

CASE STUDY: CHAIN-OF-LAKES PROJECT, ALAMEDA COUNTY, CALIFORNIA¹

Matthew W. Katen, RG, CHg², Carol D. Mahoney, RG², James F. Reilly, PE³

INTRODUCTION

The Chain-of-Lakes project is located between the cities of Livermore and Pleasanton, in Alameda County, California (Figure 1). The project, when complete, will consist of a series of abandoned gravel quarry pits converted into nine lakes (Lakes A through I), linked in series, and used for seasonal water storage and conveyance, and flood water detention and conveyance. At the end of the “chain” (i.e., Lake I), water levels will be maintained to cause the conveyed and de-silted water to percolate through the lake’s sidewalls, augmenting the “artificial recharge” that Zone 7 Water Agency (Zone 7) already provides for its Main Basin aquifers. The concept was developed in the 1970’s, and is provided for in the County-approved mining reclamation and mitigation plans.



Figure 1. Location Map - Zone 7 Water Agency covers an approximate 425 square mile area located about 40 miles southeast of San Francisco. The Chain of Lakes project is situated near the center of the Livermore Valley groundwater basin.

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²Alameda County Flood Control and Water Conservation District, Zone 7, 5997 Parkside Drive, Pleasanton CA 94588, email:mkaten@zone7water.com or cmahoney@zone7water.com, (925) 484-2600

³Stetson Engineers Inc., 2171 E. Francisco Blvd., Suite K, San Rafael, CA 94901 email:jamesr@stetsonengineers.com, (415) 457-0701

Ultimately, the lakes will cover about 2,000 acres and have a storage capacity of about 100,000 acre-feet, making the system one the largest of its kind ever constructed. However, in the near-term only Lakes H, I and Cope Lake will be deeded to Zone 7 for incorporation into the agency's operations. The remaining pits will be turned over to the agency during the next twenty-five years, as mining operations are completed.

The Zone 7 Water Agency has water supply and flood control responsibilities for eastern Alameda County. It imports and treats water from the State Water Project (SWP), and operates several high capacity municipal wells to supply its retailers who serve a population of approximately 180,000 people. Several of the retailers also operate municipal supply wells. Zone 7 conjunctively manages the local groundwater basin, which has about 240,000 acre-feet (ac-ft) of storage potential. Zone 7 limits the retailers' pumping to stay within the safe yield of the basin, while Zone 7 pumps from the volume it recharges through its recharge program. Currently, the source water for Zone 7's artificial recharge program is primarily from its SWP entitlements, which are released from the South Bay Aqueduct (SBA) to several arroyos for percolation along a combined 16 miles of channel.

Zone 7 normally pumps 20-25% of its demand from the groundwater basin; however, it pumps more during dry years when the State cuts SWP contractors' allocations. In addition, Zone 7 has a reliability policy of being able to supply 75% of its maximum-day demand with well water in case of a complete SBA outage. Zone 7 plans to increase its conjunctive use of the groundwater basin water to keep up with the retailers' increasing demands. The retailers' water demands are projected to increase by 40% through year 2030, with most of the increase occurring by 2020. While the Chain of Lakes project should provide for the necessary increase in aquifer recharge, plans for additional groundwater production facilities are being developed concurrently to meet the 75% maximum-day demand goal.

NEAR-TERM PLAN

With the acquisition of Lakes H, I and Cope Lake well before the rest of the Chain of Lakes, Zone 7 has developed a near-term delivery and recharge plan. This plan includes: releasing surplus SWP water from the SBA to the Arroyo Mocho (up to 50 cubic feet per second [cfs]) when available; conveying it down the stream channel; diverting the remainder of the flow that does not recharge through the streambed or evaporate into Lake H; transferring it to Lake I; and causing it to percolate into to the Main Groundwater Basin (Figure 2).

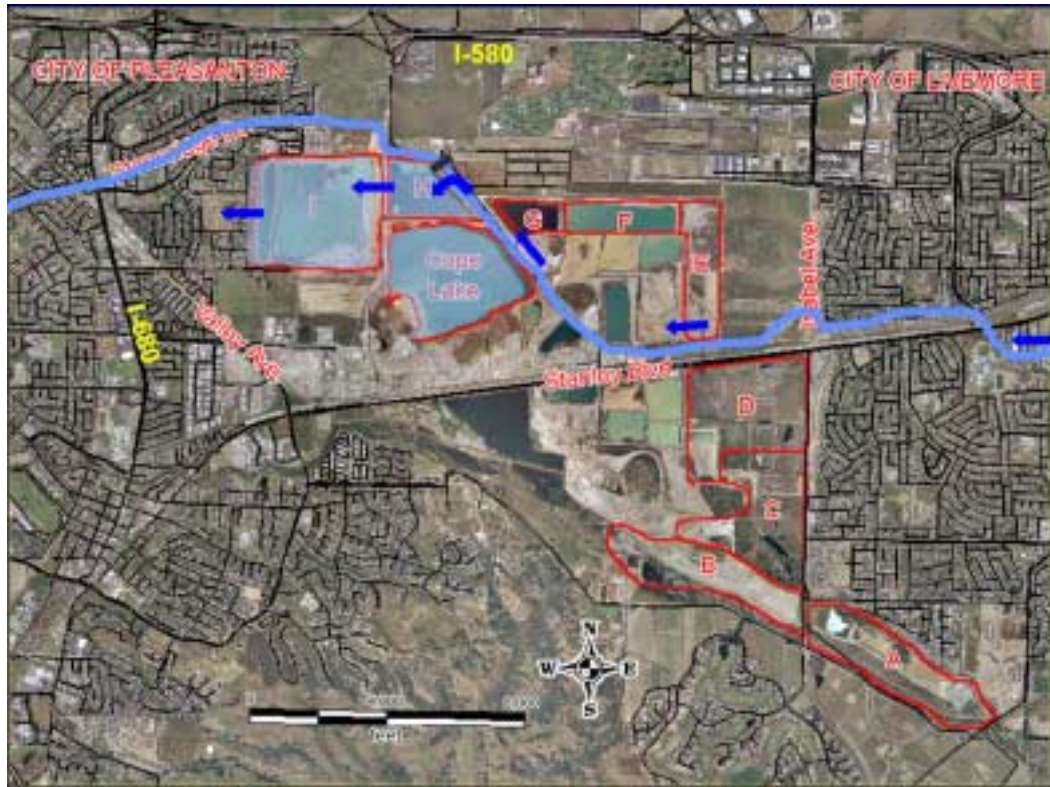


Figure 2. Chain of Lakes Near Term Delivery and Recharge Plan - Zone 7's near term plan for the Chain of Lakes is to release up to 50 cfs of imported State Project Water to the Arroyo Mocho and divert the flow that remains after nine miles of natural conveyance into Lakes H and I where the water will recharge.

Zone 7 already conducts artificial recharge of the groundwater basin with SWP releases to the Arroyo Mocho through an SBA turnout located approximately nine miles upstream from Lake H. The recharge capacity of the Arroyo Mocho varies seasonally from 12 to 20 cfs. With this project, Zone 7 will increase its releases up to 50 cfs to the Arroyo Mocho to effect flow down to Lake H. Flow into Lake H will be accomplished with an inflatable dam diversion structure designed to capture 100 cfs should Zone 7 later acquire rights to some of the natural flow or choose to enlarge the turnout capacity. Once in Lake H, the water will gravity-feed into Lake I through 30-inch diameter conduit that was 'jacked and bored' between the two lakes. Approximately, two-thirds of Lake I's slopes, and most of Lake H's, are lined by fine-grained materials placed by the quarry operators to reduce the incline of the sideslopes and reduce seepage inflow during mining. However, the entire west face and part of the adjacent sides of Lake I are unlined and consist of mostly gravels. It is through this exposed aquifer that recharge is expected to occur when the lake fills. The bottoms of both lakes are essentially sealed by a native clay layer down to which the quarries were mined.

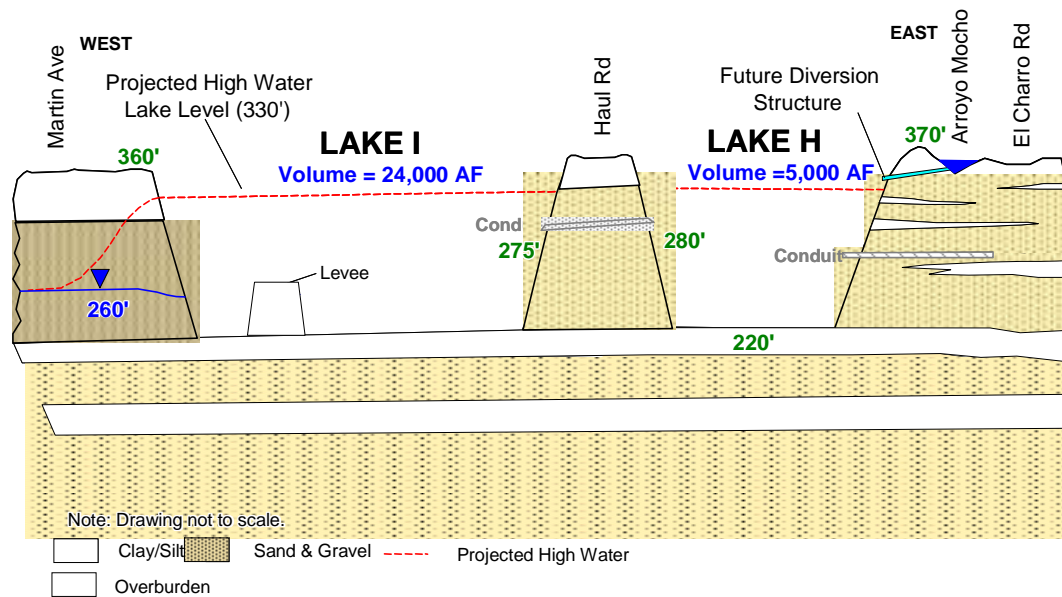


Figure 3. Geologic Cross Section Across Lakes H and I - Because the lakes sit above semi-regional clay layers and the lake sidewalls were sealed with fine sediments during mining, most recharge will occur through the west sidewall of Lake H where the aquifer face was left exposed.

CHALLENGES

The project, however, poses many challenges. There are upstream crossings along the Arroyo Mocho that will have to be improved to accommodate the higher artificial flows. In addition, because the upper reaches of the arroyo have been determined to be suitable habitat for rearing steelhead trout, regulatory agencies have required that fish screens be installed on the diversion structure intake; restrictions be placed on the dam's operation; and all stream crossing improvements be made "fish friendly".

Slope stability and erosion control along the lake sides are major concerns. Typically the native slopes are two vertical to one horizontal (2H:1V) and the fill slopes are 3H:1V. There are wave-cut benches and other erosional features along many of the slopes. On the northeast corner of Lake I there is a small landslide. Urban growth is encroaching upon the Chain of Lakes. Residential units already exist with setbacks of only 80 feet from the top of slope along the north side of Lake I. The City of Pleasanton's General Plan includes plans for future annexation and development of other adjacent properties, however, Zone 7 will only own a 25-foot setback from the top of most slopes. Zone 7 will have to confirm all development setbacks with regard to its anticipated lake level operations. In addition, Zone 7 intends to work on developing relationships and means of two-way communications with its future Chain of Lakes neighbors.

The 2V:1H slope of the recharge face in Lake I creates another challenge; it makes it difficult to use conventional basin cleaning methods to remove clogging materials forming on the gravel face. Also the inverts of the basins will always be lower than the groundwater table and there is no outflow for draining the lakes to facilitate cleaning of the lower one-third of the recharge face. The final solution has yet to be developed, but Zone 7 intends to investigate alternatives.

Zone 7 has already identified some of the facility improvements needed to convert the abandon quarries into functioning water storage and recharge facilities. Besides the diversion structure, water level controls and instrumentation, monitoring wells, access roads, fences, and security provisions are going to be needed. There will also be maintenance associated with these facilities as well as the need for periodic replacement of broken and outdated equipment.

In addition to Lakes H and I, Zone 7 will acquire Cope Lake from the mining operator in 2003. Cope Lake is also a depleted gravel pit but was used by the mining operators as their water supply and return pit for gravel washing operations. Although it covers approximately 220 acres, Cope Lake has been substantially filled in with fines washed from the gravels during their processing. Since Cope Lake is not part of the Chain of Lakes and is largely sealed from the aquifer, it offers the potential for other uses, such as flood detention or recycled water seasonal storage.

Lastly, Zone 7 intends that the near-term plan will dovetail with the longer-term plan as much as possible. All of these identified challenges are being addressed in a comprehensive Lakes H, I and Cope Management Plan that is being developed with the assistance of Stetson Engineers.

MANAGEMENT PLAN DEVELOPMENT

Zone 7 is near completion of the management plan for implementation of the Chain-of-Lakes project. The management plan will provide a “road map” for conversion of the Lakes H, I and Cope Lake properties from gravel mining and operation for artificial recharge. The management plan will consist of the following elements (details of each are described in the following paragraphs):

- Facility needs and plans
- Operational plans and implementation
- Inspections and maintenance
- Operational and performance monitoring

Facilities Needs and Plans

This element of the management plan involves study and preliminary design and cost estimation of needed improvements and new facilities to implement Zone 7's near term plan. Comprehensive geotechnical and hydraulic studies have been completed. Design and cost estimation of site improvements and facilities is in progress.

The geotechnical study, which is completed, aimed to determine the extent of state regulatory jurisdiction (ie., dam safety) on use of the lakes for water management purposes, if any; to identify any potential geologic or geotechnical hazards; and, to determine constraints on recharge operations. The study concluded that state jurisdiction does not extend to the lakes because the lakes occur below the natural grade. No major geologic or geotechnical hazards were identified. The stability of the lake slopes, when filled, under static, pseudo-static, and rapid drawdown conditions was found to be acceptable, although measures to correct potential instability due to seepage forces observed along the northeast corner of Lake I were recommended. Erosion from wind generated wave action was found to be potentially problematic in some areas, so shoreline erosion control measures were recommended. Operating constraints were recommended to reduce the potential for slope instability. These included: (1) lake drawdown (if necessary to dewater the lake for maintenance or other purpose) should be limited to 2 feet per day and 10 feet per week; and (2) differential water levels between lakes should be limited to 50 feet.

The hydraulic study, which is completed, aimed to evaluate the proposed water delivery and recharge system for adequate capacity to meet Zone 7 goal to accommodate sustained releases of up to 50 cfs between the months of September and May. The study examined the capacities of each individual component of the delivery and recharge system, from the release capacity of the SBA turnout to the recharge capacity of Lakes H and I. The study concluded that recharge capacity is the limiting component (Figure 4).

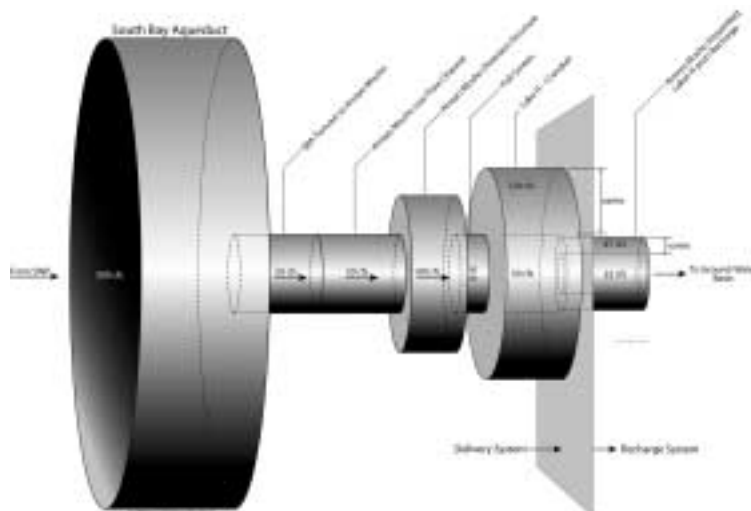


Figure 4. Schematic of Relative Capacities of Delivery and Recharge System Components - Capacities of delivery components meet or exceed the 50 cfs goal, but additional recharge capacity is needed. Zone 7 will explore measures to increase recharge capacity.

Further studies will identify measures to increase the recharge capacity of Lakes H and I. Possible measures include (1) raising the maximum water level in Lakes H and I from 330 feet up to 350 feet to provide a greater driving head and increase recharge (Figure 5); and (2) installing gravity injection wells that penetrate the clay layers underlying the lakes and force water, using the gravity head of the lake, into deeper aquifers.

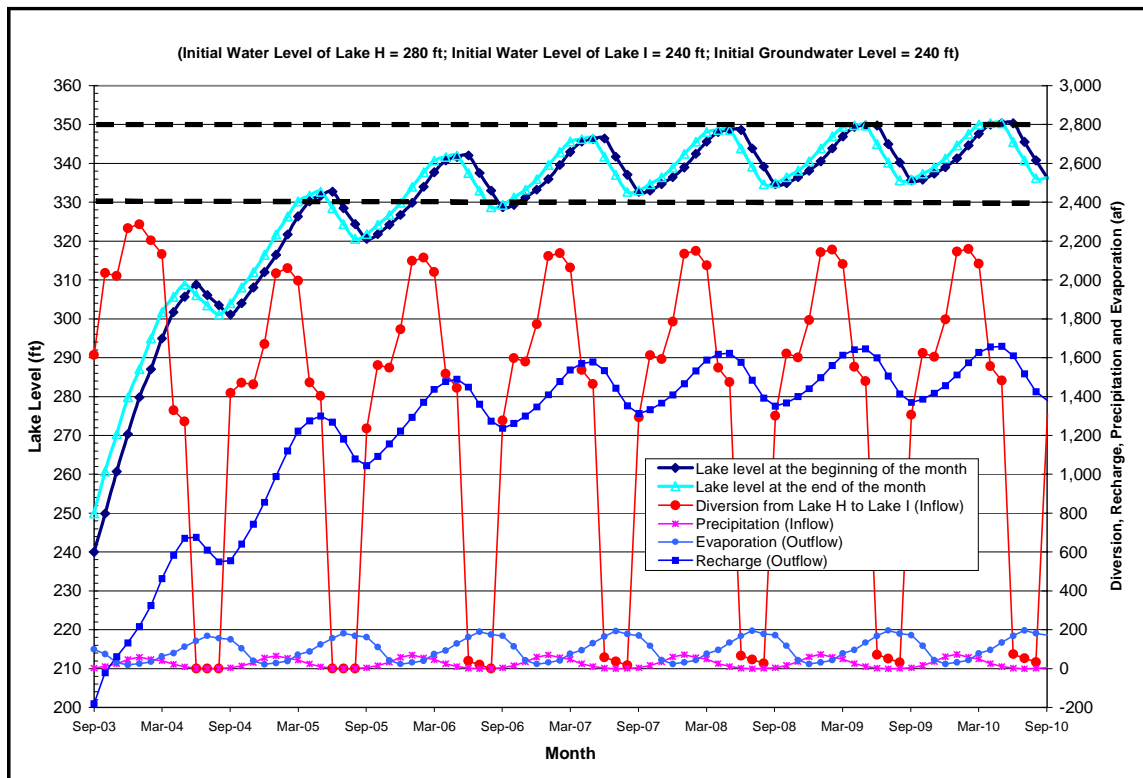


Figure 5. Graph of HISIM Computer Simulation Output for Filling and Recharge at Lake I - Sustained releases of 50 cfs to the Arroyo Mocho and diversion of remaining flows to the lakes between the months of September through May (beginning in September 2003) will fill Lakes H and I. Recharge and evaporation offset diversion inflows and lake levels will not exceed elevation 350 feet.

Design and cost estimation of site improvements and facilities is in progress. Site improvements will include measures recommended in the geotechnical study to correct instability due to seepage forces and potential wind-generated wave erosion problems observed in specific areas. Other major site improvements will include upgrading of access roads along lake perimeters; installing surface drainage systems; and installing fencing and access gates.

Operational Plans and Implementation

This element of the management plan is in progress and will involve development of a plan for operating Lakes H, I, and Cope Lake as safe, highly functional basins for artificial recharge and other immediate uses. The plan will address normal and emergency operations.

Operating constraints will be identified. Special emphasis will be placed on those related to potential geotechnical hazards identified in the geotechnical study needed to ensure public safety and protect adjacent properties (i.e., lake drawdown, differential lake levels); limitations on the rate of diversion and flow routing from basin-to-basin; and, restrictions on lake drawdown to protect habitat conditions and sensitive wildlife, if any. Operating objectives that reflect Zone 7's desired performance will be quantified. These operating objectives will be tied to Zone 7's projected near term operations plans. A plan setting forth operating procedures and protocols to comply with the identified constraints and to achieve the operating objectives will be developed. Procedures and protocols will provide guidance on:

- Timing of imported water deliveries during the wet season to avoid in-channel commingling with natural streamflows;
- Operation of diversion structures (timing of raising and lowering);
- Routing of flows from lake-to-lake;
- Segregation of waters to avoid in-basin commingling;
- Control of lake drawdown and water levels;
- Operation of pumpout facilities, if any (timing, rate, and routing of pumped water) and,
- Emergency communications and operations.

Inspections and Maintenance

This element of the management plan is in progress and involves development of a plan for inspecting and maintaining of Lakes H, I, and Cope Lake, hydraulic structures, and surrounding Zone 7 properties. The plan will describe what should be inspected, how it should be inspected or tested, and at what frequency. Inspection and maintenance needs will likely cover:

- Lake water levels to maintain operations within range of safety;
- Lake water quality, particularly to control algae blooms, and prevent odor problems and fish kills;
- Testing and servicing of hydraulic structures, including diversions, conduits and discharge aprons, valves, and basin pumpout facilities, if any;

- Vegetation, trash and debris accumulated in hydraulic structures;
- Lake water level gages, conduit and open-channel flow measuring devices, and scada/telemetry system components;
- Dividing levees and lake embankments (for seeps, piping, embankment movement or failure, erosion);
- Tools and heavy equipment;
- Landscaping and irrigation systems;
- Control of mosquitoes and other insects;
- Control of burrowing rodents and other animals;
- Fencing;
- Security; and,
- Service roads.

In addition, inspection and maintenance of wildlife habitat conditions in areas affected by facilities or operations will likely be required by regulators.

Operational and Performance Monitoring

This element of the management plan is in progress and will involve development of a plan for monitoring and measuring the operations and performance of Lakes H, I, Cope Lake, establishing performance standards, and setting action thresholds. The monitoring plan will focus on the primary immediate water management function of the lakes; that being groundwater recharge through diversion of imported water releases to Arroyo Mocho. The plan will also cover other aspects of operations that may need to be monitored, including water quality and habitat conditions.

The monitoring plan will identify sites for locating surface flow gaging stations to directly measure diversion rate, transfer of water from lake to lake, and water level at each lake so that recharge can be calculated. Area and storage vs. elevation curves developed for each lake and water level measurements will be used to determine change-in-storage. Evaporation (if significant in comparison to recharge) will be estimated from measurements at the nearest applicable climatic station. The monitoring plan will specify the frequency for measurements. A listing of recommended monitoring equipment manufacturers and models that meet required performance standards will also be provided.

The plan will also identify a key well network for measuring nearby and regional groundwater levels. The plan will utilize existing wells. The plan will utilize existing wells to the fullest extent but, for areas where existing wells are not available and data is needed, the plan will recommend sites and depths for new monitoring wells. The plan will specify water level monitoring methods and equipment to be installed, if any, and

frequency of measurement. If equipment is recommended, a listing of recommended monitoring equipment manufacturers and models that meet required performance standards will also be provided.

Thresholds that trigger initiation of a recharge management action will be determined. The efficacy of installing telemetry and/or SCADA capability for remote monitoring and/or operation of hydraulic controls and incorporating it into Zone 7's district-wide system will be assessed. The assessment will consider practicality, reliability, security and maintenance needs, success in similar settings and applications, particularly at OCWD, labor savings, cost, and other factors. A conceptual layout of a telemetry and SCADA system will be prepared.

FUTURE OPPORTUNITIES AND PLANNING ISSUES

Implementation of the long-term Chain-of-Lakes project will present Zone 7 with a wide range of opportunities and planning issues. These include:

- Diversion, storage, and recharge of imported deliveries, natural stream flow, recycled and potable waters;
- Individual lake functions (recharge, treatment, recycled storage, etc.);
- Treatment of potentially clogging waters prior to recharge;
- Treatment wetlands for water quality improvement of recharge water or recycled storage water;
- Periodic clogging layer removal and lake cleaning strategy;
- Corporation yard and other major support facilities;
- Public recreation needs;
- Access points and service road network;
- Utilities (electrical, communications, water, sewage)

The above opportunities and planning issues will be addressed in Zone 7's future master planning efforts for the Chain-of-Lakes.