Application of Nature-Based Solutions for Temperature Management
Santa Clara River Case Study

Summary of Expert Panel Workshop
May 5-8, 2024

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SOUTHERN CALIFORNIA COASTAL WATER RESEARCH PROJECT

Technical Report 1418

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INTRODUCTION

An expert panel workshop was held on May 5-8, 2024, to discuss options for the use of nature-based solutions (NBS) and hybrid infrastructure approaches to meet temperature requirements in recently modified NPDES permits for the upper Santa Clara River and to develop recommendations for advancing the application of these solutions. The temperature requirements set an effluent temperature limit of 80°F and require that the receiving water temperature is not altered by more than 5°F above the natural temperature associated with discharge from the Water Reclamation Plants (WRPs)[1](hereafter referred to as the delta-five requirement).

The desired outcome was to provide NBS recommendations that Los Angeles County Sanitation Districts (LACSD) can use to further investigate potential temperature management solutions to include in an overall permit compliance strategy. Although the focus of the workshop was on the upper Santa Clara River study area, recommendations should be viewed through the larger lens of application to southern California streams in general.

Definition: Nature-based solutions (NBS) use, restore, or emulate natural processes to achieve engineering objectives and provide co-benefits. In contrast to conventional infrastructure, which can be narrowly purposed and comprised of "hard" structures built of man-made materials, nature-based infrastructure uses natural materials and/or processes to meet engineering objectives and to provide societal, environmental, and economic benefits. NBS can be integrated with conventional infrastructure in hybrid designs that strengthen the overall resilience of infrastructure systems.

Study Area: The focus of the workshop was on the Saugus and Valencia Water Reclamation Plants (WRPs) and the area of the Santa Clara River directly influenced by the discharge from these two WRPs (Figure 1).

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[1] Per Section 5.1.1 of the Valencia and Saugus NPDES permits: "The natural receiving water temperature of all regional waters shall not be altered unless it can be demonstrated to the satisfaction of the Los Angeles Water Board that such alteration in temperature does not adversely affect beneficial uses. Additionally, for waters designated with a warm freshwater habitat (WARM) beneficial use, water temperature shall not be altered by more than 5°F above the natural temperature."

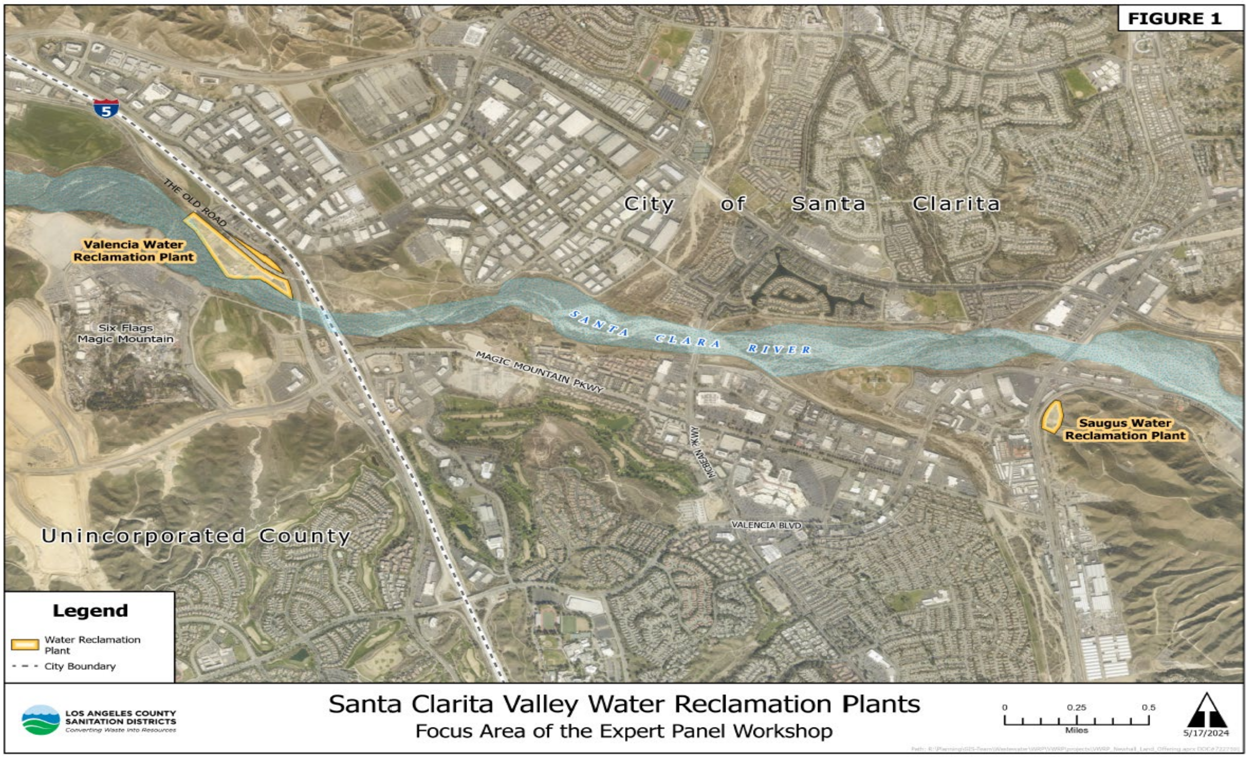

Figure 1. Focus area of the expert panel workshop.

EXPERT PANEL PROCESS

The concept of convening an expert panel was discussed with the project's technical advisory committee and experts were selected based on their knowledge and expertise in development and application of nature-based solutions for temperature and flow management, their independence from ongoing temperature management projects in the Los Angeles Region, and their willingness to participate in the process and provide their objective and thoughtful input and analysis. The expert panel was first convened in February 2024 to develop and evaluate options for the use of NBS to help address temperature management issues in the study area. The panel consisted of the following individuals:

- Brian Bledsoe – University of Georgia, Athens
- Elizabeth Fassman-Beck – Southern California Coastal Water Research Project
- Jon Hathaway – University of Tennessee, Knoxville
- Scott Struck – National Renewable Energy Laboratory
- Eric Stein – Southern California Coastal Water Research Project (*Facilitator*)

Participants in the May 2024 expert panel workshop (left to right): Mischelle Mikulas, Thomas Parker, Katie Marjanovic, Jon Hathaway, Brian Bledsoe, Ray Tremblay, Eric Stein, Ziad El Jack, Scott Struck, Jodie Lanza, Lysa Gaboudian. Not pictured: Josh Westfall, Erika Bensch, Joe Chang, Elizabeth Fassman-Beck, Jan Walker, Elisa Garvey, Hem Vora.

The panel met five times virtually in March and April 2024 to develop an approach, a list of potential solution strategies, and criteria for evaluating strategies. Initially, each panelist independently developed a list of candidate solutions and combinations of solutions. The solution list was refined using a modified Delphi approach where the composite list of solutions from all the panelists was iteratively constrained and re-evaluated to produce a list of 12 priority solutions[2] that reflected different approaches (e.g., evaporation, infiltration, vegetative cooling). During each iteration, solutions were “scored” using a set of criteria developed by the panel members that reflected functionality, regulatory feasibility, physical feasibility, risks, costs, and co-benefits (see Table 2 for the final list of criteria). During the four-day workshop, the panel visited the WRPs and the river and consulted with LACSD operators and managers to better understand on-the-ground constraints and opportunities. Discussions during the workshop resulted in the recommendations summarized in this report.

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[2] Three strategies were subsequently eliminated by the expert panel and the remaining nine strategies were evaluated.

OVERALL WORKSHOP OUTCOMES

The iterative evaluation process allowed the expert panel to incrementally narrow the list of management alternatives to identify strategies that hold promise for achieving some (but perhaps not all) of the regulatory temperature requirements. The recommended NBS solutions should be reviewed with other potentially affected parties (e.g., Santa Clarita Valley Water Agency) and the Technical Advisory Committee established for the project. Ultimately, solutions may need to be used in combination with each other and with traditional engineering approaches to achieve the overall temperature management objectives.

The 80^{o}F requirement may be achievable using a combination of strategies, particularly those that involve infiltration and thermal exchange with groundwater. Potential effects of these strategies on environmental flows and groundwater resources will need to be considered and could ultimately affect their feasibility. The larger challenge is meeting the delta-five requirement. Given the large seasonal and diurnal variations in stream temperatures, it may be challenging to meet this at certain times of the year without using more intensive processes (e.g., mechanical chillers), particularly in the winter when stream temperatures are low relative to effluent temperatures. Groundwater temperature data suggest that even if relatively cooler groundwater was discharged into the river, this requirement may be difficult to achieve as the groundwater differential may not provide enough mass cooling to achieve the permit limits.

The panel recommends a focus on understanding the biological relevance of the permit requirements to determine how to best evaluate compliance that ultimately protects designated beneficial use in the river. This will require additional discussion with regulatory and resource agencies regarding biologically relevant management targets.

Recommended NBS strategies will need to be done within the boundaries of the WRP facilities and nearby properties. The ecological sensitivity of the river combined with its dynamic nature will limit what can be done within the river corridor (e.g., within or just outside of the 100-yr floodplain).

RECOMMENDED STRATEGIES

The panel recommends nine strategies that should be considered for further investigation (Table 1). These strategies should be considered in combination with each other and potentially with other more traditional engineering approaches, to provide an overall temperature management strategy. These strategies can apply to both the Valencia and Saugus WRPs, although each facility may have different constraints associated with available space/areas (Figure 2). In general, the delta-five requirement is more difficult to achieve during the cooler winter months due to the higher differential between upstream river temperature and effluent temperature.

Table 1. Recommended NBS strategies along with their potential to achieve both the absolute temperature requirement and the change in temperature (delta-five) requirement throughout the year. The delta-five requirement typically applies only to the Valencia WRP as there is usually no surface flow upstream of the Saugus WRP.

Management Approach	Cooling potential (80°F)	Cooling potential (delta five)	Uncertainty
Hyporheic discharge	High	Very low [a,b]	Low
Extractive groundwater mixing	High	Very low [a]	Low
Open loop groundwater heat exchange	Moderate	Very low [a]	Moderate
Closed loop groundwater heat exchange	Moderate	Very low [a]	Moderate
Infiltration	Unlimited	Moderate [b]	High
Green roof and green wall	Moderate	Low-moderate [c]	Moderate-high
Subsurface gravel beds	Moderate-high	Moderate	Moderate-high
In-plant thermal recovery	Low-moderate	Very low	Low
Spray-diffuser add on	Low-moderate	Very low	Low

a – uncertainty related to lack of data on groundwater temperatures
b – uncertainty related to need to determine how much infiltrated water returns as surface flow
c – limited potential associated with the relatively low volume that can be treated with this strategy

The following strategies were considered, but were eliminated from further consideration:

- **Constructed wetlands** – Subsurface gravel beds achieve the same function with less space and less concern over the potential for algal growth.
- **Shading** – Dynamism of the river and high stream power resulting in frequent changes in the location and form of the main channel make this strategy unreliable over the long term.
- **Evaporation ponds** – Effectiveness is lower during warm months when ambient air temperatures are too high to provide adequate cooling. There is not enough space at either WRP, and comparable benefits can be achieved using subsurface strategies. There is no opportunity in the river or adjacent floodplain areas due to their ecological sensitivity.

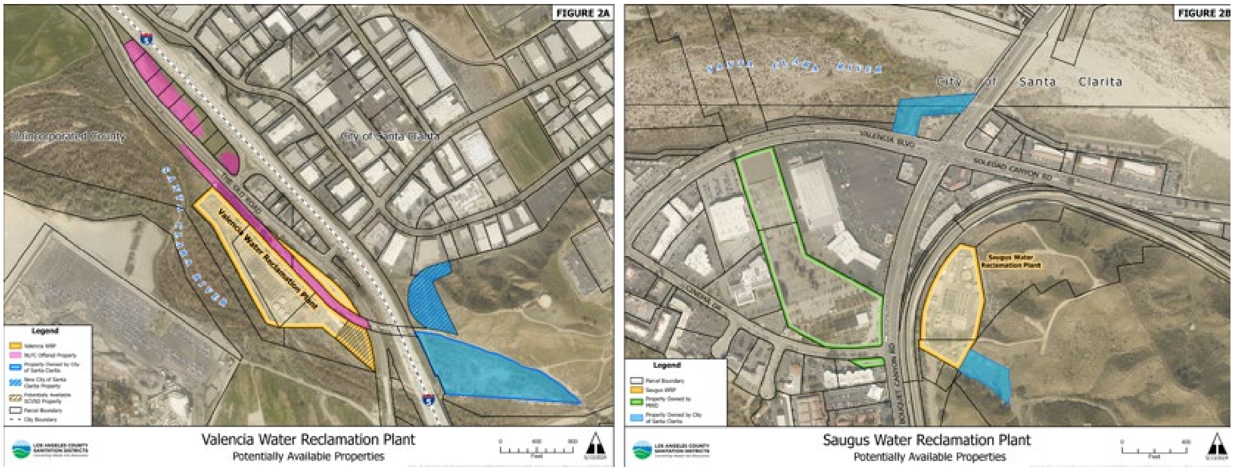

Figure 2. Locations associated with the Valencia (A) and Saugus (B) WRPs where NBS strategies could potentially be employed.

Overall, the panel recommends:

1. A combination of different strategies (used in tandem) have a reasonable potential to achieve the desired overall temperature reduction to 80^{o}F; however, meeting the delta-five requirement will be more challenging, particularly in the cooler winter months. Variable combinations of strategies can be implemented seasonally, or as needed based on ambient air or water temperature conditions.

2. Groundwater mixing, hyporheic discharge, infiltration and surface and subsurface heat exchange strategies hold the most promise. Groundwater mixing and hyporheic discharge options can be added in parallel to existing surface discharge and can be used seasonally to help achieve the delta-five requirement. The balance of surface and subsurface return flow to the river associated with these strategies is flexible and needs further investigation to determine the net effect on environmental flows and biological conditions in the river.

3. Green roofs and green walls are worth exploring further as an innovative solution that can provide incremental temperature reduction within the footprint of the facilities. These strategies (along with spray diffusers) would be particularly useful in the cooler winter months to provide incremental temperature reductions when environmental flow requirements are easier to achieve.

4. Subsurface gravel beds can be opportunistically included as part of other capital improvement projects at the facilities, such as road and parking lot repaving.

5. Spray diffusers and thermal recovery can be integrated into both WRPs for incremental temperature reduction.

6. It will be important to include redundant systems to allow for maintenance and recovery/recharge of specific strategies (e.g., open loop groundwater heat exchange, subsurface gravel beds). For example, subsurface gravel beds will need multiple redundant beds so that one can be taken offline to cool, while the other is in use.
7. Additional information will be necessary to more fully evaluate NBS recommendations. Specifically, additional information is needed on groundwater quality (e.g., chloride, TDS, PFAS) and temperature, soil properties, geotechnical issues, and infiltration rates (e.g., stratigraphy, pump testing).

DESCRIPTION AND CONSIDERATIONS FOR RECOMMENDED STRATEGIES

Each recommended strategy is briefly described below along with specific considerations or additional information needs.

Hyporheic discharge

This strategy involves discharge of effluent to the river via subsurface leach fields or perforated pipes located within the riparian corridor (i.e., not deep aquifer recharge). Net discharge to the river should not change because the subsurface flow will eventually daylight back to the river as surface flow; however, the exact location where the flow will resurface is difficult to predict[3]. Nevertheless, cooling should occur during the period of subsurface flow before the water daylights back to surface flows. The proportion of effluent discharged to the hyporheic zone can be adjusted seasonally in response to environmental conditions using a weir or gate. Specific questions associated with this strategy are:

- ✓ Are there adverse ecological consequences associated with increased seasonal saturation in the riparian zone?
- ✓ What is the heat recovery potential and thermal effect on the river associated with this strategy based on expected infiltration rates?
- ✓ What depth is ideal for hyporheic recharge?
- ✓ Does subsurface discharge adversely affect environmental flow needs or groundwater quality?
- ✓ Will subsurface discharge exacerbate existing bank stability concerns?

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[3] Hyporheic flow is essentially part of the total discharge of the river. The shallow porous space beneath and along the streambed is well mixed with surface flow and forms a continuum of river discharge.

Extractive groundwater mixing

This strategy involves pumping shallow water from the alluvial aquifer, mixing the cooler groundwater with effluent and discharging it back into the river either at the existing outfall location or upstream of the WRP, or back into the shallow aquifer (Figure 3). The estimated groundwater pumping flow required to reach 80°F degrees at outfall entirely with this approach, assuming average outfall temperature is 85°F degrees and average groundwater temperature is 64°F is as follows:

Current flows:

- Valencia 13.3 MGD = 20.6 cfs requires ~ 6.5 cfs of groundwater
- Saugus 5.5 MGD = 8.5 cfs requires ~ 3 cfs of groundwater

Full capacity flows:

- Valencia 21.6 MGD = 33.4 cfs requires ~ 10.5 cfs of groundwater
- Saugus 6.5 MGD = 10.1 cfs requires ~ 3.5 cfs of groundwater

This strategy could be used year-round or seasonally during the warmer portion of the year. Specific questions associated with this strategy are:

- ✓ Are there potential geotechnical concerns depending on the location where blended effluent/groundwater is discharged back into the river?
- ✓ Is there sufficient groundwater available without affecting other uses (i.e., need a pump test for recovery)? Does this vary seasonally?
- ✓ Are there concerns with groundwater quality that could adversely affect surface water quality in the river?
- ✓ Will pumping result in a localized cone of depression (drawdown) that may adversely affect groundwater-dependent ecosystems?
- ✓ What is the expected effect of the extracted groundwater that is discharged back to the river in terms of flow and overall water balance?

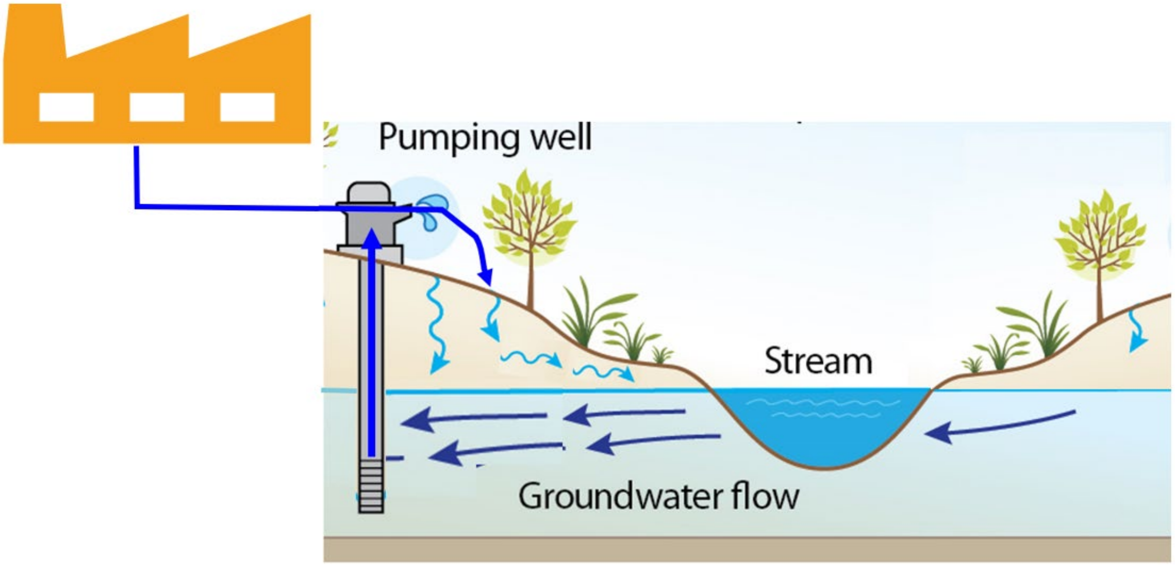

Figure 3. Extractive groundwater mixing.

Open loop groundwater heat exchange

This strategy is similar to extractive groundwater mixing, but effluent is pumped into the shallow aquifer, then pumped out some distance away thereby “pulling” the effluent through the surface aquifer. Following this it is discharged to the surface stream. This allows for longer contact time with the subsurface environment (Figure 4). The distance allowed for the heat exchange can be varied based on the cooling needed and the environmental conditions. This strategy could be used year-round or seasonally during the warmer portion of the year. Multiple or redundant cooling fields may be necessary to allow recovery between uses. Specific questions associated with this strategy are the same as for the extractive groundwater mixing with the addition of:

- ✓ Will this strategy warm the groundwater, and if so does this result in any adverse effects on either groundwater or surface water resources?
- ✓ Will this strategy affect groundwater quality or supplies at downstream wells?
- ✓ Additional design will be needed to ensure capture efficiency at the downstream end of the open loop.
- ✓ Additional information on water table depth and seasonal fluctuation is needed to evaluate the feasibility and inform the general design.
- ✓ Need to model different design configurations to understand distances, pumping rates, and to see how each will perform.
- ✓ Is there sufficient area available to implement this strategy at the Saugus WRP?

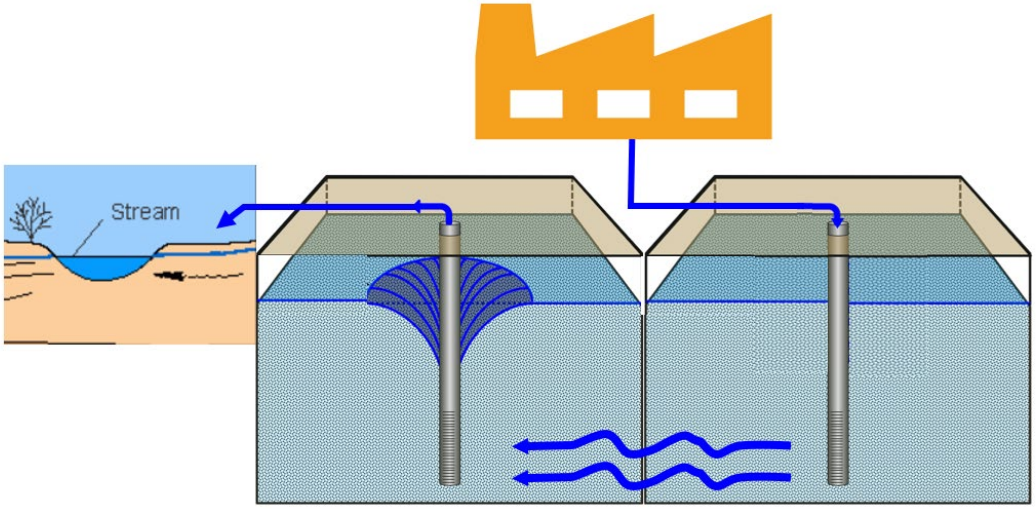

Figure 4. Open loop groundwater heat exchange.

Closed loop groundwater heat exchange

This strategy is the same as the open loop heat exchange but uses a closed pipe (subsurface) so that cooling can occur without any contact with the groundwater (Figure 5). This strategy could also include evaporation ponds over the heat exchange area to increase potential cooling capacity. Multiple or redundant cooling fields may be necessary to allow recovery between uses. As with the open loop strategy, a model will be needed to evaluate the performance of different design configurations. This strategy will have several of the same questions and information needs as the open loop heat exchange solution; however, questions about potential effects on groundwater quality and capture efficiency at the downstream end would not apply to the closed loop system (because there is no direct contact with the groundwater and the pipe is enclosed so losses are minimal).

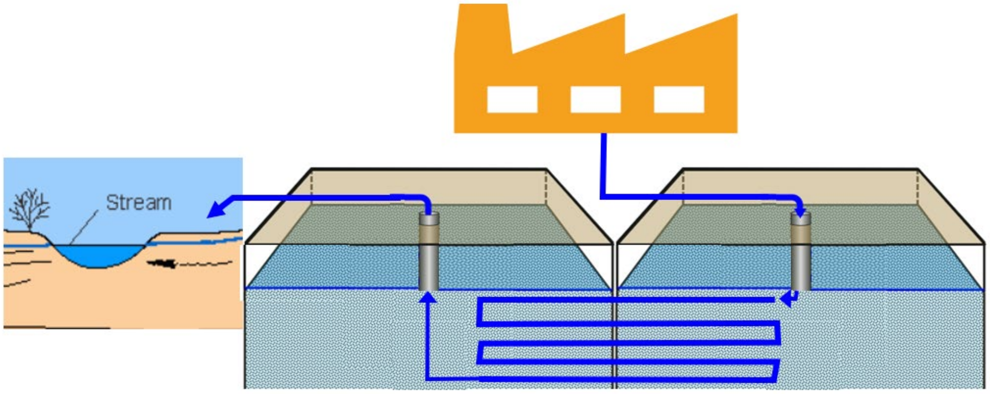

Figure 5: Closed loop groundwater heat exchange.

Infiltration

This strategy involves infiltrating warm effluent into the ground via perforated leach fields, well fields, or dry wells (Figure 6). Unlike the hyporheic discharge solution, infiltration can occur away from the river providing more flexibility in terms of how the strategy is implemented without affecting any portion of the riparian corridor and the risks of damage to the outfall structures due to migration of the river channel during high flow events. This strategy can be applied seasonally or on an as-needed basis. The estimated area necessary to implement this strategy as an exclusive approach, assuming an infiltration rate of 2 inches/hour are shown below:

Current flows:

- Valencia 13.3 MGD = 20.6 cfs requires ~10 acres
- Saugus 5.5 MGD = 8.5 cfs requires ~ 4 acres

Full capacity flows:

- Valencia 21.6 MGD = 33.4 cfs requires ~17 acres
- Saugus 6.5 MGD = 10.1 cfs requires ~ 5 acres

Specific questions associated with this strategy are:

- ✓ Additional information is necessary on stratigraphy and soil hydraulic conductivity to fully evaluate this strategy.
- ✓ What are the potential effects on shallow groundwater quality?

- ✓ What are the potential effects on environmental flows, depending on whether the flow makes it back to the river. This needs to be modeled and/or investigated further.

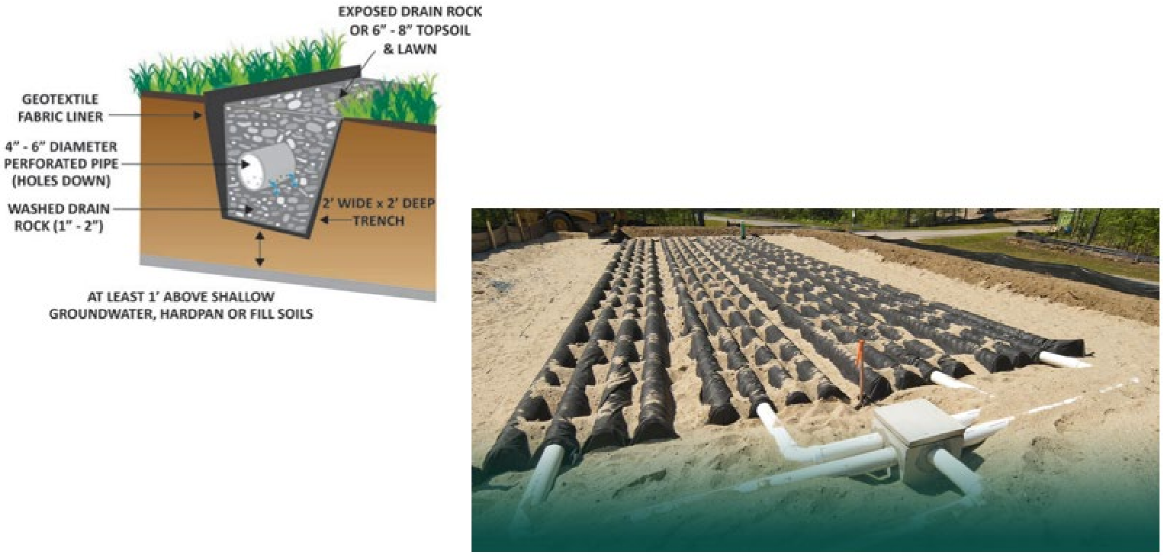

Figure 6. Infiltration.

Green roof and green wall

Construction of green roof or green walls within the facilities uses the system to provide different functions for cooling, depending on the time of day (Figure 7). Evapotranspirative losses from plants during the day to reduce the volume of the effluent discharged to the river. At night, the thermal mass of the green roof substrate is used to cool effluent prior to discharge to the river. The addition of sprayers to irrigate plants with effluent during the day facilitates vigorous plant growth and increases cooling. Spraying at night provides additional cooling. Green roofs or walls could be constructed on top of equalization tanks or on walls of existing tanks. Irrigation of green roofs with grey water has been shown to be effective and to allow the use of low nitrogen substrate, reducing the potential for nitrogen leaching. This strategy can add incremental cooling with minimal reductions in discharge to the river and would improve the overall aesthetics of the facilities. This strategy likely has measurable seasonal impacts: plant water demand (and thus evaporative loss) will be highest in summer (daytime application), while thermal mass for cooling (nighttime application) may be most effective in winter. Specific questions associated with this strategy are:

- ✓ What is the appropriate media composition and installed media depth that should be used for optimal thermal benefit?

- ✓ What is the appropriate effluent application rate to satisfy plant water demand and achieve incremental temperature reductions?

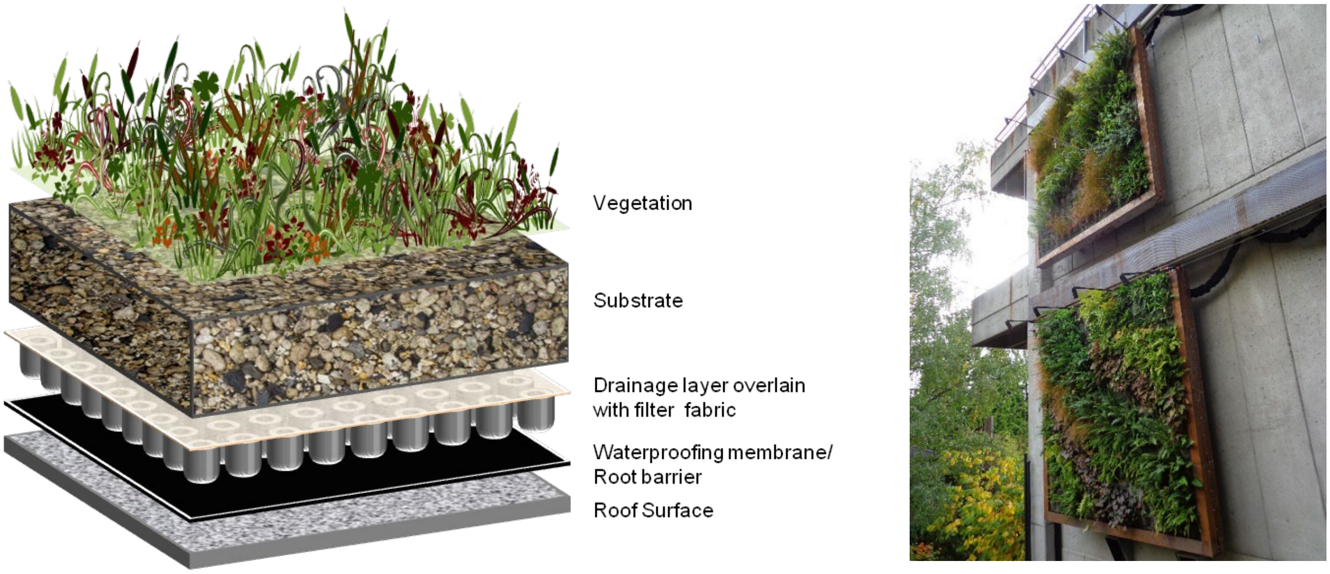

Figure 7. Example green roof (left) and green wall (right).

Subsurface gravel beds

This strategy involves routing effluent flows through a coarse gravel bed while allowing it to mix with cooler groundwater, and then discharging the blended effluent back into the river (Figure 8). Subsurface gravel beds can be constructed beneath existing roads and facilities (preferably as part of planned roadway maintenance or other facility capital improvements) and could be constructed as a lined flow through system or as a system that allows conversion of some of the flow to subsurface flow. There would need to be multiple gravel beds so that one can be taken offline and allowed to cool while the other is being used. Geotechnical stability issues would need to be addressed as part of the design process.

In-plant thermal recovery

There are opportunities to use traditional engineering methods for heat capture within the plant via the treatment process. Excess heat can be converted to fuel cell power plants using heat pumps. This strategy would provide incremental cooling, but the potential energy capture associated with the strategy would need to be calculated as part of the design process to better understand feasibility.

Spray-diffuser add-on

This add-on strategy would provide incremental reduction in temperature via evaporative heat loss. A gallery of sprayers could be constructed as part of the total discharge to the river. This strategy could be used seasonally as needed and would be most beneficial during the warmer months (or to help meet the delta-five requirement during the cooler months) and could improve overall habitat quality. We estimate that approximately 20 psi of head would be needed to run the sprayers.

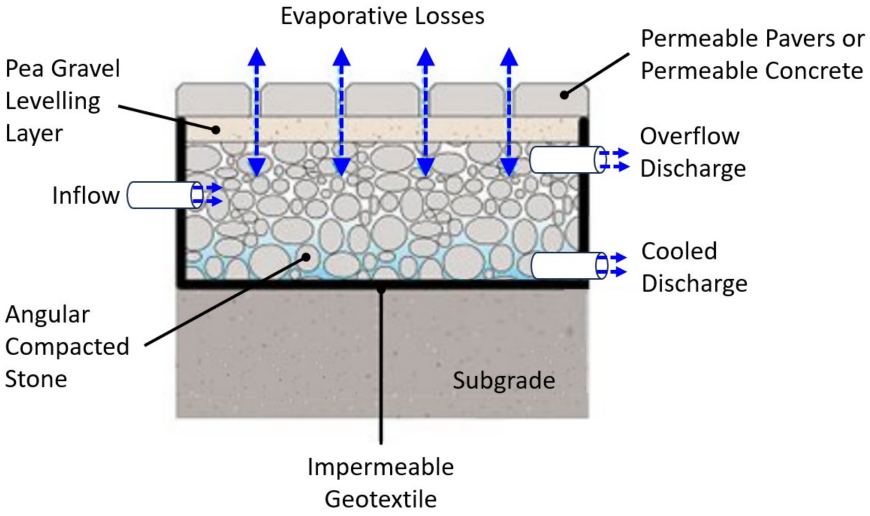

Figure 8. Subsurface gravel beds.

EVALUATION OF RECOMMENDED STRATEGIES

The recommended strategies were evaluated by the expert panel using a multi-criteria decision analysis based on 16 criteria (organized into five major categories). The first 16 criteria addressing functionality, regulatory feasibility, physical feasibility, risks, and costs were used to rank strategies relative to each other. Criteria were weighted by the panel based on their relative importance in determining a preferred strategy(ies). Benefits were evaluated qualitatively to illustrate opportunities for co-benefits of various strategies beyond temperature control. Rankings can be used to help prioritize strategies in terms of further investigation and future investment (Table 2). Feasibility criteria were more variable between strategies, whereas risk criteria were less variable, suggesting that feasibility considerations may be a more important factor in discriminating strategies.

Based on the expert panel ratings, strategies that capitalize on the thermal capacity of subsurface flows/groundwater have higher potential as practical control strategies (e.g., extractive groundwater mixing, open loop groundwater heat exchange and closed loop groundwater heat exchange). Additionally, within plant thermal recovery and spray diffusers may offer additional benefits worth exploring. As stated above, the ultimate approach will likely require a hybrid solution that uses multiple strategies in concert with each other (Figure 9).

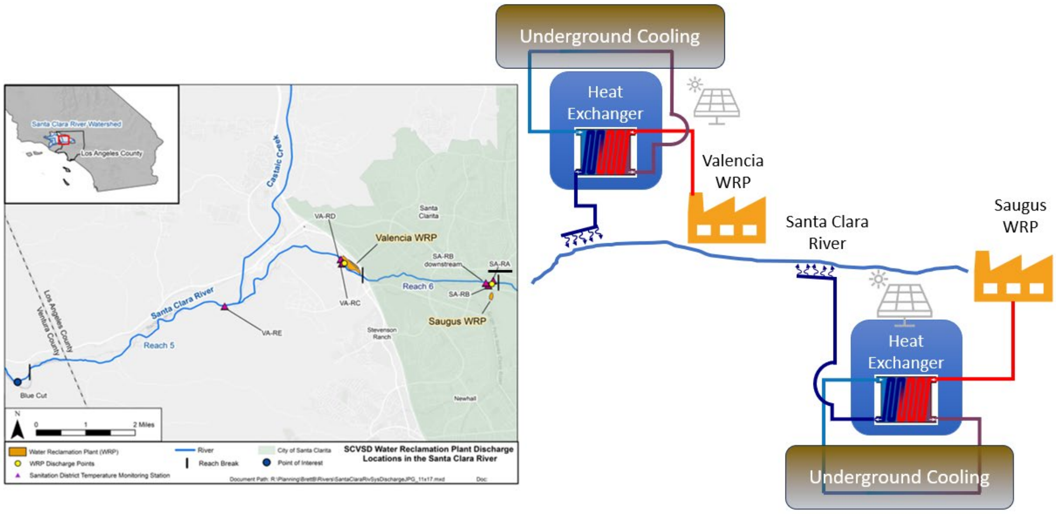

Figure 9. Example of combination of multiple strategies being used in concert with each other (closed loop subsurface cooling and hyporheic discharge).

Table 2. Ratings of each strategy based on the evaluation criteria. Colors denote different ratings with warmer colors being less desirable (higher numbers). Weighting were assigned based on the relative importance of each criterion from HIGH (1) to LOW (3).

Major Criterion	Sub-criterion		Relative Importance	Strategy								
			weighting	Hyporheic discharge	Exctractive GW mixing	open loop GW heat exchange	Closed loop GW heat exchange	Infiltration	Green roof and green wall	subsurface gravel beds	In-plant thermal recovery	spray-diffuser add on
Functionality			HIGH									
	limitations on magnitude of temperature reduction under different conditions	1 (low) - 5 (high)	1	2	1	2	2	1	5	4	4	4
	Loses value over time	1 (low) - 5 (high)	1	1	1	1	1	2	2	3	1	1
	lacks flexibility / adaptability / modularity	1 (low) - 5 (high)	1	3	3	3	3	2	5	4	5	2
Physical Feasibility			MEDIUM									
	area necessary to implement strategy	1 (low) - 5 (high)	2	3	1	2	3	5	5	4	2	2
	limitations based on availability of suitable substrate	1 (low) - 5 (high)	2	5	1	2	1	5	1	1	1	1
	limitations on effluent volume treatable (feasibility)	1 (low) - 5 (high)	2	1	3	2	1	2	5	1	1	5
Regulatory Feasibility			HIGH									
	difficulty in obtaining agreements/permits for water management/discharge	1 (low) - 5 (high)	1	5	4	3	2	4	1	3	1	3
	difficulty in obtaining permits for construction	1 (low) - 5 (high)	1	5	1	4	1	2	1	1	1	1
Risks			MEDIUM									
	potential for adverse ecological impacts	1 (low) - 5 (high)	2	2	2	1	1	1	1	1	1	1
	potential severity of effects on water availability/supply	1 (low) - 5 (high)	2	1	3	1	1	1	2	1	1	2
	potential magnitude of ancillary disadvantages (e.g., potential for fouling)	1 (low) - 5 (high)	2	2	1	2	3	2	3	4	3	2
Costs			LOW									
	construction cost	1 (low) - 5 (high)	3	2	1	2	3	2	2	4	3	1
	energy demand	1 (low) - 5 (high)	3	2	2	3	3	2	2	2	1	1
	magnitude of O&M needs	1 (low) - 5 (high)	3	2	1	2	3	2	5	4	4	2
		OVERALL (no weight)		36	25	30	28	33	40	37	29	28
		OVERALL (weighted)		62	44	54	56	61	75	69	54	49
Benefits												
	ecological co-benefits obtained	H, M, L		M-H	L	L	L	M	H	L	L	M
	other co-benefits obtained (e.g., water supply, community benefits)	H, M, L		M	M-H	M	M	M	H	M	M-H	M

NEXT STEPS AND ADDITIONAL INFORMATION NEEDS

The expert panel was able to identify a set of NBS strategies that hold promise for addressing temperature requirements necessary to protect beneficial uses. Additional analysis will be necessary to fully evaluate the potential effectiveness and feasibility of these solutions over a range of conditions. This subsequent analysis should include (at a minimum) the following:

A. More detailed design of recommended strategies coupled with modeling and analysis of the expected performance of different solution configurations.

B. Full analysis of the effectiveness of the recommended strategies will require modeling temperature response in the river and preferably the interaction between flow and temperature to ensure that both needs/requirements can be met. Flow and temperature responses should be related to the probability of supporting target ecological communities. This requires agreement with resource and regulatory agencies on both environmental flow and temperature requirements.

C. To support design analysis additional information is needed on:
    - ✓ Groundwater quality (e.g., chloride, TDS, PFAS) and temperature
    - ✓ Soil properties, including geotechnical stability, infiltration rates, etc.
    - ✓ Stratigraphy, pump testing, etc.
    - ✓ Available land/space for implementing various strategies.

D. Additional discussions should be pursued on the relationship between the delta-five temperature requirements and relevant ecological targets reflective of beneficial use goals.

E. Once priority strategies are agreed upon, they should be tested using pilot scale implementation where performance can be assessed, and designs adjusted to optimize performance.

F. Ultimately, a monitoring program will need to be developed with indicators that can appropriately evaluate the effectiveness of the NBS strategies. This information will help improve performance for this project and inform other temperature management efforts in the region.