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Technical Memorandum 3-Engineered Facilities Evaluation for Phase 1 Conjunctive Use and Enhanced Aquifer Recharge Project:

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Prepared for

County of Santa Cruz
Environmental Health Services
701 Ocean Street
Room 312
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K/J Project No. 0864005

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Technical Memorandum No. 3

To: Mr. Mike Cloud and Mr. John Ricker
Santa Cruz County Health Services Agency

From: Sachi Itagaki, P.E. and Gregg Cummings, P.E.
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Subject: Engineered Facilities for Groundwater Conjunctive Use
Santa Cruz County Conjunctive Water Use and
Enhanced Aquifer Recharge Study
K/J 0864005

1 Introduction

Kennedy/Jenks Consultants (Kennedy/Jenks) is pleased to provide the Santa Cruz County Health Services Agency (County) with the Draft Technical Memorandum No. 3 (TM3) in support of the Conjunctive Use and Enhanced Aquifer Recharge Project (Conjunctive Use Project). The Conjunctive Use Project is one of 16 projects funded by a Proposition 50 Water Bond Grant from the State Water Resources Control Board to the Regional Water Management Foundation, a subsidiary of the Community Foundation of Santa Cruz County. The Conjunctive Use Project is Project #3 of the grant and is being administered by the County.

The structure of TM3 is as follows:

1. Introduction
2. Background
3. Overview of Potential Source Waters
4. Inventory of Existing Infrastructure
5. Overview of Conceptual Infrastructure Requirements
6. Planning–level Cost-estimating Approach

Depending on the source of the water, treatment and end use needs, a combination of the facilities described in Section 5 will be used to achieve the project goals.

2 Background

Scope

The objective of the Conjunctive Use Project is to assess the most appropriate approaches for coordinating water projects and increasing groundwater storage to provide reliable drinking water to the lower San Lorenzo River Watershed (Watershed), mitigate declines in groundwater levels, and increase stream baseflow. This portion of the Conjunctive Use Project will provide an overview of the engineered facilities necessary to implement opportunities such as water exchanges, winter streamflow diversion, active and in-lieu recharge, and/or reclaimed wastewater to replenish groundwater storage in the Santa Margarita Groundwater Basin (SMGB).

3 Overview of Potential Source Waters

As described in more detail in Draft Technical Memorandum No. 2A – Water Rights Evaluation and Draft Technical Memorandum No. 2B – Availability of Water Sources for a Conjunctive Use Framework Approach to Water Resource in the San Lorenzo Creek Watershed, Santa Cruz County, there is a range of supply sources of varying quantities and qualities that can be used conjunctively within the SMGB. These sources are summarized in the table that follows and are described in detail in the following sections.

3.1 Surface Water Quantity and Quality

The groundwater could be supplemented with the surface water sources within the SMGB as summarized above. From a water rights and hydrologic perspective, Bean Creek and Carbonera Creek appear to be the most feasible because they appear to be largely unappropriated as described in Draft Technical Memorandum 2A and have ample winter supply in most years as described in Draft Technical Memorandum No. 2B. In addition, Zayante Creek has a filing of 17,000 AF on behalf of North Santa Cruz County which could also be accessed. Exchange/transfer of existing water rights on the San Lorenzo River held by Santa Cruz Water Department or San Lorenzo Valley Water District are also potential sources of surface water. (See Technical Memorandum 2A for Task 2.2 for more information regarding water rights.)

However, recent regulatory activities with respect to the draft Coho Recovery Plan and draft Habitat Conservation Plan, will require reevaluation of surface water availability on a broader basis outside of strictly water rights and hydrologic availability.

The water quality of surface waters are likely to be high in suspended sediments, especially during large storm events. Most of the flow in Carbonera Creek is stormwater from urban runoff as evidenced in the high wintertime peak flows and low dry season base flows as discussed in Technical Memorandum 2B.

Table 1: Overview of Potential Source Waters

Source	Quantity		Quality	Notes
Surface Water	Ave. Stream Flow[1] (AFY)	Ave. Yield[1] (AFY)		
Bean Creek	8,000	520	Some sediments; may be controllable through erosion control	
Carbonera Creek	4,000	480	Suspended sediments from eroded creek bed and first flush urban runoff contaminants[2]	Highly urbanized watershed resulting in highly erosive peak flows.
Newell Creek	11,000 – 12,000 (est)[3]			Loch Lomond Reservoir not specifically evaluated
San Lorenzo River	96,100	1,643	Suspended sediments likely (70 – 1,700 tons/day during wet season)	Flow estimate from Big Trees Gauge, approximately 90 % of total watershed; cumulative flows including upstream tributaries (e.g. Newell Creek)
Zayante Creek	8,000	500	Suspended Sediments likely (8,000 tons of sediment/yr)	
Stormwater	300 – 500 AFY from urban runoff in Scotts Valley[4]		First flush urban runoff contaminants[2]	Not all available stormwater is likely to be captured and recharged.
Recycled Water for groundwater recharge	Up to 400 AFY based on 0.877 MGD of future wastewater flow for 5 month winter season		Treated to Title 22 Tertiary unrestricted use level; emerging contaminants such as personal care products	Demand for recycled water for dry season urban reuse exceeds supply regionally. Likely wintertime availability.
In-lieu Exchange	Likely to be accommodated within existing excess wet season surface water supplies		Treated potable water	Potential exchange partners include Santa Cruz Water Department, San Lorenzo Valley Water District, Scotts Valley Water District

[1] Average stream flow in acre-feet per year (AFY) is the average of the period of record available for the flow gage. The Average yield is a calculated value that accounts for a flow sufficient for environmental uses, then assumes an additional diversion for conjunctive use during the wet season. More detailed explanation is found in Technical Memorandum No. 2B for this Conjunctive Use Project (Balance Hydrologics, 2009).
[2] Urban runoff contaminants include nutrients from fertilizers, bacteria, zinc, copper, lead, and some oils and greases.
[3] Estimated based on rainfall-runoff relationship for Eastern Santa Cruz Mountains (Balance Hydrologics, 2009) and mean annual precipitation at Newell Creek of 45 – 46 inches.
[4] Based on estimated impervious area along Scotts Valley Drive and Mt Hermon Drive of approximately 300 Acres and average annual rainfall of 42 inches (3.5 ft).

3.2 Stormwater Quantity and Quality

As water supplies become more limited, stormwater increases in its potential to contribute to overall water supplies. In some areas, such as Scotts Valley, urbanization that has produced increased quantities of stormwater, also has resulted in reduced groundwater recharge. Capture and recharge of stormwater in Scotts Valley could have multiple benefits such as increased aquifer storage, increased summer base flows to Bean and Carbonera Creeks, as well as reduced erosion and downcutting of Carbonera Creek.

Quantity

As summarized above, most of the stormwater in the SMGB is generated within Scotts Valley along Scotts Valley Drive and Mount Hermon Road. Much of it is discharged to Carbonera Creek while a small portion flows northwest toward Bean Creek. An initial estimate of impervious area within Scotts Valley is approximately 300 acres as distributed in the table below and shown on Figure 1 that follows.

Table 2: Impervious Area Estimates in Scotts Valley

Impervious Area Type	Estimated Area
Roadway	29.8 Acres
Parking Lot	199.4 Acres
Building/Structure	62.25 Acres
Total	291.45 Acres

However, the impervious area also includes landscape and unpaved areas. An estimate of 15% of the 291 acres may be landscaped and/or unpaved areas for a net impervious area of about 250 acres.

The average annual rainfall in Scotts Valley is 42 inches, which is equivalent to 3.5 feet. If all of the stormwater is captured, that is over 1,000 AFY. However, the estimated impervious area is likely to be less than estimated in Figure 1 and the actual rain fall that is likely to be captured and recharged is less than 100% of the average annual rainfall. Therefore, a more likely estimate is in the 300 – 500 AFY range.

The discussion below provides an overview evaluation of water quality issues from urban stormwater runoff that including the potential constituents such as sediment and contaminants.

Figure 1: Estimated Areas of Impervious Coverage in Scotts Valley

General Water Quality Characteristics of Urban Stormwater Runoff

Unlike the non-point source runoff from pre development conditions, runoff from urbanized areas contains various pollutants associated with human activities. It is now well understood that urban runoff is a significant source of water pollution resulting in impacts to water resources. When discussing urban runoff it is important to understand that urban runoff is composed of all flows that conveyed from urban land uses including both wet weather flows (runoff associated with storm events) and dry weather flows (i.e. runoff from other typical urban sources, landscape irrigation, residential wash down waters, hydrant flushing, etc). Some studies have indicated that nearly one-half of the discharge from an urbanized area could be dry weather flows. However, in the Scotts Valley area, it is likely that wet weather flows will be a higher proportion of stormwater than in other urbanized areas.

The urban activities of most concern can be categorized into municipal activities (corporation/maintenance yards, facilities, street maintenance, etc), industrial/commercial activities, construction activities, and residential activities (pets, car washing, fertilizer and pesticide application).

Examples of typical urban elements and activities that generate pollutants include the following.

- Parking lots
- Atmospheric deposition
- Pavement maintenance
- Building exteriors
- Animal waste
- Waste handling/disposal
- Vehicle fueling, operation and maintenance
- Materials handling and storage
- Construction activities
- Fertilizer and pesticide application
- Cleaning activities
- Illicit connections
- Illegal dumping

The pollutants may generally include the following:

- Sediment
- Metals
- Organics
- Pesticides
- Bacteria
- Pathogens
- Nutrients
- Poly chlorinated biphenyls (PCBs)
- Poly aromatic hydrocarbons (PAHs)
- Plasticizers
- Oil and Grease

Vector control resulting from standing water is also a potential concern when managing urban stormwater runoff.

In an effort to better control urban runoff, USEPA has promulgated storm water regulations, in the form of NPDES Permits, for large and small municipalities, industrial facilities, and construction activities. The focus of these regulations and the programs developed under the permit requirements has been on the use of Best Management Practices (BMPs) to control and reduce the pollutants. The regulations generally require municipalities to reduce the discharge of pollutants to the maximum extent practicable (MEP). To date, the BMPs developed have been largely source-control in nature, but, increasingly permitees are required to implement treatment type controls, a trend that will likely increase in future years.

Water Quality of Urban Stormwater Runoff near Scotts Valley

As part of the USEPA storm water regulations for small municipalities, the City of Scotts Valley (City) is regulated under the California Small Municipal Separate Storm Sewer System (MS4) General Permit. In the 2008 Scotts Valley Storm Water Management Plan (SWMP), the City identified impairments by sediment and fecal indicator bacteria in both Carbonera and Camp Evers Creeks in accordance with the listings of the Regional Water Quality Control Board (Regional Board). Total Mass Daily Load (TMDLs) allocations have been developed for sediment and pathogens by the Regional Board. As part of TMDL development the following were identified as controllable sources.

- Storm drain discharge
- Pet waste
- Homeless encampments
- Septic systems
- Domesticated animals
- City sanitary sewer collection system leaks
- Private laterals

The City's SWMP contains BMPs to address these sources. The water quality of urban stormwater runoff can be improved prior to recharge by implementation of low impact development (LID) measures that treat and infiltrate runoff from streets, roofs and parking lots. LID measures are described in greater detail in Section 5.3.

Other discussions related to the regulatory requirements of stormwater can be found in Technical Memorandum No. 4 – Regional Water Demand.

3.3 Recycled Water Quantity and Quality

Title 22 tertiary treated, unrestricted use recycled water is already being used in the Scotts Valley area for irrigation during the summer period. It is estimated that at build-out, there may be a wastewater influent of 0.877 MGD which could be fully used for irrigation during the dry season. Excess recycled water is available in the wet season (estimated at up to 400 AFY based on 5 month availability) when irrigation demands are low and could potentially be used for recharge. However, there is currently more dry season recycled water demand identified than supply, and permitting a wintertime groundwater recharge facility using recycled water will require additional dilution water and may have significant challenges. Additional discussion regarding recycled water quantities can be found in Technical Memorandum No.4.

3.4 In-lieu Exchange Quantity and Quality

In the SMGB, the concept of an in-lieu exchange is to obtain other potable water through exchange such that the groundwater basin is not pumped. The alternative water supply, which could be wet season surface water, is used in-lieu of groundwater pumping allowing water in storage to accumulate. Some of the exchange concepts are discussed below.

At present, there is a 2-inch diameter meter connecting a 6-inch pipeline of the Scotts Valley Water District (SVWD) with a 4-inch diameter pipeline in a satellite, groundwater-only system of the San Lorenzo Valley Water District (SLVWD). Limitations in the quantity and elevation of water storage restrict the water that can be be exchanged between the two systems. There is more storage within the SVWD system than in the SLVWD satellite system so SLVWD may derivee greater benefit from this intertie. Therefore, this intertie is only of benefit during short-duration emergencies and presents no long-term quantity or water quality benefits since both the SVWD and SLVWD wells draw from the same groundwater basin.

SLVWD is considering interties between the various portions of the SLVWD including the northern portion served largely by surface water; the recently acquired Felton surface water system, and the two groundwater-only systems, Probation Wells and Manana Woods, in Scotts Valley. However, there may be water rights and other issues that prevent movement of water between the various SLVWD systems. If constructed, an intertie between the northern or Felton system and the groundwater-only systems of SLVWD could be continued to SVWD to allow water from SLVWD's surface supply to be accessible to SVWD. Surface water quality from the northern systems may vary from the groundwater quality but can be blended to minimize impacts.

The SVWD is also in the process of evaluating an intertie with the Santa Cruz Water Department (SCWD). A likely route is to continue north along Sims Road to La Madrona Road and into the SVWD system. A small booster pump station would be needed to provide adequate pressure to SVWD's system. The intertie would deliver potable water treated at the

SCWD's Graham Hill Water Treatment Plant (WTP) to SVWD in the wintertime. It could also be used during an emergency in the summer time. Similar to the SLVWD, surface water quality from SCWD could vary from the groundwater served in SVWD; however, these differences can be minimized through blending. Some studies have been initiated to further evaluate this option.

SLVWD also has 313 AFY (102 MGY) raw surface water stored in Loch Lomond reservoir that could be used to offset groundwater pumping. The mostly likely mechanism for SLVWD to use Loch Lomond Reservoir water is to exchange raw water for treated Loch Lomond Water from the SCWD, through a proposed intertie. There should be essentially no difference in water quality between Loch Lomond and the San Lorenzo River; any differences between the surface sources and groundwater can be minimized through blending. A study to evaluate alternative delivery mechanisms for Loch Lomond water to SLVWD is currently underway and expected to be completed in summer 2010.

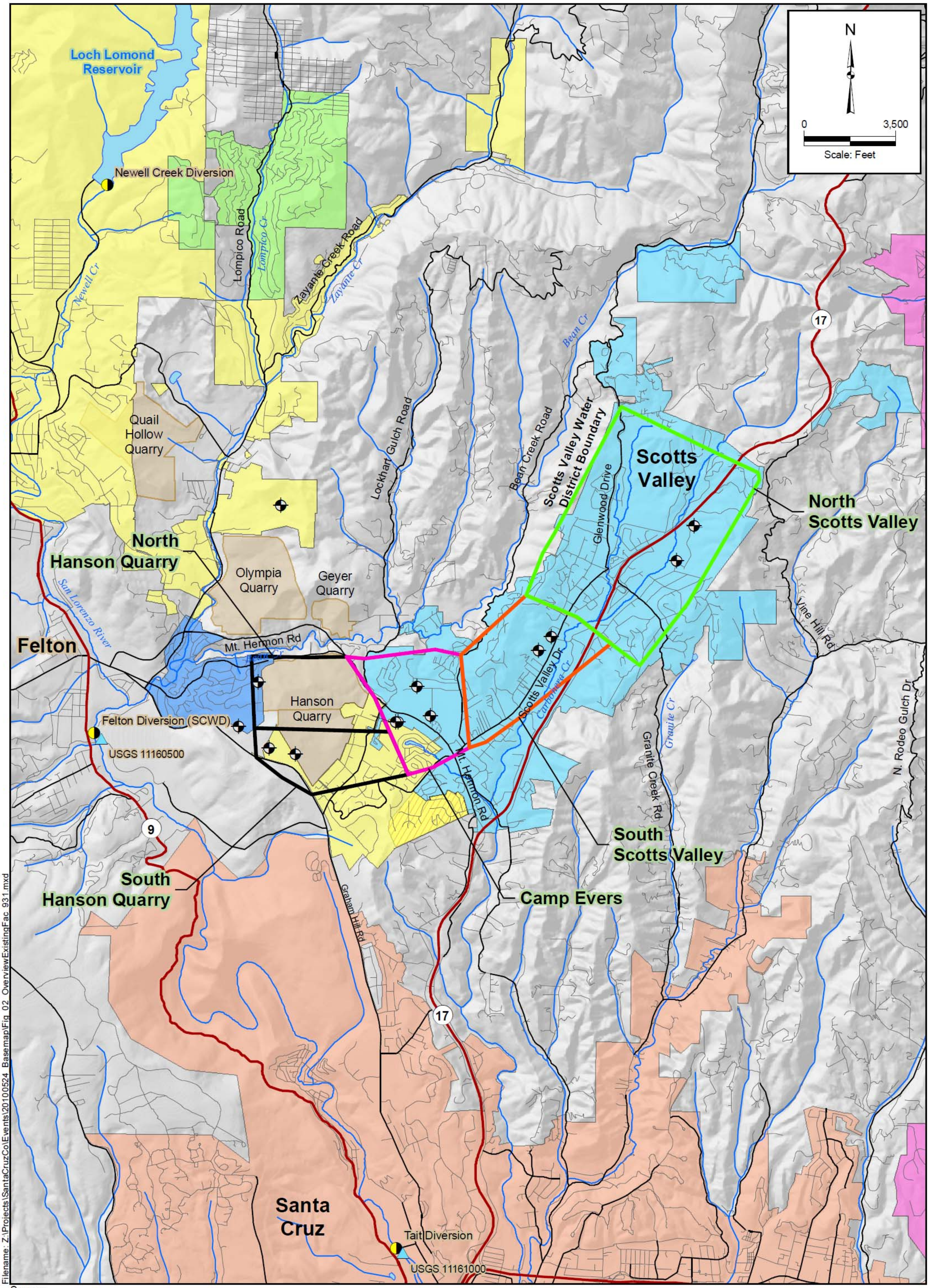
4 Inventory of Existing Infrastructure

There is existing infrastructure that could be integrated into a conjunctive use project. This infrastructure could include surface water diversion facilities, pipelines, and recharge facilities. These facilities are described below and shown on Figure 2 that follows.

4.1 Existing Diversion Facilities

There are several existing diversion facilities that are owned and operated by the area water agencies as follows. The SCWD facilities that are potentially relevant to the SMGB are the Felton and Tait Street Diversions located on the San Lorenzo River and Loch Lomond Reservoir. It should be noted that from the June 1 – October 31 period, the San Lorenzo River and its tributaries are fully appropriated from a water rights perspective. However, there are likely high winter flows that are available for diversion that will require consultation and negotiation with State and Federal fishery agencies.

The Felton Diversion is located just downstream of the confluence of Zayante Creek and the San Lorenzo River and is a diversion structure with an inflatable dam to divert flows into a screened intake sump that is typically used during the winter months of dry years. Water rights limitations at Felton include a 20 cfs/12.9 MGD year-round rate limit as well as instream flow requirements ranging from 10 cfs/8.4 MGD to 25 cfs/16.2 MGD depending on the time of year. Water from the Felton Diversion is pumped up to Loch Lomond Reservoir via the Newell Creek Pipeline or directly to the Graham Hill WTP. There are 3 pumps at the Felton Diversion as well as 6 pumps at the Felton Booster Station that can be used in various combinations to regulate the diversion rate.



Source:

- USGS Stream Gauge Location
- Santa Cruz Water Department Diversions
- Well Location
- Camp Evers
- North Scotts Valley
- South Scotts Valley
- Hanson Quarry
- Santa Cruz City Water Department
- Mt. Hermon Association
- Lompico County Water District
- Scotts Valley Water District
- Soquel Creek Water District
- San Lorenzo Valley Water District
- San Lorenzo Valley Water District - Manana Woods
- Mineral Resource Area (Quarry)

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OVERVIEW OF EXISTING FACILITIES

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Figure 2

The SCWD Tait Street Diversion is located just north of Highway 1 on the San Lorenzo River and is comprised of a surface water diversion as well as wells. There is a concrete check dam which directs flow to a screened intake sump. There are 3 vertical turbine pumps with a total capacity of 7.8 MGD to pump water to the Graham Hill WTP. This 7.8 MGD pumping rate compares to a wintertime SCWD demand of 11 MGD or less. Water rights specify that there is a 12.2 cfs/7.9 MGD maximum diversion rate year round at Tait Street. Near the Tait Street diversion are the Tait Well No.1 and Tait Well No. 4 that are 92 feet and 79 feet deep respectively. Each of these wells can produce 0.6 MGD. The well pumps discharge to the Tait Street diversion sump allowing a single set of pumps to pump surface diversion and/or groundwater flow to the Graham Hill WTP.

The Loch Lomond Reservoir on Newell Creek has 8,900 AF of storage and an estimated annual yield of 3,230 minus 742 AFY for instream releases or 2,500 AFY net annual yield. The SCWD is entitled to 2,187 AF of the annual yield while the SLVWD is entitled to 313 AF of the annual yield although SLVWD currently has no means to access this entitlement. The SCWD is currently applying to make changes to their water rights to maximize water to storage such that up to 5,600 AFY from Newell Creek is allowed to flow to storage in Newell Creek Reservoir/Loch Lomond and to allow up to 3,000 AFY of the City's Felton water right to flow to storage.

To supply its northern service area, SLVWD obtains surface water from diversions at seven surface streams in the Ben Lomond Mountain watershed. These seven diversions supply approximately 900 AFY on average. In addition, as a result of the acquisition of the Felton water system, SLVWD also acquired water rights and facilities for water from the Fall Creek watershed to be diverted at Felton and treated at the existing SLVWD Felton Water Treatment Plant. In the wintertime, there may be excess surface water in SLVWD's northern service area, Felton, and/or in Loch Lomond that could, with new intertie facilities, be piped to the SLVWD southern service area which is currently served exclusively with groundwater, thus providing in-lieu conjunctive use in the SMGB.

4.2 Existing and Abandoned Pipelines

During discussions with the TAC and others knowledgeable in Santa Cruz County, a few pipelines were identified that could be used to operate groundwater conjunctively with surface water or other waters. In Scotts Valley, there is an existing pipeline currently used to deliver recycled water, that runs from the Scotts Valley Wastewater Plant (WWTP) located northwest of the junction of Mount Hermon Road and Scotts Valley Road to the Hanson Quarry. The pipeline was originally used to convey treated secondary wastewater to the quarry area for disposal. The 8-inch diameter pipeline was constructed of fused poly vinyl chloride (PVC) with a maximum pressure rating of 70 pounds per square inch (psi) and is scheduled for replacement as a recycled water pipeline because of its poor condition and low pressure rating. The segment to Hanson Quarry is currently unused, but may be limited in its pressure rating.

In addition, there is a secondary effluent disposal pipeline from the Scotts Valley WWTP to the Santa Cruz WWTP's ocean outfall pipeline. Scotts Valley WWTP discharges to this pipeline when recycled water demand is low, mostly in the wintertime. At present, this effluent disposal pipeline is under consideration to deliver secondary effluent to the Pasatiempo Golf Course so that the Golf Course can provide additional treatment and replace potable water with recycled water for part of their irrigation demand.

As discussed earlier, there are several emergency intertie pipelines. Given the small diameter of the existing pipelines, they would be of limited utility in the transfer of larger quantities of water. However, projects are currently under consideration to construct new pipelines of larger diameter and to construct pump stations in order to increase their usability for transfer of water regionally.

4.3 Recharge Facilities (e.g. quarries)

As discussed earlier, the three quarries in the SMGB are potentially viable recharge facilities as shown on Figure 2. In fact, Hanson Quarry was one of the original disposal sites for treated secondary wastewater. The Hanson Quarry is about 100 Acres of which about 30 acres is the southern portion of the quarry which is hydrogeologically distinct from the northern 70 acres of the quarry. The Olympia Quarry is about 50 Acres, and the Geyer Quarry is about 5 Acres. Since the Geyer Quarry has been turned over to a non-profit land conservancy and is quite small compared to the other two quarries, it is no longer considered as a feasible site for recharge activities.

Each quarry is geologically distinct and presents a range of advantages and disadvantages for use in direct recharge. These advantages and disadvantages are summarized in the table that follows.

Table 2: Summary of Quarries

Quarry Name	Advantages	Disadvantages	Ownership/Status
North Hanson Quarry	- Proximity to Bean Creek - Possible location for raw water sedimentation facilities prior to recharge and/or injection.	- Surface Recharge will be to Santa Margarita formation which will not reach the deeper Lompico (unless injected) because of Monterey shale that occurs between Lompico and Santa Margarita therefore will not have significant regional GW benefit, recharged water will quickly leak back to Bean Creek from Santa Margarita	Owned by Hanson Aggregates and in reclamation planning process; SVWD is exploring purchase of 1 acre in a location that coordinates with existing infrastructure for potential new well.
South Hanson Quarry	- At south end, Monterey formation pinches out, allowing Santa Margarita to be in direct contact with deeper Lompico formation which makes this site more attractive from a surface recharge perspective.	-Somewhat greater distance from Bean Creek -Need to coordinate reclamation planning/development process	Owned by Hanson Aggregates and in reclamation planning process.
Olympia Quarry	-Proximity to Bean and Zayante Creeks -Relatively low elevation gain from creeks - Possible location for raw water sedimentation facilities prior to recharge.	-Same disadvantage as North Hanson Quarry	Owned by Lonestar Aggregates in reclamation planning process?

5 Overview of Conceptual Infrastructure Requirements of Potential Alternatives –

In addition to the existing infrastructure described in Section 4, the types of infrastructure necessary to deliver and/or recharge water directly or in-lieu have been identified and are described in summary as follows. The facility types include:

- Diversion Facilities for Surface Water
- Aquifer Recharge Facilities for Surface and Storm water
- Stormwater Recharge Approaches-Treatment and Low Impact Development (LID) Measures
- Treatment and Delivery of Surface Water for In-lieu Benefit Directly or in Exchange

5.1 Diversion Facilities for Surface Water

There are two options for obtaining surface water: surface diversion, and subsurface diversion. The facilities that would be used for these types of diversion are discussed below.

5.1.1 Surface Diversion Overview

A surface diversion would generally consist of the following major components each of which are described in greater detail below:

- Impoundment Structure: The impoundment structure is comprised of two components, a dam and a fish ladder, that need to function together as a unit.
    - Full or partial dam in the creek/river to back-up the water to allow it to be diverted. The dam could be a:
        - Concrete dam
        - Earthen/Rock dam (not common)
        - Inflatable rubber dam
        - Rock Weir Impoundment with Terraced Rock Pool Bypass Structure
    - Fish passage facilities such as fish ladders.

- Diversion Structure: The diversion structure allows the water in the impoundment to be diverted to the use site and is also comprised of up to three components; a trash rack, a fish screen and an intake structure.
  - Trash rack to prevent large debris from being diverted
  - Fish screen to prevent entrainment of fish – this could also function to screen debris depending on the inlet structure.
  - Inlet structure to control rate of diversion
- Flow equalization and desilting basin, to remove large suspended solids.
- Pipeline and pump system, if required, at the basin to convey the water from the basin to where the water will be used/recharged.

5.1.1.1 Impoundment Structure

Impoundment structures are used to create an area of ponded water such that the water can flow by gravity or be pumped for its ultimate use. One of the largest impediments to construction of impoundments is the need to allow fish passage past the structure. A range of impoundment structures and fish passage facilities are described below.

<u>Concrete Dam:</u> Concrete dams are commonly used to impound water. For small streams, they can be fairly simple structures, trapezoidal in cross-section using wooden weir boards that slide into steel tracks or steel sluice gates that raise and lower to impound water. Weir boards need to be easily removed and sluice gates need to be easily opened to increase capacity during high flow events. Operational and maintenance access across the dam is often provided in the form of an H-20 rated roadway.

As the waterway increases in size and flows increase, more complex concrete dam structures (e.g. buttress or arch dams), control structures (e.g. radial dam gates that open and close), and spillways are often constructed. Fish ladders, described in greater detail below, can be integrated into the concrete dam structure. As the size of the dam and the complexity of the dam gate controls increase, electricity, telemetry and control buildings are often required. For the relatively modest diversion quantities envisioned for this project, a concrete dam may be overly complex and difficult to obtain permits to construct.

<u>Earthen/Rock Filled Dam:</u> As with concrete dams, earthen/rock dams can be used for both small and large-scale applications. They are generally used for reservoir impoundments but not in an in-stream application such as is being considered in this project. The primary reason that they are generally unsuitable for in-stream applications is that flow control is generally either through a spillway or a release pipeline with valves through the base of the dam. Neither of these flow controls lend themselves to diversion of relatively modest flow quantities from a

waterway. Earthen dams are constructed of layers of well compacted earth. Rock dams are constructed of compacted free draining earth with an impervious layer (either at the surface or inside the dam itself). Both types are often filled with a clay core to provide an impervious material. They are often more cost-effective than a concrete dam if suitable material is available near by. However, as with concrete dams, for the modest flows envisioned for diversion an earthern/rock-filled will be difficult to obtain permits for construction.

Rubber Dam: Rubber dams are made of inflatable rubber tubes that are anchored to a concrete foundation structure across the bottom of the water way. They can be inflated by either air or water and therefore require pumps, air/water inlet/exhaust lines, controls to inflate/deflate depending on in-stream flow conditions, electrical access, and structures to control operations. The dam base is often integrated with rip rap and boulders to create entry to fish passage facilities, as well as to protect the rubber dam structure. Integration of fish passage facilities, described below, is critical for rubber dams.

Rock Weir Impoundment with Terraced Rock Pool Bypass Structure: Rock weirs, or step-pools, can be effectively used to facilitate the diversion of streamflow for water resource reasons and yet still provide for conditions conducive to successful fish passage. The range of possible approaches in the use of rock weirs for such purposes depends in large part on the size of the river system, the magnitude of flows over which the structure must function, the geologic and geomorphic characteristics of the river corridor at point of use, and the diverse range of fish species which must be able to pass the weir structure(s). A variety of engineering solutions can also be integrated with the rock weir design to primarily manage for flow rates which are bypassed into an adjacent diversion channel, as well as to convey the associated volume of bedload carried by that flow. These types of structures and approaches have been implemented throughout the western United States with great success, including one local example within the lowermost reaches of San Vicente Creek.

Fish Passage Facilities: Fish passage facilities are critical facilities to any water impoundment/diversion scheme. In addition to a rock weir impoundment with terraced rock pool bypass structure which integrates fish passage with impoundment described previously, there are a range of fish passage options that include:

- concrete rectangular channels with concrete v-notch or rectangular weir structures that have graduated steps from the base to the top of the dam (with or without vertical slots to facilitate fish passage),

- use of multiple rubber dams, each with a drop passable by fish, at increasing elevations to provide impoundment as well as fish passage,

- fish elevators that collect fish with water in a tank-like facility and lift the tank to the higher elevation above the dam, and

- the use of baffles in a natural or manmade channel to create areas of variable flow velocity that the fish can swim against (for an earthen dam, this could be constructed in a culvert that penetrates the dam base). These baffles can be constructed of metal, wood, rock, concrete and can be extended over a steep or shallow slope and can be engineered to be like a pool/riffle system of a natural waterway.

5.1.1.2 Diversion Structure

Diversion structures are usually constructed in an embankment to divert water to a pipeline, open channel, or pump station wet well. As summarized earlier, there are a number of facilities associated with a diversion structure which are described further as follows:

- Trash rack to prevent large debris from being diverted. They are often constructed of bars or screens. Trash rack cleaning is a critical element to trash rack design and needs to occur to prevent overtopping of the turnout structure. Cleaning can be accomplished manually or mechanically.

- Fish screen to prevent entrainment of fish – this could also function to screen debris depending on the inlet structure. Similar to trash racks, fish screens to prevent entry of anadromous salmonids are critical to operation of turnout structures. As described in TM 2C- Fisheries, both the NOAA Fisheries and California Department of Fish and Game have fish screen criteria that describe placement of screens, approach velocities relative to fish size, screen area, sweeping velocity, screen face material and construction, bypass systems, and other technical information associated with fish screens.

- Inlet structure to control rate of diversion. The inlet structure connects to the open channel, pipeline, or pump station wet well and can be comprised of gated (with valve or weir) cast-in place concrete inlet or a cast-in place head wall for a pipeline.

5.1.1.3 Flow Equalization and Desilting Basin

Flow equalization structures are used to capture large peak flows and meter them out to downstream facilities (e.g. pipelines and pump stations) so that downstream facilities can be sized for more constant, smaller flows and do not have to meet peak flow conditions. Desilting basins are used to settle out larger sediment particles, which will be particularly important to prevent recharge impoundment facilities from becoming clogged. It is expected that the high flows that are planned for diversion will carry a comparatively high sediment load so desilting basins are likely necessary prior to groundwater recharge. Depending on the rate of diversion, the largest challenge may be in finding sufficient space to locate flow equalization and desilting basin facilities.

5.1.1.4 Pipeline and Pump System

If the diverted water cannot be conveyed by gravity to its recharge or use site, a pump station will need to be constructed either at the turnout structure or at the flow equalization/desilting basin. The pump station discharge can be either to a pipeline, into an open channel, or into a combination pipeline/open channel depending on the destination of the diverted water. The use of flow equalization basins can reduce the size of a pump station and reduce overall capital and operations and maintenance costs.

5.1.2 Subsurface Diversion

Subsurface diversions are constructed in the alluvial material adjacent to a surface water body. A subsurface diversion would generally consist of the following major components:

- Vertical or horizontal well(s), located adjacent to the creek/river, with screened openings. Vertical wells are similar to groundwater wells while horizontal wells are described in greater detail below.

- Well pump to pump the water from the basin to where the water will be used.

A horizontal collector well consists of a concrete caisson (approximately 16- feet in diameter) which extends to a depth appropriate for the site conditions, sometimes to bedrock, and lateral well screens extending radially from the caisson. This type of horizontal well is often called a Ranney Collector after the inventor. A lateral may be up to 175 feet long. There may be one to ten or more laterals at multiple elevations. The high pumping rate of a horizontal collector well lowers groundwater levels under the surface water, causing surface water to flow into the aquifer in a process known as induced infiltration. Induced infiltration is a significant portion of the available yield for a horizontal collector well. The elevation of the lateral well screens, slot size, and number of linear feet of well screen is dependent on aquifer properties. Horizontal collector wells are constructed using a natural gravel pack design with an entrance velocity less than 2 feet per minute. (Riegert, 1999)

5.2 Aquifer Recharge Facilities for Surface Water, Stormwater, or Recycled Water

A variety of facilities may be considered for aquifer recharge purposes. Larger recharge rates may require larger facilities such as percolation ponds, recharge/infiltration basins and injection wells. For smaller recharge rates, aquifer recharge facilities could include gravity recharge wells, infiltration galleries, or pressurized leachfields. Both the larger recharge and smaller recharge rates facilities are described in greater detail as follows. Regardless of the method of recharge, monitoring of groundwater would be a prudent measure to determine the impact of the recharge operation. Draft Department of Public Health regulations for groundwater recharge with recycled water indicates that significant monitoring will be required if recycled water is considered for recharge.

5.2.1 Percolation Ponds (large shallow ponds)

Percolation ponds are shallow basins enclosed by dikes or levees. The pond bottom is situated above the water table (the upper boundary of the saturation zone in a groundwater system). The discharge flow percolates through the unsaturated soils in the pond to reach groundwater. Thus, the ponds have no direct connection to underlying groundwater. The actual discharge capacity will depend on the site-specific soil and aquifer characteristics.

5.2.2 Recharge/Infiltration Basin (deep ponds)

The second aquifer recharge method considered is the infiltration basin. Infiltration basins are similar to percolation ponds, except that they are much deeper, containing no unsaturated zone, and they are in direct contact with the groundwater. The basins are typically excavated deep below the water table – as deep as 50 to 100 feet – to allow infiltration directly into the groundwater aquifer.

An infiltration basin facility would be significantly more costly than a percolation pond facility, because of the extent of excavation activities. However, the costs would be expected to be significantly lower if the quarries near the SMGB were to be used for percolation. Other considerations such as the quarry restoration plans may preclude the use of deep ponds for recharge.

Recharge/infiltration basins would generally consist of the following major components:

- A graded area surrounded by berms to hold the water in place during percolation.
- One to two feet of sand at the bottom of the basin, to promote percolation. As debris began to accumulate on top of the sand, the debris along with the top few inches of sand would be removed and disposed of. Additional sand would then be provided to replace the sand removed.
- An overflow structure (e.g., spillway, vertical pipe) to handle excess water in the basin.
- An influent distribution system, such as manifolded pipe.

5.2.3 Injection Wells

The injection well option consists of a series of wells drilled into transmissive zones of the aquifer. Water is pumped under low pressures into these wells and allowed to flow into the aquifer. The wells discharge water directly to the saturated zone and bypass the unsaturated zone; therefore, the injection well option would produce the water-quality benefits from flow through the aquifer, but not the benefits from flow through the unsaturated soils (Kennedy/Jenks 2008).

The operation of injection wells include facilities that allow water to be injected into the well through a drop pipe equipped with a submerged hydraulic restriction. The restriction ensures that back pressure can be maintained on the drop pipe during operation to prevent the introduction of air (Kennedy/Jenks, 2008). A minimum pressure of 5 pounds per square inch (psi) is required to avoid air entrainment in the well, which would seriously impact performance. Typically, it is assumed that pump maintenance and other operational contingencies may arise that require some number of wells to be out of service at any time. This may be less of a consideration in the SMGB because recharge operations are most likely to occur in the wet season providing a 5 – 7 month window for maintenance during the dry season.

In the well casing, the buildup of the water level is a function of the flow rate of water into the well and the transmissivity of the aquifer. Transmissivity is a parameter that defines the ability of the aquifer to transmit water. The greater the transmissivity, the greater the flow of water that the aquifer is capable of accepting. Injection rates vary with water levels (Kennedy/Jenks, 2008).

Wells can be very sensitive to clogging. Clogging occurs when sediment, buildup, biological fouling, or chemical precipitation occurs, thus reducing the open area of the well screen and thereby reducing the flow of water into the aquifer. To allow monitoring for the effects of clogging, each well would require automated level controls and shut-off valves. Level controls would be necessary to shut down the well in case of such a problem. Clogging could be minimized by injection of treated potable water. For raw surface water or stormwater, sedimentation basins or other settling and/or treatment will likely be required prior to injection.

Maintenance of injection wells typically constitutes periodic “backwashing” of each well to remove the buildup of sediments and organic materials. To facilitate this activity, each well would be equipped with a submersible pump at the bottom of the well casing to provide suction pressure and thus clean out any accumulated obstructions in the well screens. Well backwashing is expected to take place at a frequency between daily and weekly. More intensive maintenance activities, such as chemical cleaning or well redevelopment, may be necessary when a well demonstrates further deterioration in performance. Chemical cleaning would entail the application of hydrogen peroxide solution or the equivalent to remove organic buildup on the well screen. Well redevelopment would entail using a drilling rig to mechanically swab the well screen to break up heavy buildups or mineral precipitates that resist other forms of maintenance. As with any well, ongoing maintenance and replacement of pumps and valves also would be required.

5.2.4 Gravity Recharge Wells

Gravity recharge wells are similar to injection wells with the exception that recharge occurs through gravity, not pressure. Therefore, many of the considerations discussed in the prior section on injection wells apply. The main advantage of the gravity recharge well over an injection well is simplicity of operation. However, site selection for transmissivity is critical for a gravity recharge well. The rates of recharge are likely to be lower with gravity recharge than with injection wells and storage of recharge waters may become a critical factor in optimizing recharge quantities. A gravity recharge well would generally consist of the following major components:

- One or more vertical wells with screened openings, gravel packing, and housekeeping slab around the well.
- Pipelines and valves connecting the walls to the main pipeline providing the recharge water

If necessary, recharge wells can be pumped. However, this option is not considered at this time because of additional cost and complexity. It is expected that existing water agency production wells will be used to recover the recharged water.

5.2.5 Infiltration Trench/Gallery

An infiltration gallery is assumed to be similar to a recharge well, but where the perforated pipe/slotted well screen is oriented horizontally in a gravel-lined trench, similar to a leachline for a septic system. Recharge water will flow by gravity through the perforated pipe which makes this a relatively simple option when compared to a pressurized leachfield described in the section that follows. As with a gravity recharge well, site selection for transmissivity is critical for optimizing recharge quantities.

5.2.6 Pressurized Leachfield

A pressurized leach field utilizes a system of perforated pipes installed in a series of shallow trenches backfilled with highly permeable material to disperse the discharge flow. The pipes and trenches are situated above the water table and recharge water is pumped into the perforated pipe/slotted well screen. A pressurized leach field uses the same principle as a percolation pond, namely percolation of discharge water through the unsaturated zone. The discharge flow percolates through the unsaturated soils to reach groundwater; thus, the trenches have no direct connection to underlying groundwater. Actual recharge capacity would depend upon the site-specific soil and aquifer characteristics.

5.3 Stormwater Recharge Approaches

There are several approaches for diversion of stormwater to be used for groundwater recharge. As described earlier, stormwater could be collected and diverted in gravity and/or pressurized facilities such as those described in Section 5.2. These approaches will likely require additional infrastructure as described in Section 5.3.1. and may require treatment as described in Section 5.3.2. An alternative approach is to implement Low Impact Development (LID) techniques as described in Section 5.3.3. LID is intended to treat smaller quantities of water so may need to be supplemented with additional storage in order to be able to recharge the larger quantities of rainwater that are available in the SMGB.

5.3.1 Storm drain diversion to dedicated aquifer recharge facilities

As summarized earlier, diversion of storm drain facilities may require infrastructure, especially, if it is to be directed to dedicated aquifer recharge facilities as described in Section 5.2. The infrastructure may include pipelines, or open channels, flow equalization and/or wet well structures, especially if the stormwater will have to be pumped. As discussed in Section 5.3.2, depending on the type, location, and flow to be diverted, settling and/or other treatment may be required prior to recharge.

If the diversion is coming from an urbanized, piped system, it may be easier to intercept and have higher flows, but may also have a higher pollutant load that will likely require treatment. Identifying the optimal location for interception to minimize pumping and treatment will be critical to using this type of runoff for recharge. If the diversion is for rural runoff from drainage ditches or local small, ephemeral streams, the treatment need may reduce because the water quality is likely better. However, the flow may also be reduced. These considerations should be evaluated during a feasibility study.

Stormwater collection or diversion would generally consist of the following major components:

- Pipeline or series of pipelines connected to existing stormwater discharge points or manholes upstream of the discharge points.
- Storage tank or wet well to collect and equalize the stormwater prior to pumping, if necessary.
- Pump system at the tank/wet well to pump the water from the tank/wet well to where the water will be treated and/or recharged. Recharge facilities are addressed Section 5.2.

It should be noted that sizing of stormwater collection, diversion, and storage needs to be carefully evaluated because flows occur relatively infrequently and can be highly variable. Sizing is especially critical in pumping facilities whereby the highest flow rates occur infrequently and large pumping capacities are therefore infrequently used.

5.3.2 Potential Stormwater Treatment Measures

Depending on the recharge facility that will be used, stormwater treatment may be necessary prior to recharge. Treatment of urban runoff is challenging because of the need to improve water quality while managing for a wide range of flow conditions. Stormwater quality issues were previously discussed in Section 3.2. Most technologies to date have focused on passive treatment with no mechanical systems or active treatment. Some agencies with combined sanitary sewer/storm sewer systems provide active treatment such as activated sludge and other chemical/biological treatment processes. Additionally, a more recent focus is developing in the area of active treatment technologies using flocculants. Active treatment is not considered further for this study.

The typical passive treatment technologies currently in use include both public domain and propriatey devices. As defined by the California Stormwater Quality Association (CASQA), public domain devices can be designed and constructed without purchase of patented equipment while proprietary devices are purchased from vendors and cannot be re-created without potentially violating patents.

Public Domain	Proprietary Devices
Constructed Wetlands	Vortex Separators
Wet Basins	Oil/Water Separators
Dry Basins	Media Filtration
Vegetated Swales and Buffer Strips	Drain Inlet Devices
Infiltration Systems	

There are unique challenges associated with storm water treatment that must be considered in designing systems. As in stormwater pumping facilities, a key challenge is in sizing stormwater treatment to handle the variability associated with storm events and the uncontrolled large volume of water generated over a short period of time.

In implementing these storm water treatment technologies, various implementation strategies can be considered as follows.

- Distributed vs centralized systems
- Low impact development (LID) strategies to be discussed in Section 5.3.3

- Storage and reuse strategies
- Hydromodification control strategies
- First flush capture strategies
- Hot spot capture strategies
- Treatment train strategies

Treatment selection decisions need to be driven by the storm water quality characteristics and the treatment objective to be attained. The types of pollutants, sources, dissolved fraction, particle size distributions, settling velocity, sediment chemistry all need to be considered along with the available technologies. These parameters are discharge specific and adequate characterization of the discharge must be completed.

In addition to the selection and design considerations to meet the treatment objectives, other considerations need to be addressed when implementing structural treatment devices in an urbanized setting. Examples of other considerations include.

- Maintenance requirements and cost
- Asthetics
- Ownership and responsibility
- Ordinances
- Other watershed, air, soil, and groundwater impacts

These measures would have to be coordinated with the stormwater management activities of the City of Scotts Valley, or other local jurisdictions.

5.3.3 Onsite Recharge of Runoff using LID techniques

An alternative to dedicated multi-use aquifer recharge facilities are smaller, more distributed treatment/runoff measures that can be implemented at individual sites using LID techniques. These measures, which include public domain measures summarized in Section 5.3.2 above, provide both water quality treatment and the potential for stormwater recharge. In the SMGB and the Carbonera Creek and Bean Creak Watersheds, LID measures have added benefits of reduced downstream hydromodification which is stream erosion from high peak flows and volumes which can result in reduced fish passage and habitat. LID measures are highly encouraged in stormwater management permits and appear to have available funding for implementation.

5.3.3.1 Low Impact Development

As described earlier LID measures can be used to improve water quality and to allow first flush quantities of stormwater to recharge directly into the groundwater at multiple, disperse locations. If the facilities are sized to capture larger storm events than are typically used for treatment, recharge quantities can be increased. At a minimum, the LID measures would be installed with new development, as this tends to be more cost effective and is consistent with the City of Scotts Valley's Stormwater Management Plan. However, some large surfaces, such as parking lots or rooftops, could be retrofitted with LID measures such as:

- Pervious Pavement: Porous asphalt over geotextile over gravel base, plastic grid with trays filled with grass, or open grid paver blocks with the area between blocks filled with a porous medium. Subsurface storage can be enhanced with deeper gravel bases.

- Bioretention/Vegetated Facilities

    - Rain Gardens: Curb and gutter or other type of containment, planted topsoil, gravel layer, and weep holes or underdrain to drain excess water during high flow storm conditions.

    - Vegetated Swales and Buffer Strips: Depressed channel with native soil, compost and plants. An underdrain may be required if the swale does not discharge to another storm water conveyance system or has soils with low infiltration rates.

Other measures that could be applied for stormwater recharge have been discussed earlier in Section 5.2 and include:

- Infiltration Trench/Gallery

- Infiltration/detention basins. Water quality treatment requirements dictate that infiltration/detention facilities are generally sized for approximately 2-year return interval storm events. These could be oversized if sufficient flow exists to enhance additional recharge.

Some of the issues related to stormwater treatment using Infiltration Trenches and Infiltration/Detention Basins are described below:

- Operation and Maintenance
    - More difficult to establish vegetation on 2:1 slopes
    - Observe the drain time for several storm events to make sure it is consistent with calculations to prevent vector issues and is providing sufficient treatment
    - Maintenance check after major storms and at start and end of the wet season

- Sediment removal is typically at 10+ year intervals

- Expected Stormwater Treatment Performance
  - Interception of constituents from surface water is 100% for the water quality volume infiltrated
  - Soluble constituents (TDS, Nitrate, some organic compounds) may contaminate groundwater
  - Not recommended in industrial areas or where groundwater contamination could be a problem from spills or dumping

A summary of the more technical aspects of the pervious pavement, bioretention, and vegetated swales and buffer strips are discussed in greater detail in the following sections. A more detailed discussion of the planning aspects that support LID implementation is provided in Appendix A.

Some of the specific considerations for implementation of LID in the SMGB are:

- Location is very important because the subsurface geology is such that there are some places that have nominal deep groundwater recharge benefit from recharge at the ground surface. The geology is such that the recharged water cannot easily flow to the aquifer which has the most storage capacity.

- Similarly, a close understanding of the storm drain system and the receiving creeks is important to removing flows that have greatest hydromodification benefit.

5.3.3.2 Pervious Pavement and Interlocking Concrete Pavers

Pervious concrete and pervious asphalt can be typically be used interchangeably to reduce runoff from paved areas. Pervious asphalt is typically cheaper than pervious concrete, although both are more expensive than traditional concrete and asphalt. In addition to reducing runoff, pervious paving can also reduce surface heat. In area with high traffic, conventional paving should be used. The pervious surface may eliminate the need for catch basins and a drainage system for the area in which it is used. This has two benefits, cost and the ability to have a flat surface.

Pervious Pavement Source: Clear Creek Solutions; LID Hydrology and Hydraulics Presentation

Interlocking concrete pavers are available as both permeable and impermeable, although generally impermeable are used. Water is allowed to infiltrate between the pavers. Permeable pavers are able to handle heavy loads if properly designed. Pavers can be easily removed and replaced if settling occurs.

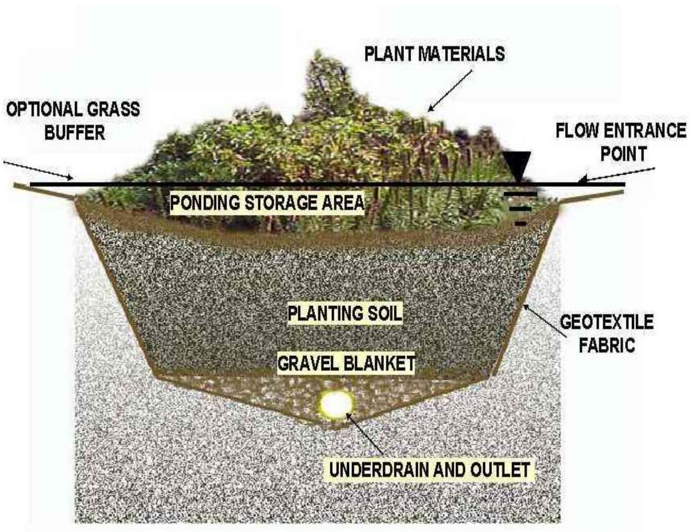
In either instance, the gravel base can range in thickness between 6-inches minimum by up to 3 feet or more, depending on the desired stormwater retention capacity of the pavement system. The subgrade should be evaluated by a geotechnical engineer. The subgrade should be un-compacted if possible, or should be compacted the minimum amount necessary to provide structural support for the pavement above, but not overly compacted to prevent infiltration.

Interlocking Pavers- Source: Clear Creek Solutions; LID Hydrology and Hydraulics Presentation and Kennedy/Jenks Consultants Installation at Castaic Lake Water Agency

5.3.3.3 Elements of Bioretention

Bioretention is the filtering of stormwater runoff through a terrestrial aerobic plant/soil/microbe complex to remove pollutants through a variety of physical, chemical, and biological processes. The word bioretention was derived from the fact that the biomass of the plant/microbe (flora and fauna) complex retains or uptakes many of the pollutants of concern such as nitrogen, phosphorus, and heavy metals. Plant matter traps oils and greases and allows it to degrade through ultraviolet exposure and/or biological processes. It is the optimization and combination of bioretention, biodegradation, physical and chemical, that makes this system the most efficient of all Best Management Practices for providing stormwater treatment. Types of bioretention include rain gardens, vegetated swales, and buffer strips. Infiltration and detention basins if designed appropriately can provide treatment and have been discussed in prior sections.

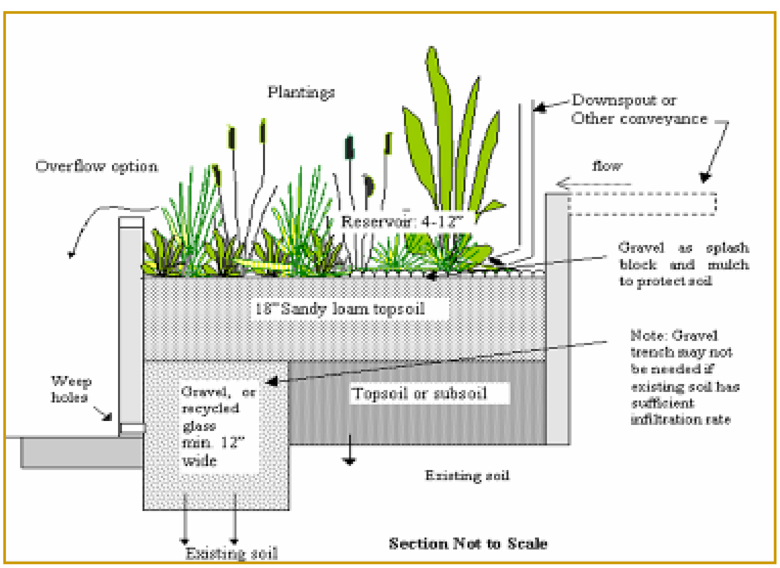
Bioretention measures are typically sized to provided stormwater treatment. They can be oversized to provide enhanced groundwater recharge. The example that follows shows a type of facility that could be used adjacent to a parking or road facility. The underdrain provides overflow protection should there be excessive flows to the facility beyond the infiltration capacity.



Source: Larry Coffman, ACEC, Bioretention Rain Gardens Overview Presentation

5.3.3.3.1 Rain Gardens

A rain gardens is a planted depression that is designed to absorb rainwater runoff from impervious urban areas like roofs, driveways, walkways, and compacted lawn areas and provide treatment of the runoff. There are several commercial and residential applications of rain gardens, some of them are shown in the figures below:



The example that is adjacent could be used adjacent to a building to capture and treat rooftop runoff from a residential or commercial building. Attention needs to be paid to protect the building foundation from water. .

Source: Cunningham Engineering, Low Impact Development Site Planning Techniques Presentation

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The examples that follow show applications of stormwater treatment bioretention/rain gardens for parking lots, larger commercial buildings, as well as for road runoff in a residential area

Source: Larry Coffman, ACEC, Bioretention Rain Gardens Overview Presentation

Filterra offers proprietary, compact, bioretention catch basin treatment units as shown below.

Source: Larry Coffman, ACEC, Bioretention Rain Gardens Overview Presentation (Urban Applications)

The system components and features of Filterra treatment units include:

- Mulch
- Engineered media consisting of coarse sand, organics, and other soil components
- Plants

The units remove pollutants through a combination of sedimentation, filtration, adsorption, absorption, cation exchange capacity, polar/non-polar sorption, microbial action (aerobic and anaerobic), plant uptake, cycling of nutrients/carbon/metals, biomass retention and evaporation/volatilization. The biological treatment is provided in pore spaces, and on soil surfaces that create microbes/biofilm to remove contaminants

5.3.3.3.2 Vegetated Controls: Vegetated Swales and Buffer Strips

Some relatively simple examples of the use of vegetation to cleanse stormwater are vegetated swales and buffer strips which are planted areas adjacent to impervious surfaces that provided filtration and treatment for small, frequent storm events.

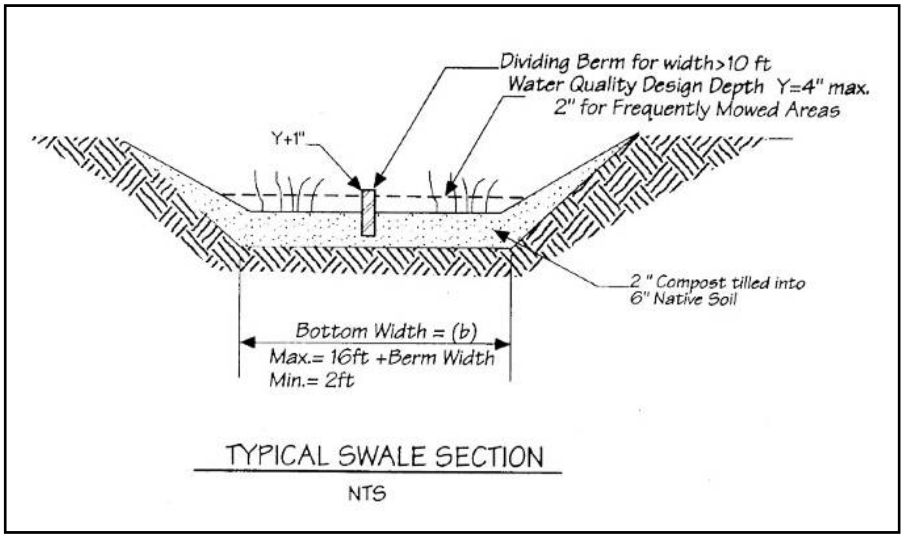
Vegetated Swales

Vegetated swales are designed to convey concentrated flow. The swales are generally a flat bottomed channel (as shown in the graphic that follows) and can treat up to about 10 tributary acres.

Design considerations for vegetated swales include

- 1 to 2 % slope in the direction of flow
- 6% maximum slope
- Hydraulic residence time > 5 minutes
- Velocity < 1 feet per second
- Vegetate with fine, turf-forming grass
- Mowing grass is optional

(Reference: WEF Urban Runoff Quality Management)



Source: RBF Consulting, Vegetated Controls Presentation

Swale Performance

- Removes gross pollutants, coarse and medium sized particulates
- Some dissolved removal depending on quantity of infiltration
- Tend to export total and fecal coliform
- About 30% and 60% TPH oil and diesel removal respectively

Examples of Vegetated Swales

RBF Consulting, Vegetated Controls Presentation (King County and Orlando Swale)

RBF Consulting, Vegetated Controls Presentation (Baltimore Swale)

Buffer Strips

Buffer strips are used to diffuse shallow sheet flow across a vegetated surface adjacent to roadways and parking areas. The buffer strips generally have a maximum tributary area of 100 square-foot per foot of buffer strip. Since buffer strips typically offer treatment of low, frequent flows, stormwater management for high flows needs to be considered adjacent to buffer strip areas.

Example of a Buffer Strip

RBF Consulting, Vegetated Controls Presentation

Advantages of Vegetated Swales and Buffer Strips:

- Viewed as landscape
- Inexpensive
- Urban development or roadway drainage conveyance
- Minimal Maintenance
- Significant water quality benefit

Limitations to Vegetated Swales and Buffer Strips:

- Cannot treat a very large drainage area (<10Ac)
- May not have significant attenuation of the Volume and Rate of Runoff during intense rain events
- Dissolved constituents removal only through infiltration
- Channelization may occur
- Require surface area

5.4 Treatment and Delivery of Surface Water for In-lieu Benefit Directly or in Exchange

As discussed earlier in Section 3.4, there are several options for in-lieu recharge by providing an alternative potable supply that is not groundwater. The delivered water can be used for direct potable reuse and/or for groundwater recharge. The first option is to use available wintertime capacity in existing diversion and treatment facilities and building infrastructure to deliver the treated water which is being called an exchange option. Another option is to use an existing or new diversion from one of the surface water bodies and treating it in a new surface water filtration plant and conveying the treated water to end users which is being called a direct delivery option. Both options are described as follows.

Exchange

Treated water could be transferred from an adjacent agency, such as the SCWD's Graham Hill Water Treatment Plant, and would generally consist of the following components:

- Connection to the adjacent agency's closest pipeline via a tee and valves.
- A meter station, consisting of a flow meter, bypass line, and valves. A pressure reducing valve may also be required depending upon the pressures in the sending and receiving systems.
- A pipeline and possibly pump station, between the adjacent water supplier and the receiving agency's distribution system and/or the recharge area.
- A discharge to a groundwater recharge basin, which would likely consist of a concrete box with overflows or pipe connections; or a tee with valves connecting to the receiving agency's distribution system.

As described earlier, SVWD is already in discussions with SCWD to evaluate the feasibility of an exchange between the two agencies. In addition, an intertie to allow an exchange between the various SLVWD systems is also being evaluated. The exchange option may provide the simplest, most cost-effective means of providing in-lieu benefit to the SMGB.

Direct Delivery

Direct delivery of surface water would require either the surface diversion facilities described in Section 5.1.1 or the subsurface diversion facilities described in Section 5.1.2. In addition to the diversion facilities, direct delivery would require conveyance pipelines and possibly pump stations to treatment and distribution facilities as well as treatment facilities to meet the surface water treatment rule. A subsurface diversion facility could reduce the required treatment level depending on whether the water is considered groundwater under the direct influence of surface water.

A surface water filtration plant can either be a conventional media filtration plant or a membrane filtration plant. A conventional media filtration plant or even a simple slow sand filtration system will likely have greater space requirements than a membrane (microfiltration or ultrafiltration) treatment plant. Disinfection facilities including feed systems and contact facilities will also be required to meet the surface water treatment rule. Operations and maintenance of a surface water treatment system to meet the surface water treatment rule will also require licensed treatment plant operators.

6 Planning-Level Cost estimating approach

The Conjunctive Use and Enhanced Aquifer Recharge Project is the first phase of a larger feasibility study to evaluate potential conjunctive use projects in the southern Santa Margarita Groundwater Basin (SMGB). These projects may have many alternatives, including new water sources, storm water recovery, and groundwater recharge. As part of this project, a set of these alternatives will be developed and evaluated to mitigate declines in groundwater levels. Part of the evaluation will be to prepare a planning level engineers opinion of probable construction costs (cost estimates) for up to three alternatives. This memo presents a general description of the assumptions that will be used in developing the cost estimates. Where available for specific types of facilities (e.g. injection wells, recharge ponds, etc.), more specific estimates for an overall facility will be used in-lieu of creating an estimate from a unit cost basis.

6.1 Factors and Contingencies

The capital cost estimates will include the following:

- Unit Costs for construction items (described in following sections) which will be marked up with the following factors to arrive at a capital cost estimate
- Construction contingency: 25%
- Contractor overhead and profit: 15%
- Design, construction management, and administration: 25%

Based on the unit costs described below and factors and contingencies assumed above, the estimate of probable construction cost is a conceptual, order of magnitude estimate with an accuracy of +50% to – 30%.

For the three recommended alternatives, annual operation and maintenance (O&M) costs, will be estimated to be 10% of the total capital costs for the pumps and 5% for the other items. The capital and O&M costs will be converted to lifecycle costs, assuming a 20-year lifecycle and 5 percent interest rate.

6.2 Unit Capital Costs

Where required by the recommended alternative, the following types of construction will be used to develop the overall estimate for the alternative.

6.2.1 Pipeline Installation

The estimated costs for pipeline construction will be based on a unit cost of $20/lineal foot (lf) of pipeline / inch diameter. This unit cost includes sawcutting and pavement removal, excavation, shoring, bedding installation, pipeline installation, backfilling, compaction, and pavement restoration. Bore and jack costs for highway crossings are not included in this cost and will be estimated separately if necessary.

6.2.2 Concrete

The estimated costs for concrete installation will be based on a unit cost of $500 per cubic yard of concrete in place. This unit cost includes formwork, reinforcement, and concrete.

6.2.3 Earthwork

The estimated costs for excavation, such as for recharge basins, will be based on a unit cost of $5 per cubic yard. This unit cost includes excavation, on-site hauling, and on-site disposal.

One cubic yard equals 27 cubic feet equals 202 gallons. So, the unit cost per gallon would be about $0.025 per gallon.

6.2.4 Above Ground Storage Tank

The estimated costs for above ground steel storage tanks will be based on a unit cost of $1 per gallon stored. The unit cost includes site grading, foundation construction, tank installation, and on-site piping.

6.2.5 Wells

The estimated costs for well construction, assumes a 6-inch diameter well approximately 200 feet deep, will be based on a unit cost of $200 per foot of depth. The unit cost includes drilling, well screen and casing installation, well cap installation, and well development.

6.2.6 Well Pumps

The estimated cost for a well pump, assumes a pumping rate of 250 gallons per minute (gpm), will be based on a lump sum cost of $85,000 per pump and motor. The unit cost includes connecting the pump to discharge piping and installing the pump with piping but does not include disinfection, treatment, electrical or SCADA instrumentation and controls.

6.2.7 Booster Pumps

The estimated costs for a booster pump and motor, assuming up to 2,500 gpm, will be based on a lump sum cost of $50,000. The cost includes installing the pump outside on a concrete slab but does not include electrical or SCADA instrumentation and controls.

6.2.8 Iron and Manganese Treatment

The estimated costs for iron and manganese treatment will be based on a unit cost of $500 per gallon per minute. The unit cost includes the treatment system installed outside on a concrete slab.

6.2.9 LID Construction Costs

In order to provide order of magnitude planning estimates for LID measures, the 2009 Water Environment Research Foundation (WERF) Whole Life Cost Spreadsheet model was used to develop estimated capital costs for the types of LID measures that enhance infiltration that may be used for new or retrofit construction. The estimates were prepared for a generic 0.5 acre site and are summarized in the table that follows. These estimates should be compared to the actual costs from the stormwater retrofit projects currently underway.

LID Type	Estimated 2010 Cost for 0.5 Acre Impervious Area	Notes
Pervious Pavement - Asphalt	$1.50/ft2 for new construction	Based on $1/ft2 installed cost; and 25% design allowance and 20% contingency. Estimated yield for 3 ft of rainfall/yr = 1.5 AFY
Pervious Pavement - Concrete	$9.75/ft2 for new construction	Based on $6.50/ft2 installed cost; and 25% design allowance and 20% contingency. Estimated yield for 3 ft of rainfall/yr = 1.5 AFY
Vegetated Swale	$0.40/ft2 of tributary drainage area for new construction	Based on construction cost of $0.32/ft2 tributary drainage area adjusted for small project plus 25% for engineering and planning; Approx 870 ft2 of swale (based on 4% of tributary area) for an estimated yield for 3 ft of rainfall/yr =0.06 AFY
Curb Contained Bio-retention	$1.10/ft2 for 1,300 ft2 of bioretention as retrofit	Based on construction cost of $0.97/ft2 of tributary drainage area plus 25% engineering/planning and retrofit adjustment; 1,300 ft2 of bioretention area for an estimated yield for 3 ft of rainfall/yr = 0.09 AFY

6.2.10 Facility Construction Estimates

Based on prior work Kennedy/Jenks has conducted, more specific cost estimates for treatment plants and recharge facilities have been developed. These costs are summarized in the table below and could be used to simplify cost estimating for alternatives.

Facility Type	Estimated 2010 Cost for 1 MGD/1.6 cfs/560 AFY (over 6 months) Facility	Notes
Microfiltration Membrane Surface Water Treatment Plant	$2.1 million	Includes land acquisition
Percolation Pond	$3 million	Includes land acquisition
Recharge/Infiltration Basin	$15.8 Million	Includes land acquisition and full excavation costs
Pressurized Leach Line	$3.8 million	
Injection Well Facilities (linear)	$3 million	Assumes construction along roadway and includes sufficient wells to accommodate resting of wells
Injection Well Facilities (rectangular)	$4.1 million	Assumes construction within rectangular footprint, requiring more land and includes sufficient wells to accommodate resting of wells

References

Balance Hydrologics, 2009. Santa Cruz County Conjunctive Use and Enhanced Aquifer Recharge Project, Draft Technical Memorandum No. 2B – Availability of water sources for a conjunctive use framework approach to water resource in the San Lorenzo Creek Watershed, Santa Cruz County.

California Stormwater Quality Association, 2003. Stormwater Best Management Practice Handbook for New and Redevelopment.

City of Santa Cruz, 2005. Urban Water Management Plan.

City of Santa Cruz, 2003. Draft Integrated Water Plan.

City of Scotts Valley, 2008. Stormwater Management Plan

Clear Creek Solutions, 2008. LID Hydrology and Hydraulics Presentation.

Larry Coffman, ACEC, Bioretention Rain Gardens Overview Presentation

Cunningham Engineering, Low Impact Development Site Planning Techniques Presentation

D.W. Alley and Associates, 2009. Santa Cruz County Conjunctive Use and Enhanced Aquifer Recharge Project, Draft Technical Memorandum 2C Regarding Guidelines For Maintaining Instream Flows To Protect Fisheries Resources Downstream Of Water Diversions In Mid-California Coastal Streams

Kennedy/Jenks Consultants, 2008. City of Santa Rosa Incremental Recycled Water Program, Technical Memorandum I-2 – Indirect Discharge Facilities.

Kennedy/Jenks Consultants, 2009. Santa Cruz County Conjunctive Use and Enhanced Aquifer Recharge Project, Draft Technical Memorandum No. 2A – Water Rights Evaluation.

Kennedy/Jenks Consultants, 2009. Santa Cruz County Conjunctive Use and Enhanced Aquifer Recharge Project, Draft Technical Memorandum No. 4 – Regional Water Demand.

RBF Consulting, Vegetated Controls Presentation

Riegert, D. Scott, 1999. Reassessing Ranney wells: the ins and outs of horizontal collector wells.

Water Environment Foundation, 1998. Manual Of Practice No. 23. Urban Runoff Quality Management.

Water Environment Research Foundation, 2009. BMP and LID Whole Life Cost Models.

Appendix A

Appendix A: Overview of LID Planning, Construction, and Inspection and Maintenance Topics

LID Site Planning Principles

1. Site hydrology is fundamental to the plan
2. Address runoff at its source
3. Think small-scale
4. Keep it simple
5. Integrate the drainage solutions into a multi-functional landscape
    - Sandy play area
    - Swale in greenbelt corridor
    - Bioretention
    - Rainwater as a design element

LID Site Planning Process

1. Research Regulatory context
    - Flexibility in zoning requirements
2. Perform initial site evaluation
    - Topography and drainage patterns
    - Soils and infiltration potential
    - Quantify pre-development hydrology
3. Define development envelope
    - Maintain natural features
    - Retain predevelopment drainage patterns
    - Impervious area on least pervious soils
    - Compact layout
4. Reduce impervious area (IA)
    - Reduce building footprints
    - Green roofs
    - Increase aspect ratio of lots
    - Cluster buildings
    - Reduce size of parking areas
    - Narrower streets
    - Pervious paving
5. Reduce directly-connected impervious area (DCIA)
    - Filter strips
    - Swales
    - Distributed small scale storage
    - Bioretention
    - Pervious pavement
6. Preliminary LID-integrated site layout

7. Compute post-development site hydrology
8. Refine LID elements
9. Re-compute post-development hydrology & complete LID site plan

Construction Considerations

- Preconstruction meeting” with the contractor / owner / architect / engineer
- Geotechnical Report
- Ensure sediment control measures in place
- Sub grade soils and preparation.
- Presence of ground water
- Under drain and filter media installation.
- Soil certifications for back fill.
- Topsoil layers should be thoroughly wetted to achieve settlement.
- Plant placement / warrantee / type
- Proper site grading
- Site stabilization before planting.
- Location of underground utilities

Inspection & Maintenance

- Require a long term maintenance plan
- Non Erosive Designs Inlet / Outlet / Flow- through
- Sediment build-up
- Annual inspection / plant care
- Excessive ponding (Longer than 8 hours)
- Use underdrains
- Right Vegetation
- Spills