF)	Available Groundwater Storage at Minimum Threshold (TAF)	Percentage Relative to Total Usable Storage[23] (%)	Percentage Relative to SGMA Baseline Storage[24] (%)
Main Basin	Upper Aquifer[25]	59 - 113 TAF	36 – 47 TAF	33%	48%
	Lower Aquifer[26]	102 - 120 TAF	102 TAF	89%	92%
	Livermore Aquifer[27,28]	85 – 170 TAF	85 – 170 TAF	98%	100%
North Fringe	Fringe Aquifer[25]	74 – 133 TAF	72 – 128 TAF	96%	97%
Northeast Fringe	Fringe Aquifer[25]	23 – 46 TAF	20 – 40 TAF	85%	87%
East Fringe	Fringe Aquifer[25]	0.3 – 0.6 TAF	0.2 – 0.4 TAF	67%	67%
TOTAL		343 – 583 TAF	315 – 487 TAF	78%	87%

As a whole, the Basin would remain no less than 87% full under MT water levels relative to SGMA Baseline conditions, corresponding to a total reduction in groundwater storage of approximately 28 – 96 TAF. A

[23] Percentages are based on the average of the lower and upper bound ranges in Total Usable Storage volumes calculated for each Principal Aquifer unit in **Table 1**.
[24] Percentages are based on the average of the lower and upper bound ranges in SGMA Baseline Storage volumes calculated for each Principal Aquifer unit in **Table 2**.
[25] The upper end of the range is based on the Nodal method that has historically been used by Zone 7 to estimate basin storage, see **Attachment A** and **Attachment B.**
[26] The lower end of the range is based on the Nodal method that has historically been used by Zone 7 to estimate basin storage, see **Attachment A** and **Attachment B**.
[27] The range reflects a variability in the specific yield storage coefficient of 0.025 – 0.05.
[28] Here the Upper Livermore Formation portion of the Lower Aquifer unit is presented distinctly (i.e., the "Livermore Aquifer") in order to maintain consistency with the delineation of the Lower Aquifer in the Nodal method.

large majority of this storage loss would occur within the Upper Aquifer (23 – 66 TAF) and Lower Aquifer (0 - 18 TAF) units of the Main Basin.

While groundwater storage in the Upper Aquifer unit appears to be most affected by groundwater level declines, it is important to note that groundwater production in this unit is de minimis, and that water level MTs and MOs are specifically designed to protect groundwater dependent ecosystems and prevent depletion of interconnected surface waters in the areas of the Basin where shallow groundwater conditions are known to occur[29]. Within the Lower Aquifer unit, an 18 TAF storage decline at MT water levels would still leave 92% of usable storage available relative to SGMA Baseline conditions. Meanwhile, the underlying Upper Livermore Formation portion of the Lower Aquifer unit (i.e., "Livermore Aquifer") retains 100% saturation at the MT water levels relative to SGMA Baseline conditions, demonstrating that this portion of the Lower Aquifer unit is at virtually no risk of desaturation.

The North Fringe, Northeast Fringe, and East Fringe Management Areas will remain at least 97%, 87%, and 67% full at MT water levels, respectively, relative to SGMA Baseline conditions, demonstrating that the SMCs defined for Chronic Lowering of Groundwater Levels will also be sufficiently protective of Reduction of Groundwater Storage within these areas of de minimis groundwater use.

The above calculations serve to demonstrate that the SMCs defined for the Chronic Lowering of Groundwater Levels SI are sufficiently protective of Undesirable Results for Reduction of Groundwater Storage and thus can serve as an effective proxy for defining Reduction of Groundwater Storage SMCs in the 2022 Alt GSP. It is also important to note that an UR for Chronic Lowering of Groundwater Levels would be triggered well before the entire basin reached the MT water level conditions defined in this analysis[30], and thus the available storage volumes defined in **Table 5** are inherently conservative.

[29] Zone 7 2022 Alt GSP, Section 13.1.2 *Minimum Threshold for Chronic Lowering of Groundwater Levels*
[30] Zone 7 2022 Alt GSP, Section 13.1.1. *Undesirable Results for Chronic Lowering of Groundwater Levels*

ATTACHMENT A

Comparison of Rockworks and "Nodal" Model Aquifer Volumes

EKI's development of the Rockworks stratigraphy model of the Livermore Valley Groundwater Basin (Basin) provides for a refined, high resolution (200 x 200 feet) representation of Principal Aquifer unit extents and geometries within the Basin. As described in EKI's TM entitled *Progress Update on Extending Existing Hydrogeologic Framework* (dated 02 April 2021), the Rockworks model was developed using the best available information regarding Basin hydrogeology and incorporates lithologic and geophysical data from 1,053 unique boreholes within the Basin as well as key data and representations of Basin hydrogeology from various existing studies (e.g., DWR 1974, Norfleet 2004, Zone 7 2011).

Given that the Rockworks stratigraphy model reflects an updated hydrogeologic conceptualization of the Basin, migrating from Zone 7's existing "Nodal" model of the Basin (which originated from the DWR 1974 Bulletin 118 study) to the Rockworks model was expected to, and did, result in different estimates of Total Groundwater Storage volumes for the Basin. These differences are attributable to:

1) Differences in spatial resolution (i.e., 22 zones in the Nodal model versus a 200 x 200-foot Rockworks grid);
2) Differences in representation of Principal Aquifer thicknesses (i.e., uniform thickness for each zone in the Nodal Model vs varying thickness in Rockworks grid);
3) Differences in representation of Principal Aquifer spatial extents; and,
4) Differences in Principal Aquifer definitions (i.e., Upper and Lower Aquifer in the Nodal model versus Upper, Lower and Upper Livermore Aquifers in the Rockworks grid).

As part of the current effort to evaluate groundwater storage volumes in the Basin under planned Sustainable Management Criteria (SMC), a detailed comparison of aquifer volumetrics between the Rockworks and Nodal models was completed for the Main Basin Management Area (Main Basin)[1]. Total aquifer volumes were extracted from the Rockworks model for each Principal Aquifer unit and compared to analogous aquifer volumes from each node of the Nodal model, and a weighted difference between the Nodal-based and Rockworks-based aquifer volumes was calculated for each node and Principal Aquifer unit as follows:

$$\%\ Impact\ on\ Aquifer\ Volume_{i,k} = \frac{Rockworks\ Aquifer\ Volume_{i,k} - Nodal\ Aquifer\ Volume_{i,k}}{\sum_{i=1}^{n} Nodal\ Aquifer\ Volume_{i,k}}$$

where *"i"* is the node number and *"k"* is the Principal Aquifer unit.

This metric helps to identify areas of the Main Basin where the differences between Rockworks vs. Nodal aquifer volumes results in the greatest impacts to the total groundwater storage calculation for each Principal Aquifer unit. Results of the comparative analysis are shown on **Figures 1 through 8,** and key findings are summarized by Principal Aquifer unit below.

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[1] The Nodal model does not include a complete mapping of Principal Aquifer units in the Fringe Basin and Upland Management Areas. Therefore, this comparison is limited to the Main Basin.

Upper Aquifer

As shown on **Figure 1** and **Table 1**, the Rockworks model depicts a smaller Upper Aquifer unit than the Nodal model in most areas of the Main Basin. Some of the key discrepancies in Upper Aquifer representation between the two models include:

- **Central Main Basin** (Bernal, Amador subareas) – As shown on **Figure 2**, the Rockworks model depicts a slightly thinner Upper Aquifer unit than the Nodal model within the central portion of the Main Basin and includes a more spatially resolved representation of land surface elevations. Upper Aquifer thicknesses in the Bernal and Central Amador areas averaged ~88 feet in the Nodal model, compared to ~63 feet in the Rockworks model. Additionally, as shown on **Figure 3**, the Rockworks model depicts the overlying Overburden Unit as extending into the western portion of the Amador subarea, whereas the Nodal model only includes the Overburden unit within the Bernal subarea. Also, as shown on **Figure 4**, the Rockworks Upper Aquifer surface does not extend all the way to the Basin boundary in some areas (e.g., Nodes 25 and 19 along the southern boundary of the Amador subarea), whereas the Nodal model assumes a constant aquifer thickness in each node up to the Basin boundary. Finally, Zone 7 has added a calculation of groundwater storage within the Chain of Lakes mining pits to the Nodal estimates of Upper Aquifer storage beginning in 2014, which is not directly accounted for in the Rockworks storage calculations. Based on Zone 7's calculations, storage in the Chain of Lakes mining pits could result in as much as 14 thousand acre-feet (TAF) of additional Upper Aquifer storage that is not being included in the Rockworks estimates.

- **Northern Mocho II Subarea** – As shown on **Figure 2,** the Rockworks model shows the Upper Aquifer thinning from ~50 feet to ~30 feet thickness at the northeastern edge of the Mocho II subarea before reaching "The Gap" (i.e., the boundary between Mocho II [Main Basin] and Mocho I [Fringe Basin]). The Nodal model assumes the Upper Aquifer is ~83 feet thick on average within the entirety of the northern portion of the Mocho II subarea.

- **Arroyo Valle and Arroyo Mocho stream corridors** – As shown on **Figure 5** and **Figure 6,** the Rockworks model represents the Upper Aquifer as a progressively thinning sequence of shallow alluvial fill materials moving up the Arroyo Valle and Arroyo Mocho stream corridors. The Upper Aquifer thins to ~30 feet thickness in the stream corridors and is directly underlain by the Livermore Aquifer. The Nodal model, in comparison, only includes one node for each of the Arroyo Mocho (Node 36) and Arroyo Valle (Node 41) stream corridors and assumes the Upper Aquifer is the only Principal Aquifer unit in these areas. The Nodal model maps the Upper Aquifer thickness at 105 feet in the Arroyo Valle stream corridor, and 112 feet in the Arroyo Mocho stream corridor. Additionally, as shown on **Figure 4**, the Rockworks Upper Aquifer surface does not extend all the way to the edges of the Basin along these stream corridors, whereas Nodes 36 and 41 extend to the Basin boundary.

Lower Aquifer

As shown on **Figure 7** and **Table 1**, the Rockworks model depicts a larger Lower Aquifer unit than the Nodal model in most areas of the Main Basin. Some of the key discrepancies in Lower Aquifer representation between the two models include:

- **Central Main Basin** (Bernal, Amador subareas) – As shown on **Figure 2**, the Rockworks model depicts a thicker Lower Aquifer unit than the Nodal model within the central portion of the Main Basin. Lower Aquifer thicknesses in the Bernal and Central Amador areas averaged ~148 feet in the Nodal model, compared to ~297 feet in the Rockworks model. As seen on **Figure 2** and **Figure 5**, it appears the Nodal model does not include the deepest stratigraphic sequence of the Lower Aquifer (characterized as the "Purple" sequence in the Norfleet 2004 study) within the Bernal and central Amador subareas, thus excluding as much as 50% of the total thickness of the Lower Aquifer in the central Main Basin.

- **Near the Concannon Boundary** – As shown on **Figure 7**, Node 35 in the southern-central portion of the Amador subarea shows the largest discrepancy between the Rockworks and Nodal model depictions of the Lower Aquifer (a -16% impact on total aquifer volume). As shown on **Figure 8**, the Rockworks model depicts an abrupt end to the Lower Aquifer at the Concannon Boundary in this area. As described in the Norfleet 2004 study, the Concannon Boundary delineates the southern extent of the ancestral Arroyo Mocho paleochannel that comprise the alluvial materials of the Lower Aquifer, and thus represents the de-facto southern edge of the Lower Aquifer. As such, in the Rockworks model the Lower Aquifer only extends through the northern portion of Node 35 at an average thickness of ~87 feet, whereas the Nodal model assumes a constant Lower Aquifer thickness of 112 feet throughout Node 35 before terminating the Lower Aquifer in Node 36 to the south.

Livermore Aquifer

The Rockworks model includes the Livermore Aquifer in its delineation of Principal Aquifer units. The Livermore Aquifer underlies the Lower Aquifer in the Main Basin and comprises a majority of the Fringe Aquifer in the Fringe Management Area. The Nodal model currently does not include the underlying Livermore Aquifer, thus defining the Basin bottom at the base of the Lower Aquifer, even though many production wells in the Basin are screened in this unit (see **Figures 2 and 5**). Based on the Rockworks model, it is estimated that an additional 87 – TAF of Total Usable Groundwater Storage exists in the Livermore Aquifer which is not being accounted for in the Nodal model. This represents ~28 – 44% of the Total Usable Groundwater Storage calculated for the Main Basin as further outlined below.

Net Impacts on Total Usable Groundwater Storage Estimates

As demonstrated above, differences in groundwater storage estimates from the Rockworks and Nodal stratigraphy models can be attributed to differences in the spatial resolution, thicknesses, extents, and definitions of Principal Aquifer units between the two models. **Table 1** below presents a comparison in Total Usable Groundwater Storage[2] estimates for the Main Basin between these two methods.

[2] Here "Total Usable Groundwater Storage" is defined as total available groundwater storage at historic high water level conditions. Note this is not equivalent to total aquifer volume, as some areas of the Basin were not fully saturated at historic high conditions.

Table 1. Total Usable Groundwater Storage Estimates (Main Basin)

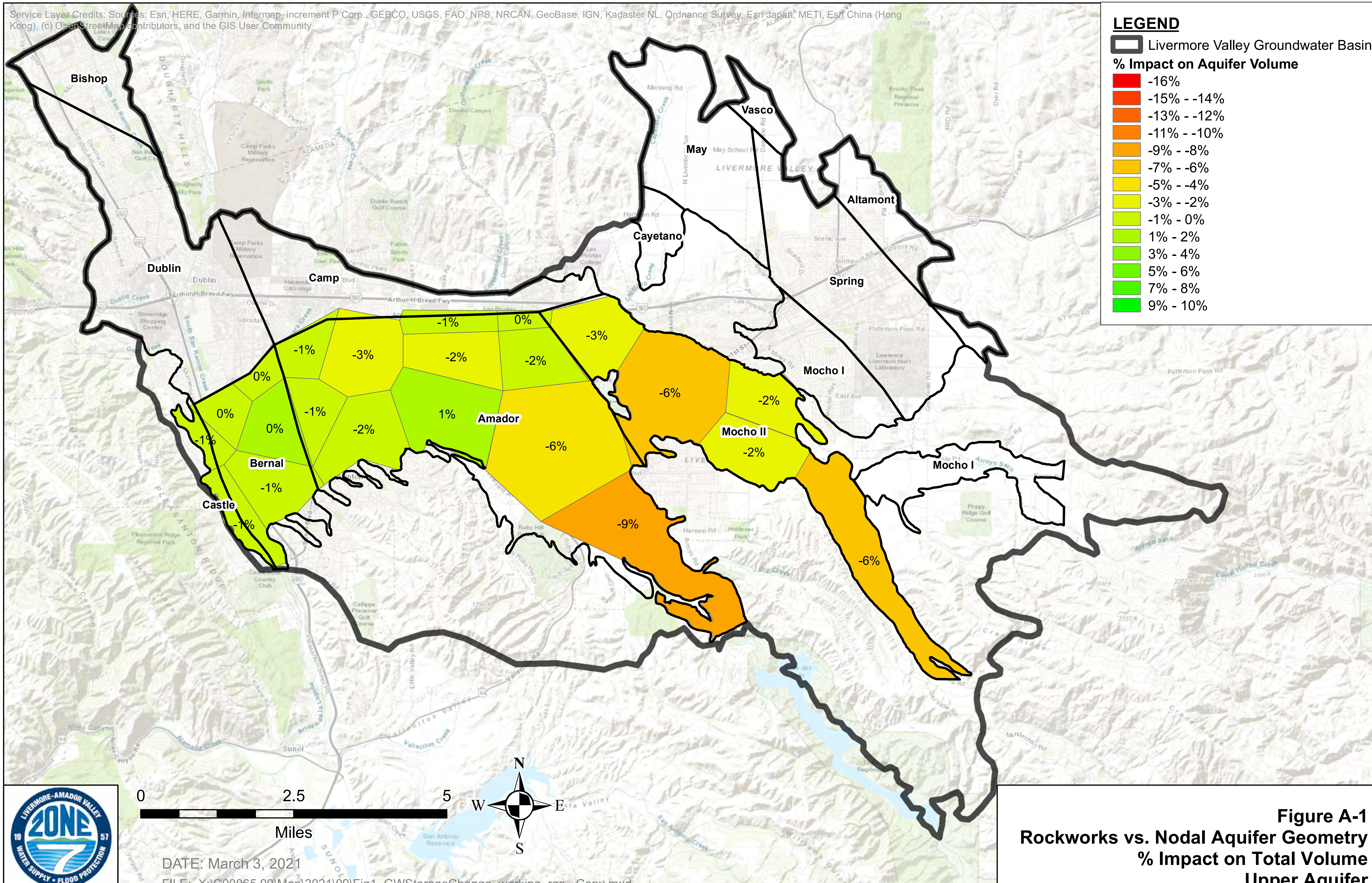
Principal Aquifer Unit	Total Usable Storage from Nodal Model (TAF)	Total Usable Storage from Rockworks Model (TAF)	Percent Difference [Rockworks vs. Nodal] (%)
Upper Aquifer	157 TAF	94 TAF	-40%
Lower Aquifer	102 TAF	127 TAF	+25%
Livermore Aquifer	-	87 – 174 TAF	+100%
TOTAL	259 TAF	308 – 395 TAF	+19% to +52%

As seen from **Table 1** above, the Rockworks stratigraphy model calculates between 19% to 52% greater estimates of Total Usable Groundwater Storage within the Main Basin compared to the Nodal model. While storage in the Upper Aquifer is decreased by 40% relative to the Nodal model, storage in the Lower Aquifer is increased by 25% and storage in the Livermore Aquifer is now included in the estimate.

Limitations

While the above analysis explains some of the differences that are observed between the Rockworks and Nodal methods, this analysis does not explain the observed discrepancies between both of these methods and the storage estimates derived from the Hydrologic Inventory (HI) method. As shown in **Figure 9**, both the Rockworks and Nodal methods underestimate storage increases and overestimate storage decreases relative to the HI method estimates over the past five years. Adjusting the assumed storativity parameters does not appear to address the issue, as it simply scales the results. As mentioned above, the discrepancy between the Rockworks and Nodal methods is further exacerbated by Zone 7's inclusion of groundwater storage volumes within the Chain of Lakes mining pits into the Nodal storage change calculations beginning in 2014. Additional analysis beyond the scope of this effort (e.g., update and re-calibration of the Basin numerical groundwater model) will be required to better refine the estimates of total and year-over-year changes in storage in the Basin, using the Rockworks, Nodal and HI methods.

Figures



Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community
LEGEND
Livermore Valley Groundwater Basin
% Impact on Aquifer Volume
-16%
-15% - -14%
-13% - -12%
-11% - -10%
-9% - -8%
-7% - -6%
-5% - -4%
-3% - -2%
-1% - 0%
1% - 2%
3% - 4%
5% - 6%
7% - 8%
9% - 10%
Bishop
Dublin
Camp
May
Vasco
Altamont
Cayetano
Spring
Mocho I
Mocho II
Amador
Bernal
Castle
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-3%
-2%
1%
-6%
-9%
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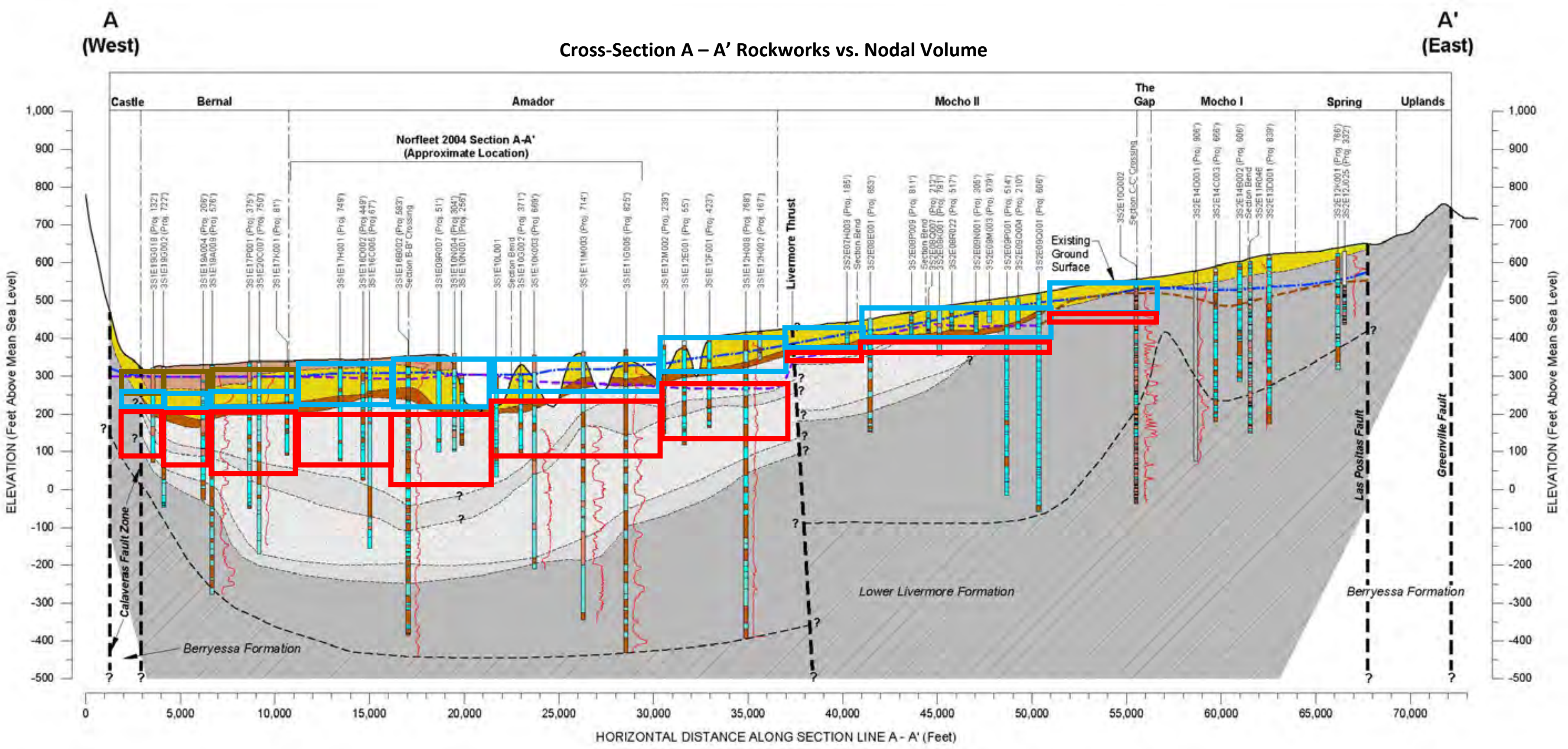
Figure A-1
Rockworks vs. Nodal Aquifer Geometry
% Impact on Total Volume
Upper Aquifer

Principal Aquifer Units in Nodal Model

- Upper Aquifer
- Lower Aquifer
- Overburden



Cross-Section A - A'

Legend:

Stratigraphy
- Overburden
- Upper Aquifer
- Aquitard
- Lower Aquifer (Quaternary Gravels/Sands)
- Lower Aquifer (Quaternary Clays/Silts)
- Upper Livermore Formation
- Lower Livermore Formation
- Bottom of Groundwater Basin
- Static Water Level in Upper Aquifer (Fall 2019)
- Static Water Level in Lower Aquifer (Fall 2019)
- Static Water Level in Upper Livermore (Fall 2019)

Lithology
- Topsoil/Fill
- Gravel
- Sand
- Silt
- Clay

Geophysical
- Long-Normal Resistivity

Map Elements
- A — A' Cross-Section Trace Location
- Livermore Valley Groundwater Basin

Management Area
- Fringe Management Area
- Main Basin Management Area
- Upland Management Area

(Vertical Scale in Feet) 0 100 200 300

(20X Vertical Exaggeration)

0 6,000 12,000 (Horizontal Scale in Feet)

Cross-Section A – A'
Rockworks vs. Nodal

Zone 7 2022 Alternative GSP
Livermore, CA
June 2021
EKI C00065.00
Figure A-2

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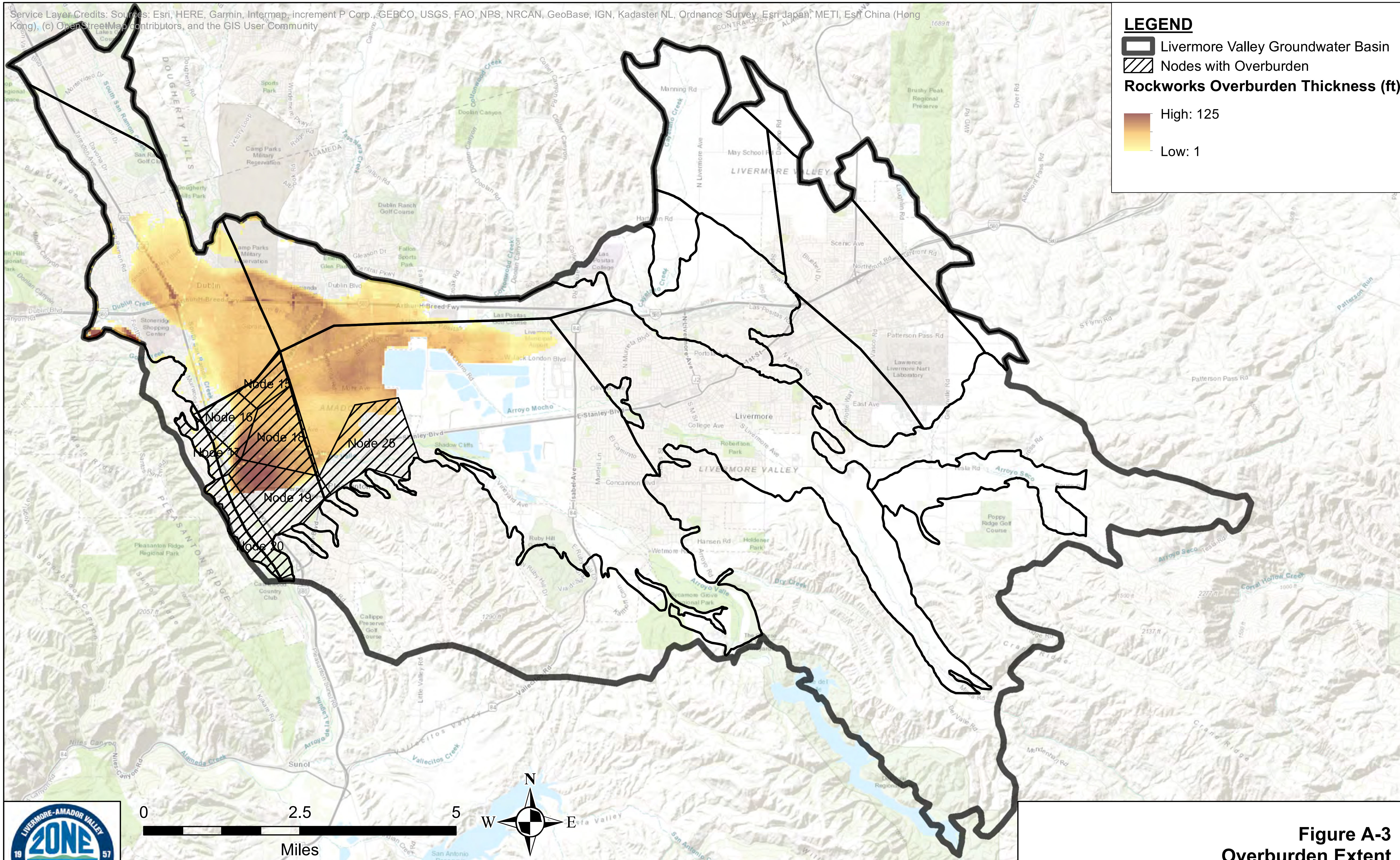

DATE: March 3, 2021

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Figure A-3
Overburden Extent
Rockworks vs. Nodal

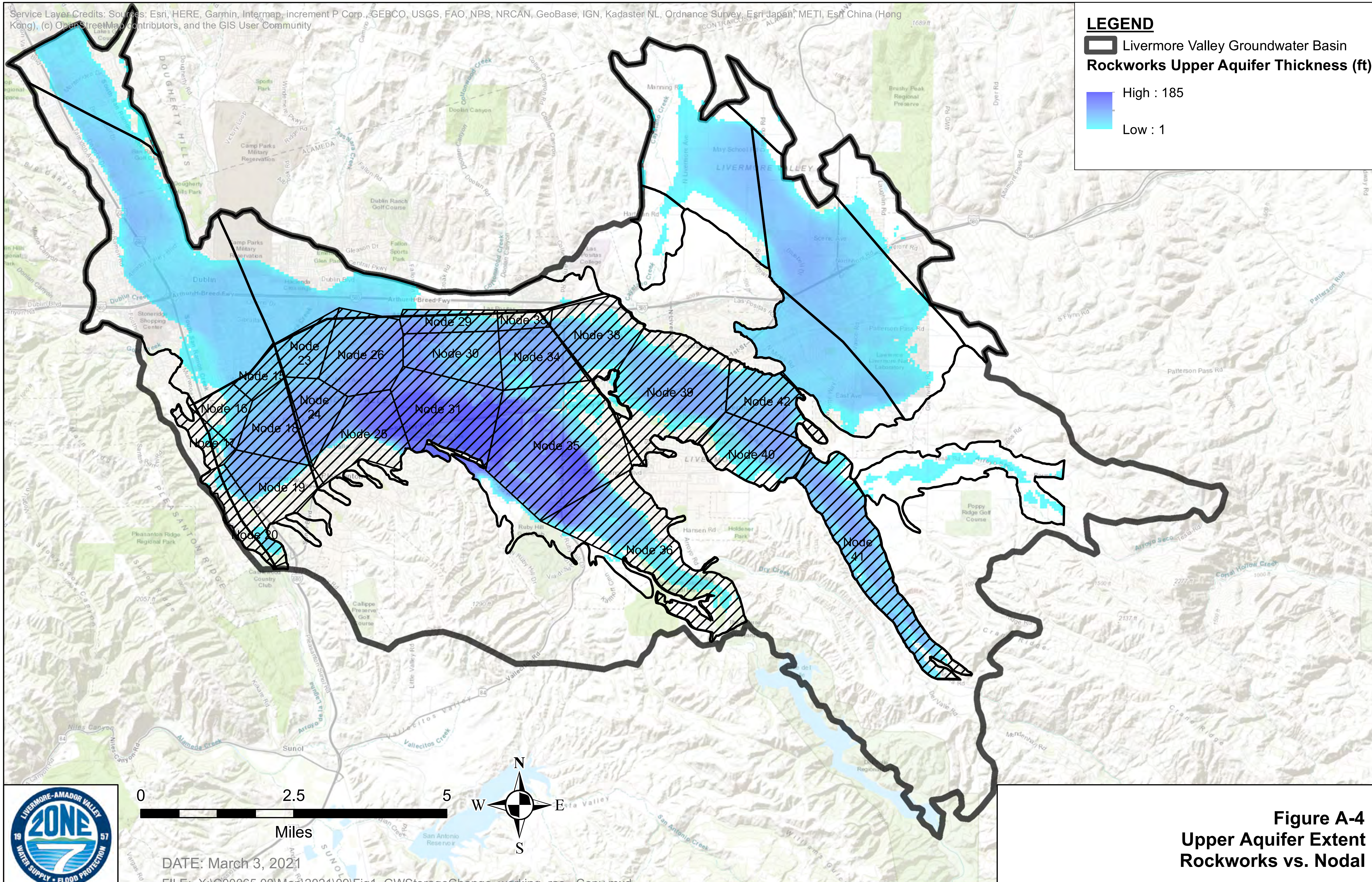
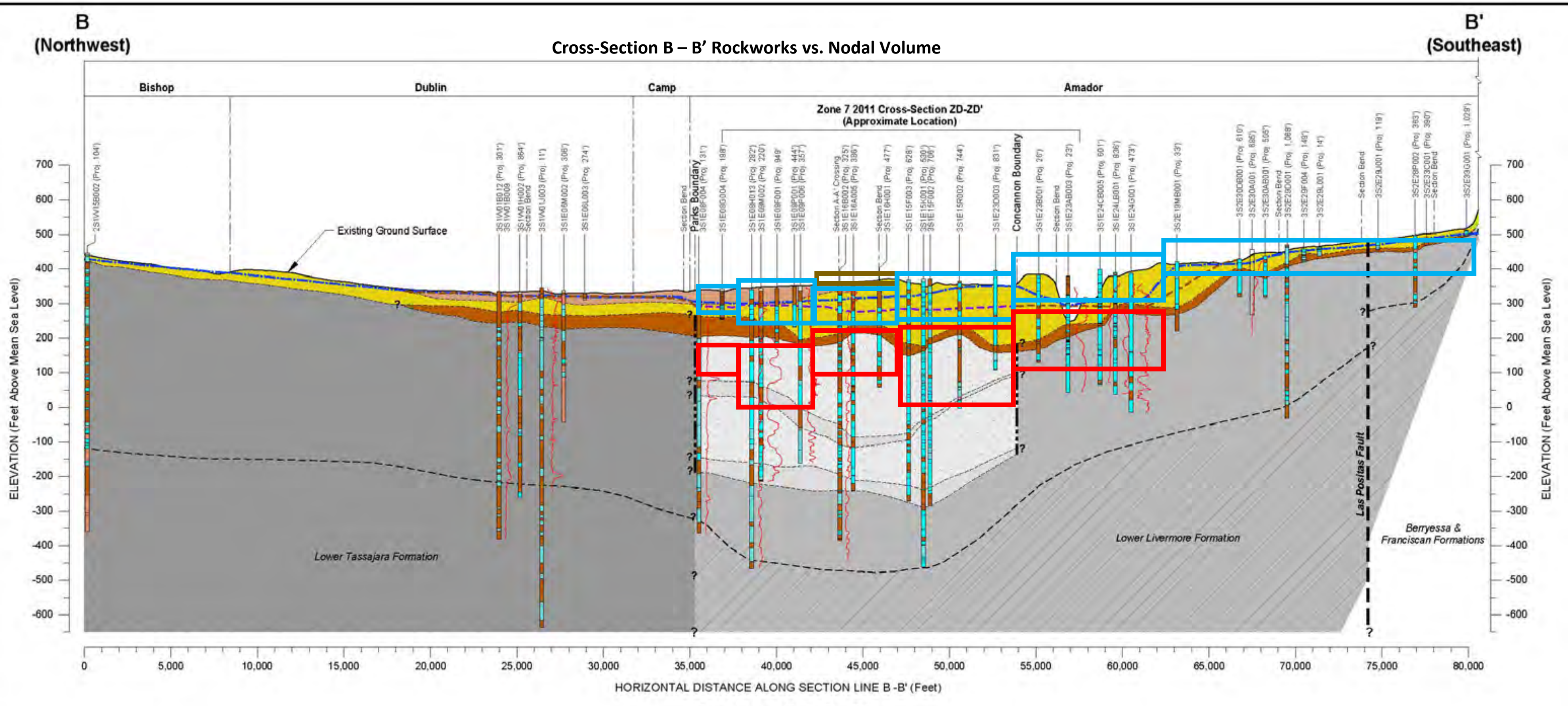


Figure A-4
Upper Aquifer Extent
Rockworks vs. Nodal

Principal Aquifer Units in Nodal Model

- Upper Aquifer
- Lower Aquifer
- Overburden



Cross-Section B - B'

Legend:

Stratigraphy

- Overburden
- Upper Aquifer
- Aquitard
- Lower Aquifer (Quaternary Gravels/Sands)
- Lower Aquifer (Quaternary Clays/Silts)
- Upper Livermore Formation
- Lower Livermore Formation
- Upper Tassajara Formation
- Lower Tassajara Formation
- Bottom of Groundwater Basin
- Static Water Level in Upper Aquifer (Fall 2019)
- Static Water Level in Lower Aquifer (Fall 2019)
- Static Water Level in Upper Livermore/Tassajara Formation (Fall 2019)

Lithology

- Topsoil/Fill
- Gravel
- Sand
- Silt
- Clay

Geophysical

- Long-Normal Resistivity

Map Elements

- A —— A' Cross-Section Trace Location
- Livermore Valley Groundwater Basin

Management Area

- Fringe Management Area
- Main Basin Management Area
- Upland Management Area

Key Map

(Vertical Scale in Feet) 300 200 100 0

(20X Vertical Exaggeration)

0 6,000 12,000

(Horizontal Scale in Feet)

Cross-Section B – B' Rockworks vs. Nodal

Zone 7 2022 Alternative GSP
Livermore, CA
June 2021
EKI C00065.00

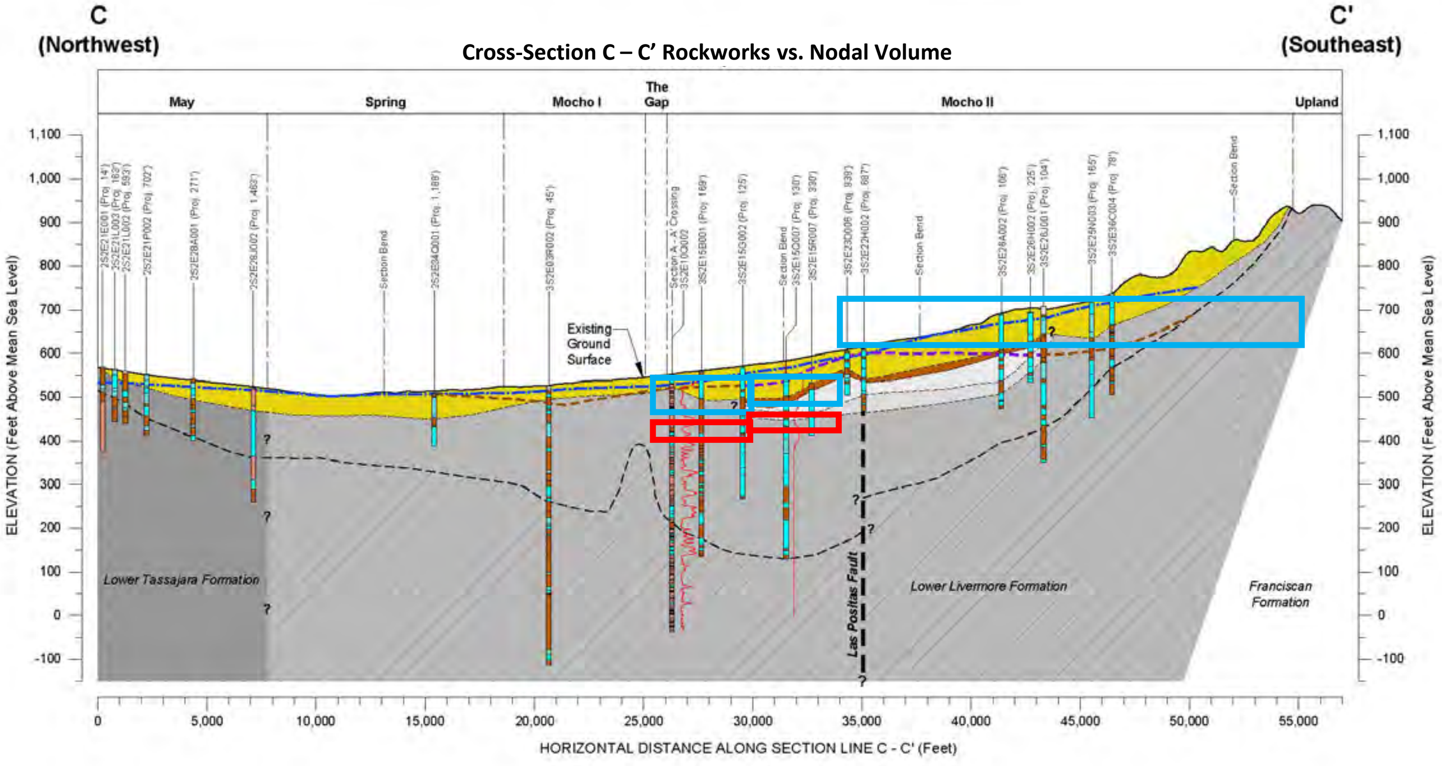
Figure A-5

eki environment & water

20210603.085738 G:\C00065.00\2021-06\Cross Section B-B.dwg Section B-B'

Principal Aquifer Units in Nodal Model

- Upper Aquifer
- Lower Aquifer
- Overburden



Cross-Section C - C'

Legend:

Stratigraphy

- Upper Aquifer
- Aquitard
- Lower Aquifer (Quaternary Gravels/Sands)
- Lower Aquifer (Quaternary Clays/Silts)
- Upper Livermore Formation
- Lower Livermore Formation
- Upper Tassajara Formation
- Lower Tassajara Formation
- Bottom of Groundwater Basin
- Static Water Level in Upper Aquifer (Fall 2019)
- Static Water Level in Lower Aquifer (Fall 2019)
- Static Water Level in Upper Livermore/Tassajara Formation (Fall 2019)

Lithology

- Topsoil/Fill
- Gravel
- Sand
- Silt
- Clay

Geophysical

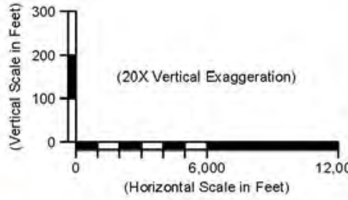
- Long-Normal Resistivity

Map Elements

- A — A' Cross-Section Trace Location
- Livermore Valley Groundwater Basin

Management Area

- Fringe Management Area
- Main Basin Management Area
- Upland Management Area



Cross-Section C – C' Rockworks vs. Nodal

Zone 7 2022 Alternative GSP
Livermore, CA
June 2021
EKI C00065.00

Figure A-6

eki environment & water

20210603.085708 G:\C00065.00\2021-06\Cross Section C-C.dwg Section C-C'

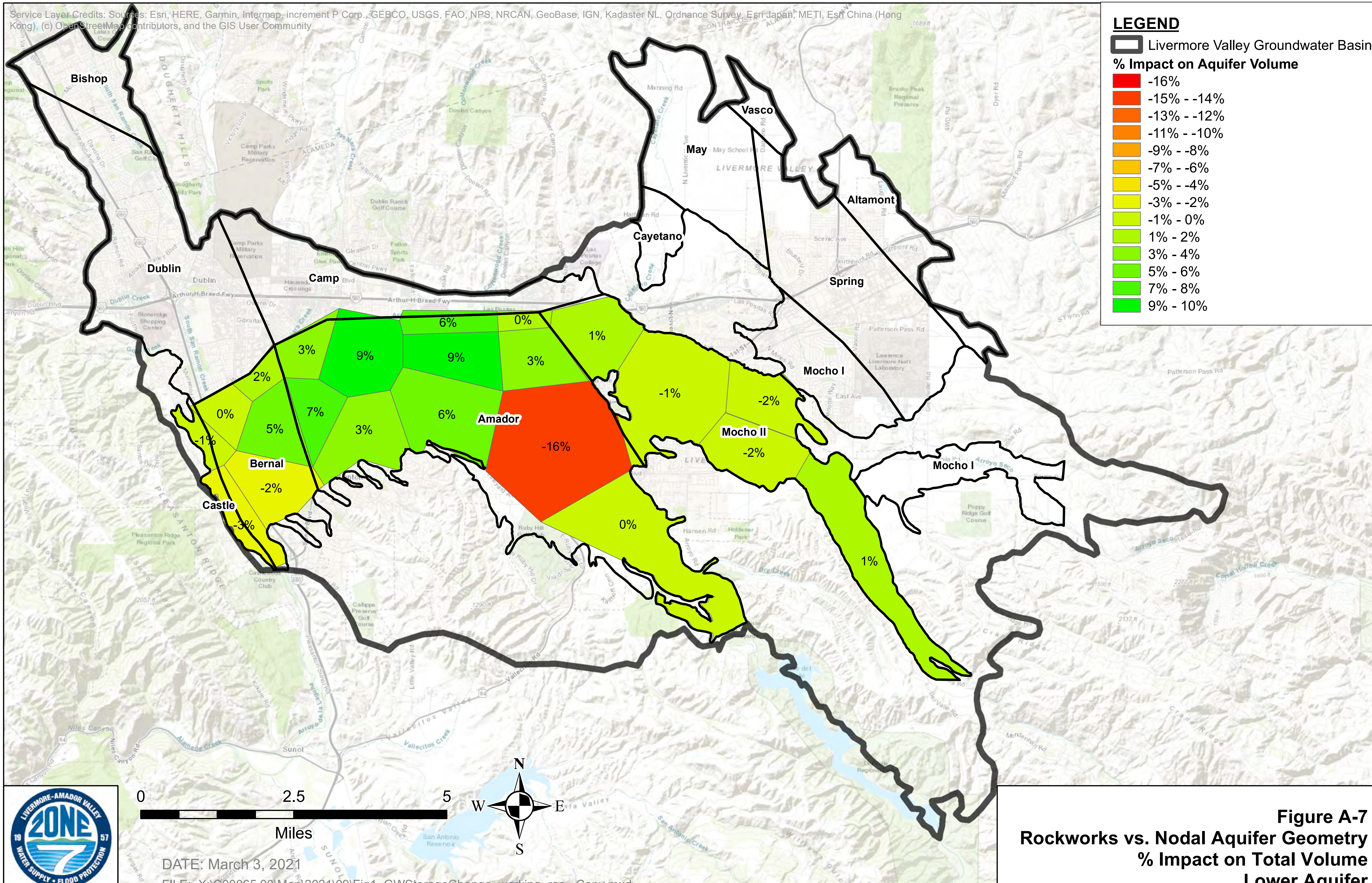


Figure A-7
Rockworks vs. Nodal Aquifer Geometry
% Impact on Total Volume
Lower Aquifer

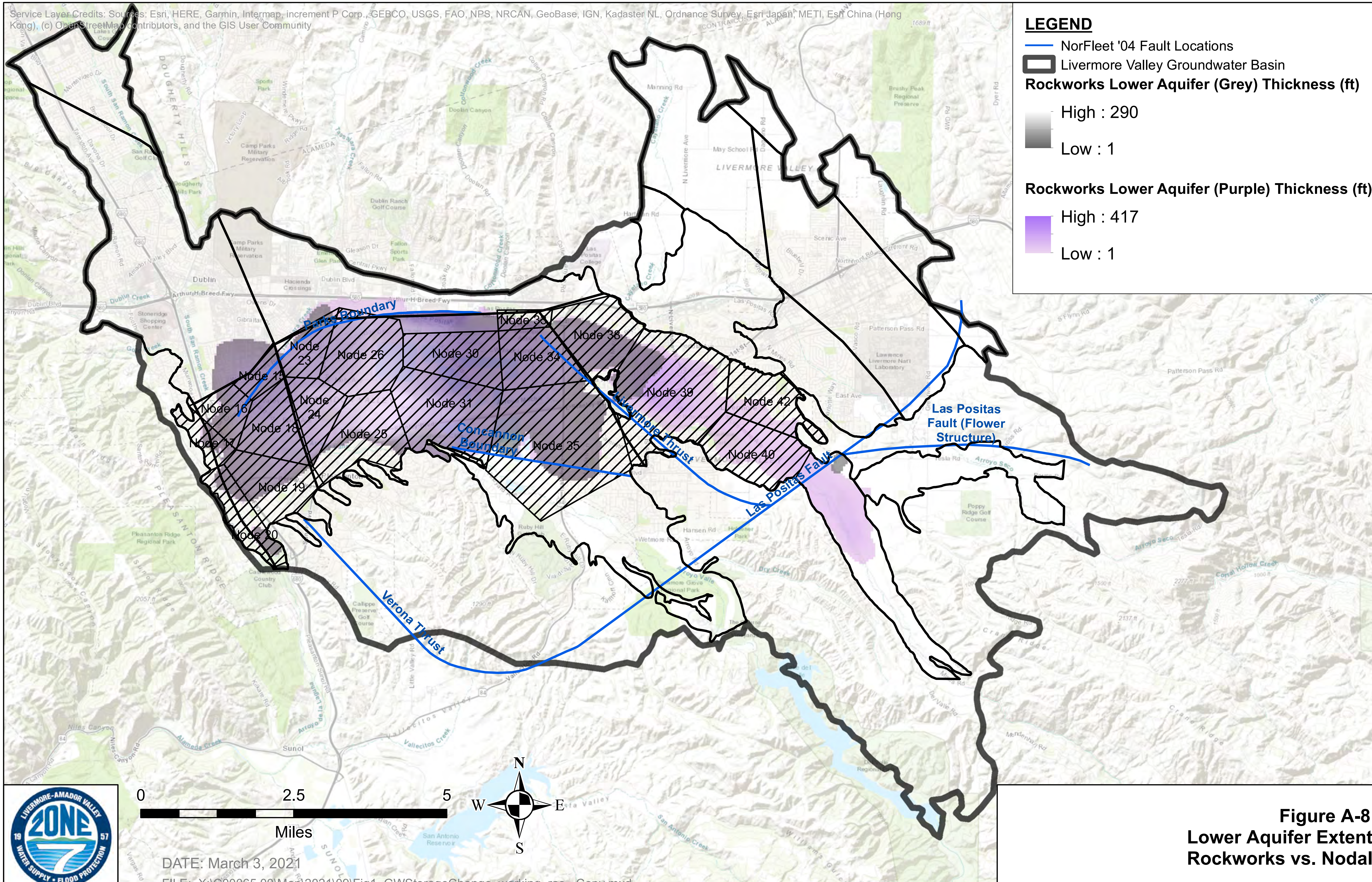
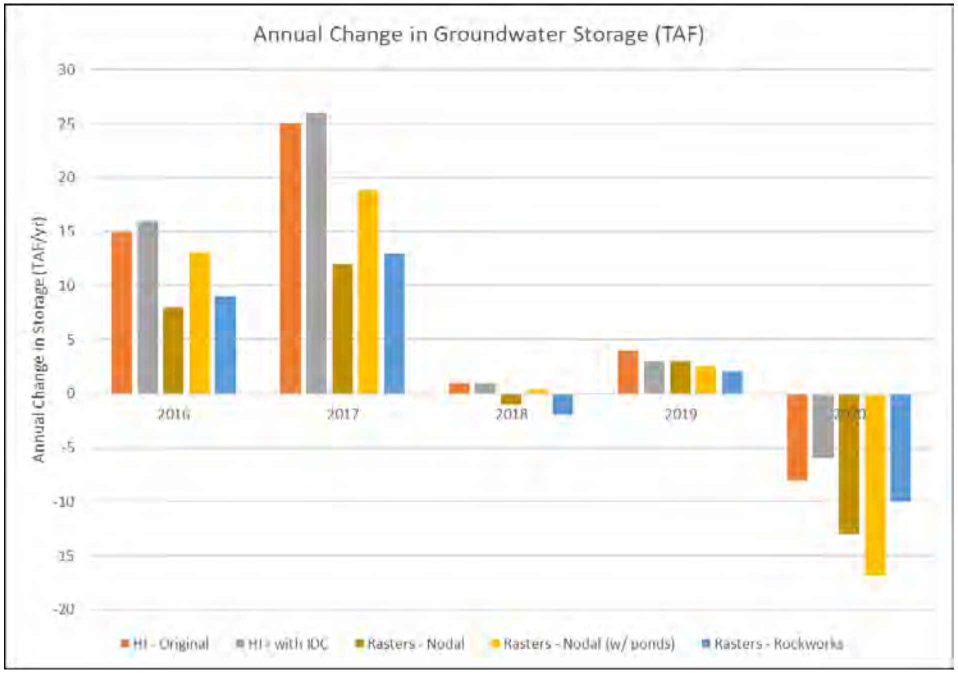
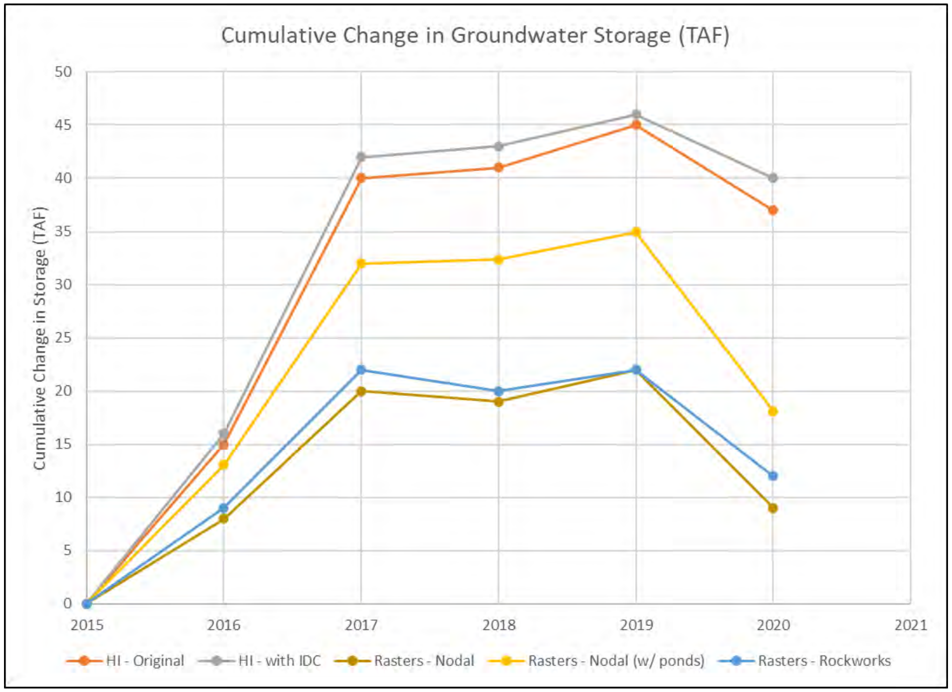


Figure A-8
Lower Aquifer Extent
Rockworks vs. Nodal





Abbreviations:

HI = Hydrologic Inventory

IDC = Integrated Water Flow Model Demand Calculator

TAF = thousand acre-feet

yr = Year

DRAFT

Comparison of Annual and Cumulative Change in Storage Estimates

Zone 7 Water Agency
Alameda County, California
September 2021
EKI C00065.00

eki environment & water

Figure A-9

ATTACHMENT B

ZONE 7 NODAL STORAGE VOLUMES

(ALL VALUES IN ACRE-FEET)

WATER YEAR / CONDITION	UPPER AQUIFER (ROUNDED)	LOWER AQUIFER (ROUNDED)	POND STORAGE (ROUNDED)	**TOTAL (without ponds)**	**TOTAL (with ponds)**
Historical High	**157,000**	**102,000**		**259,000**	**259,000**
Historical Low	**67,000**	**102,000**		**169,000**	**169,000**
1992	**82,000**	**102,000**		**184,000**	**184,000**
1993	**109,000**	**102,000**		**211,000**	**211,000**
1994	**114,000**	**102,000**		**216,000**	**216,000**
1995	**123,000**	**102,000**		**225,000**	**225,000**
1996	**121,000**	**102,000**		**223,000**	**223,000**
1997	**120,000**	**102,000**		**222,000**	**222,000**
1998	**123,000**	**102,000**		**225,000**	**225,000**
1999	**120,000**	**102,000**		**222,000**	**222,000**
2000	**120,000**	**102,000**		**222,000**	**222,000**
2001	**101,000**	**102,000**		**203,000**	**203,000**
2002	**110,000**	**102,000**		**212,000**	**212,000**
2003	**118,000**	**102,000**		**220,000**	**220,000**
2004	**111,000**	**102,000**		**213,000**	**213,000**
2005	**134,000**	**102,000**		**236,000**	**236,000**
2006	**136,000**	**102,000**		**238,000**	**238,000**
2007	**130,000**	**102,000**		**232,000**	**232,000**
2008	**132,000**	**102,000**		**234,000**	**234,000**
2009	**131,000**	**102,000**		**233,000**	**233,000**
2010	**132,000**	**102,000**		**234,000**	**234,000**
2011	**133,000**	**102,000**		**235,000**	**235,000**
2012	**126,000**	**102,000**		**228,000**	**228,000**
2013	**119,000**	**102,000**		**221,000**	**221,000**
2014	**107,000**	**102,000**	**1,000**	**209,000**	**210,000**
2015	**111,000**	**102,000**	**2,000**	**213,000**	**215,000**
2016	**119,000**	**102,000**	**5,000**	**221,000**	**226,000**
2017	**131,000**	**102,000**	**12,000**	**233,000**	**245,000**
2018	**130,000**	**102,000**	**14,000**	**232,000**	**246,000**
2019	**133,000**	**102,000**	**14,000**	**235,000**	**249,000**
2020	**120,000**	**102,000**	**9,000**	**222,000**	**231,000**