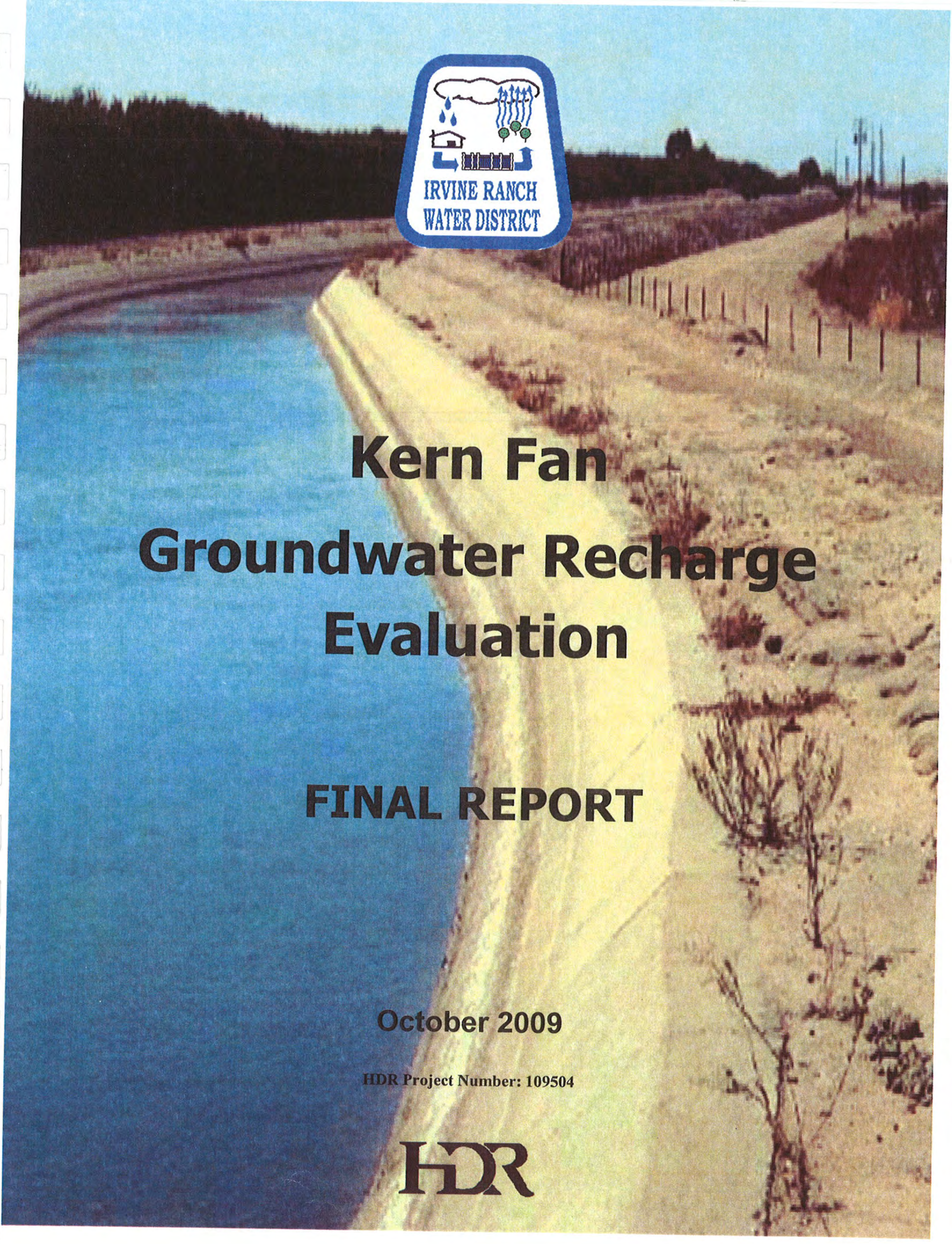

IRVINE RANCH
WATER DISTRICT

Kern Fan
Groundwater Recharge Evaluation

FINAL REPORT

October 2009

HDR Project Number: 109504

HDR

Irvine Ranch Water District

Kern Fan Groundwater Recharge Evaluation

Final Report

October 2009

HDR

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1.0 Introduction and Study Objectives

This report seeks to identify and evaluate options to improve the cost effectiveness of the Irvine Ranch Water District's (IRWD, District) water banking program at the Kern Fan project area. With the ever increasing demand on local water resources, and the continuing cutbacks in State Project Water (SPW) and Colorado River Water (CRW) supplies, it is of vast importance for water agencies to identify new and innovative opportunities for water banking and maintaining reliable sources of water. Water banking in its simplest form, is a method of temporarily transferring water entitlement based on a user's needs without a permanent change in water rights. For example, in drought years when Metropolitan Water District (MET) allotments are restricted, the water banking approach would provide IRWD with an additional resource to meet consumer demand. IRWD is currently expanding their Kern Fan recharge basins with an initial goal of recharging over 17,500 acre-feet per year. This study presents a comparative analysis of potential methods of recharging water for the purpose of expanding the water banking program and improving the reliability during drought years to provide IRWD customers with increased water supply through redundancy and diversification.

The objectives of this study as included and summarized within this report are as follows:

- Identify the methods currently used to recharge water in the Kern River Fan area.
- Evaluate five potential water recharge/infiltration concepts including the following:
    - Surface Recharge Ponds
    - Subsurface Recharge Galleries
    - Shallow Injection Wells
    - CULTEC Engineered Systems
    - Subsurface Conveyance System
- Evaluate five sediment removal strategies that could be utilized as means of optimizing recharge/infiltration potential.
- Summarize and evaluate findings from the Orange County Water District (OCWD) Recharge Water Sediment Removal (RWSR) feasibility study.
- Develop an appraisal-level, order of magnitude economic evaluation of potential recharge systems and sediment removal strategies including a determination of capital costs, O&M costs and cost per acre-foot of water recharged based on a 40-year project life cycle.
- Establish generalized conclusions and recommendations based on the findings of the comparative analysis study.

The remainder of this report is divided into the following chapters:

- Chapter 2 – Summary of Kern Fan Recharge Systems
- Chapter 3 – Identification of Recharge/Infiltration Systems
- Chapter 4 – Characteristics of Clogging During Artificial Recharge
- Chapter 5 – Sediment Removal Strategies
- Chapter 6 – Summary of OCWD Study/Results
- Chapter 7 – Non-Economic Evaluation
- Chapter 8 – Economic Evaluation
- Chapter 9 – Conclusions and Recommendations

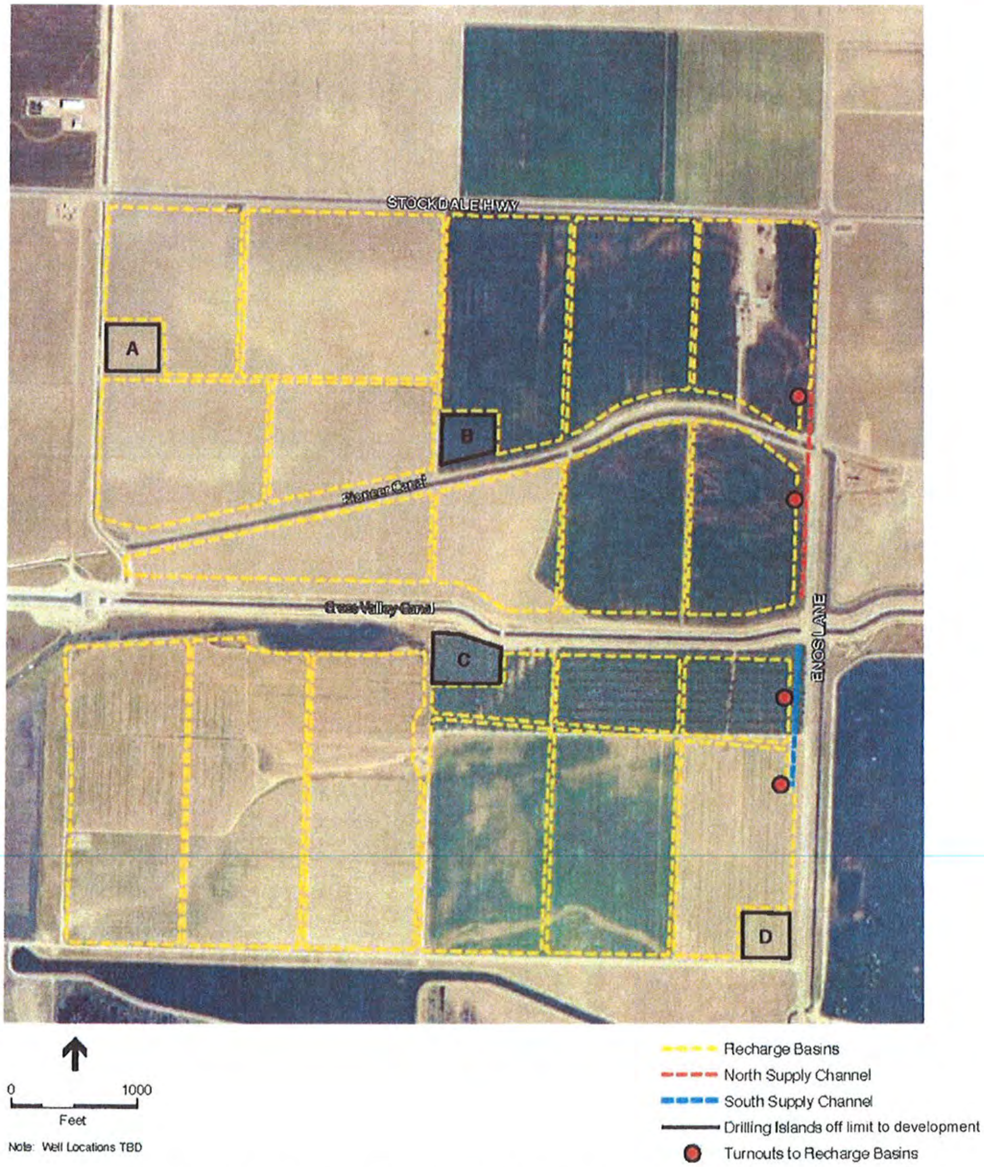
2.0 Summary of Kern Fan Recharge Systems

The Kern Fan area is located within Kern County, which is in the southern central valley of California. Some regions of the county are characterized by hydrogeologic conditions that are well-suited for groundwater recharge operations. Additionally, because of its proximity to federal, state and local water supply conveyance facilities, Kern County is also strategically located *geographically* for groundwater recharge operations.

Water banking and recharge activities have been operated extensively within Kern County for over 10 years in an effort to manage and offset overdraft conditions in the Kern County aquifer. Water recharge is currently implemented by a number of agencies who have partnered under the Rosedale Conjunctive Use Program, including; Kern-Tulare Water District, Rag Gulch Water District, Arvin-Edison Water Storage District, Castaic Lake Water Agency, Buena Vista Water Storage District, GLC (Coachella Valley Water District), and most recently IRWD (ESA EIR, 2008). Currently, these agencies jointly have the ability to recharge over 150,000 acre-ft per year. The Conjunctive Use Program manages approximately 210,000 acre-feet of stored groundwater in the underlying aquifer and includes 1,000 to 1,200 acres of recharge basins and seven recovery wells. Water supplies for this program are supplied by participating water agencies and include source water from the Kern River as well as water from the Central Valley Project (CVP) and the State Water Project (SWP). The Rosedale-Rio Bravo Water Storage District (RRBWSD or Rosedale) currently manages and operates the Conjunctive Use Program.

In 2004, IRWD purchased the 611-acre Strand Ranch property in western Kern County to develop a water banking program to improve water supply reliability during drought years. The Strand Ranch property is comprised of agricultural land located in an unincorporated portion of Kern County in the northern Kern River Fan area south of Stockdale Highway. Two existing water conveyance facilities bisect Strand Ranch including the Pioneer Canal and the Cross Valley Canal (CVC).

In 2006, IRWD and Rosedale constructed an interim recharge project on the Strand Ranch property including 125 acres of recharge basins in the southwest corner of the property (see Figure 2-1). The purpose of this interim recharge project was to test soil percolation rates, correct overdraft conditions from the on site agricultural wells, and ensure that adequate recharge capabilities existed before launching a larger project. During the interim program in 2006, 5,552 acre-ft of water was stored.



Note: Well Locations TBD

Figure 2-1: Strand Ranch Property Recharge Ponds

In 2009, IRWD entered into an agreement with Rosedale to expand the interim recharge project for enhanced capture, storage and recovery facilities based on favorable results from the interim recharge project. Since that time, IRWD has constructed approximately 502 acres of the recharge ponds on the Strand Ranch and is currently constructing the recovery facilities. The existing IRWD recharge ponds consist of excavated and contoured on-site soils to form earthen berm walls. The maximum water depth in each of the basins is approximately three feet with a minimum of one foot freeboard space. The CVC conveys water from the Kern River and SWP which is diverted through a turnout structure and transfer structures in order to supply the IRWD recharge basins. When fully operational, the Strand Ranch property is expected to recharge and recover up to 17,500 acre-feet per year for IRWD.

The Strand Ranch recharge project and future IRWD recharge projects in the Kern Fan region will integrate IRWD's participation in Rosedale's Conjunctive Use Program by providing additional groundwater recharge, storage and recovery capacity, and enhance water supply reliability for IRWD's customers by providing contingency storage to augment supplies during periods when other supply sources may be limited or unavailable.

3.0 Identification of Recharge/Infiltration Systems

Water recharge is currently implemented by a number of agencies throughout California to augment surface water supplies. The most common mechanism employed by these agencies to recharge surface water or reuse supplies has historically been through the use of recharge ponds or basins. In some areas, development and land cost have motivated agencies to consider other subsurface approaches to groundwater augmentation such as shallow infiltration galleries, injection wells, and engineered subsurface systems. A handful of agencies, such as the West Basin Municipal Water District and OCWD, have implemented more advanced indirect water reuse programs utilizing reverse osmosis membranes in order to further treat tertiary treated water for direct injection as a salt water intrusion barrier or as an advanced treatment to surface recharge. This study focuses on the evaluation of surface and subsurface recharge systems that would be appropriate for meeting the IRWD goals and objectives for water banking in the Kern Fan area.

Prior to the start of this study, IRWD completed a review of alternative groundwater recharge methods for increasing groundwater supplies. These methods included surface recharge basins and four types of subsurface recharge systems. At the first project workshop for this study held May 4, 2009, the project team reviewed the various methods and decided to evaluate the following five recharge concepts for this project:

- Surface Recharge Ponds
- Subsurface Recharge Galleries
- Shallow Injection Wells
- CULTEC Engineered Systems
- Subsurface Conveyance System

To evaluate each recharge concept on a common basis, the criteria below were mutually developed by HDR and IRWD at the first workshop. These criteria were used to size and evaluate each recharge concept.

Sizing Criteria	
Recharge Yield	10,000 AF
Recharge Duration	4 months
Infiltration Rate	4 inches per square foot per day
Distance from Cross Valley Canal (CVC)	0.5 miles

Each recharge concept is described in the sections below. The detailed evaluation and comparison between recharge concepts is presented in the non-economic evaluation in Section 7.0. The detailed economic comparison of each of the recharge concepts based on the sizing criteria described herein is included in Section 8.0.

3.1 Surface Recharge Ponds

Surface recharge ponds are constructed ponds or bodies of water where recharge water is applied to the surface and allowed to infiltrate into the soils and aquifer below. Recharge ponds are created through the excavation of native soils and construction of earthen embankments and berms designed to percolate water. Multiple recharge ponds can be constructed and operated in parallel or in series depending on operational objectives. The ponds are relatively easy to construct due to their shallow nature, are readily accessible for maintenance, and easy to operate. Management of flows to multiple ponds can either be controlled by manually actuating gates or valves, or simple automation can be incorporated to control flow from a remote location. IRWD currently utilizes surface recharge ponds as part of the recharge project at the Strand Ranch property (Figure 3-1).

Figure 3-1: Concept 1 - Strand Ranch Property Recharge Pond

Taking into account a uniform infiltration rate of 4 inches per square foot per day, approximately 250 acres of surface recharge ponds are required to recharge 10,000 acre-feet over a 4-month period.

For purposes of this evaluation, it was considered that two 125-acre recharge ponds are utilized to provide operational flexibility and the opportunity to conduct maintenance on part of the system, while maintain flows to the other half. The depth of each pond is assumed to be 3 feet based on the existing recharge ponds at the Strand Ranch property. Since the exact location or placement of the future recharge facilities is not yet known, it is assumed that the recharge ponds are approximately one-half mile from the diversion at the CVC (refer to Figure 3-2).

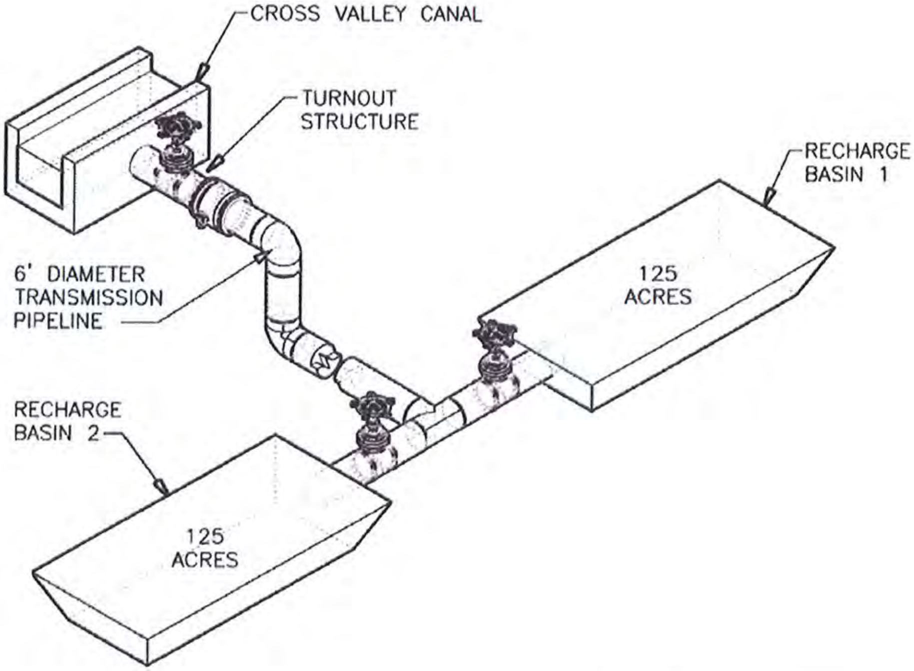


Figure 3-2: Concept 1 – Surface Recharge Ponds Concept

3.2 Subsurface Recharge Galleries

A subsurface recharge gallery is similar to a leach field, but intended to recharge water to the aquifer below. Utilities would typically consider this alternative in areas where land is unavailable or at a premium. This system is made up of smaller-diameter perforated lateral pipes that sit within shallow gravel and native soil trenches lined with filter fabric, along with headers that feed the system water from a large-diameter transmission pipeline. The filter fabric is installed in between the gravel and native soil to prevent sediment and fine particles from penetrating and clogging the native soil, thus reducing the hydraulic conductivity (i.e., movement of water into the soil). The mechanism and impacts of clogging are described in greater detail in Section 4.0.

The large-diameter transmission pipeline conveys water that is gravity-fed from a canal turn-out structure to various header pipes that feed the recharge galleries. Since the exact location or placement of the future subsurface recharge system is not yet known, this study assumes that the recharge galleries are approximately one-half mile from the diversion at the CVC (see Figure 3-3).

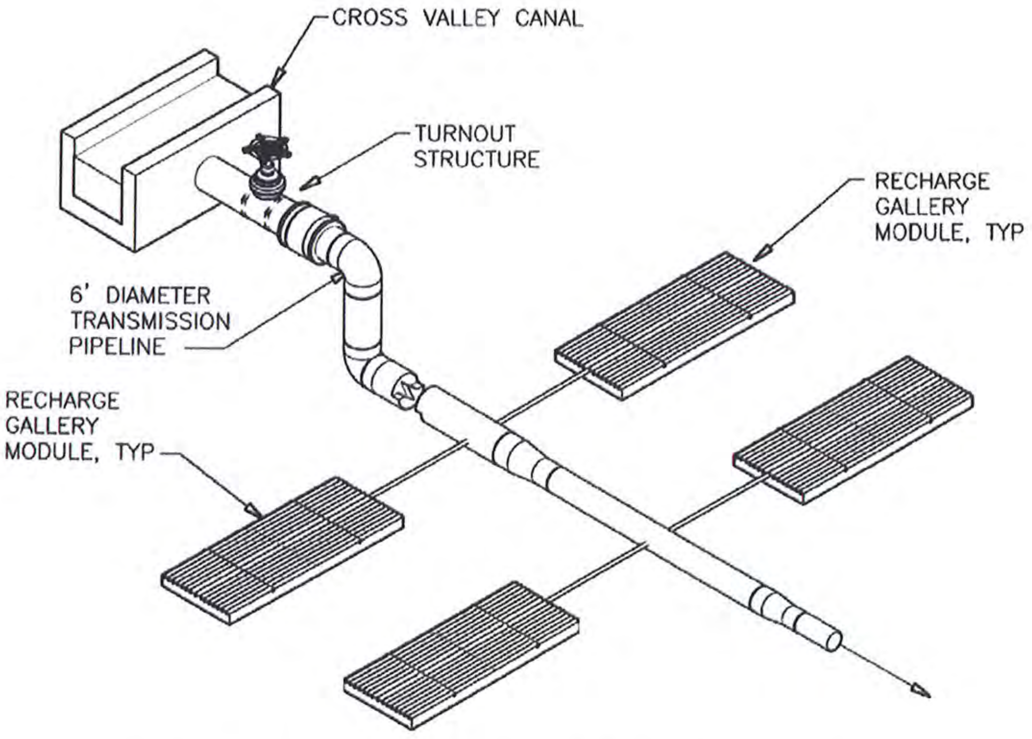


Figure 3-3: Concept 2 - Subsurface Recharge Gallery Concept

Management of flows to modular recharge galleries can either be controlled manually through valves, or automation can be readily implemented. Each module could be further modified with additional valves in an effort to isolate specific legs of the installation for maintenance while keeping the rest of the system in service. Accessibility for maintenance activities is more challenging due to the subsurface nature and configuration of this system, when compared to other alternatives.

Sizing the subsurface recharge gallery based on a uniform infiltration rate of 4 inches per square foot per day, requires approximately 250 acres of wetted area to recharge 10,000 acre-feet over a 4-month period. The spacing between lateral rows depends on the hydraulic conductivity of the soil, which may vary with location. For purposes of this study, it is assumed that the soils are such that the wetted area includes 5 feet on either side of the center of the lateral pipeline. Therefore, laterals are installed 10 feet on-center from each other.

This preliminary concept includes multiple 'modules' that each contain 80, 100-foot, 6-inch diameter perforated lateral pipelines connected by 8 or 10-inch diameter headers that can be connected to other modules or to the large-diameter transmission pipeline. One module is depicted in Figure 3-4. In order to encompass the required 250 acres of wetted area, approximately 137 modules need to be installed. The laterals are installed in trenches that are excavated approximately 5 feet deep. The lower one foot of the trench is back-filled with gravel while the rest of the depth is back-filled with compacted lifts of native soils.

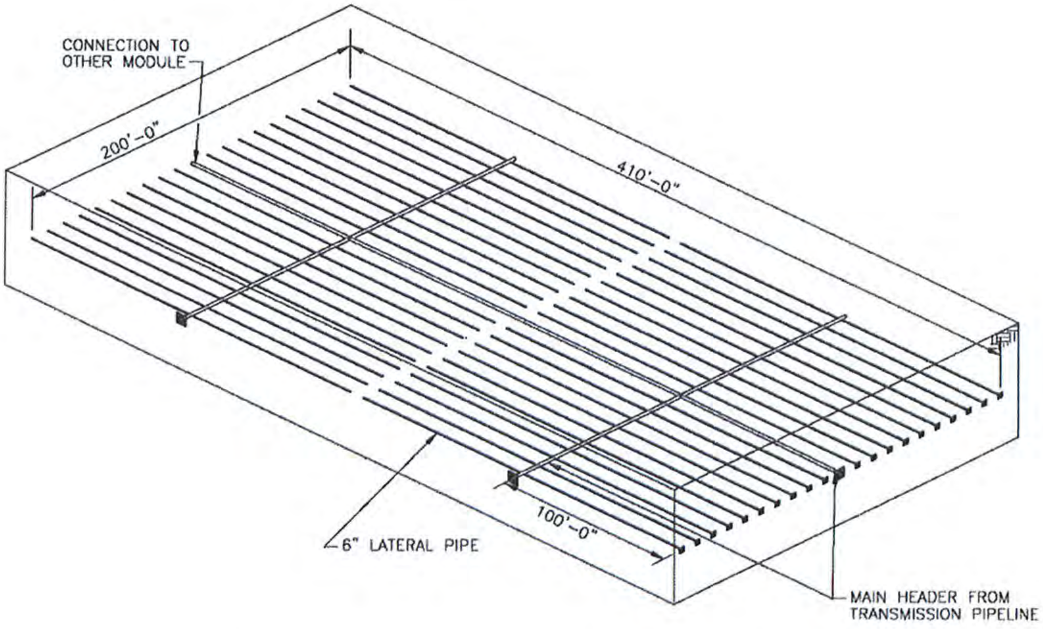


Figure 3-4: Concept 2 – Subsurface Recharge Gallery Module

The configuration assumed in this report is based on a previous study conducted by HDR that included a simulation model of river bed hydraulics in order to size a pilot scale underdrain collection system. The model accounted for site-specific soil characteristics such as saturated hydraulic conductivity, soil porosity, saturated water content, shape parameters of the soil water retention function and foulant accumulation layers. It should be noted that these soil characteristics are site-dependent and should be evaluated on their own merit under a more detailed evaluation. For purposes of this conceptual study, it is assumed that the subsurface recharge gallery concept would exhibit similar hydraulic characteristics as the underdrain collection system.

3.3 Shallow Injection Wells

The shallow injection well concept is similar to the subsurface recharge gallery concept, but instead of distribution of source water through a header, distribution occurs through a vertical shaft, stabilized by a concrete caisson, that in turn distributes water to radial laterals that extend from the shaft. Typically, these types of systems have been used in reverse, as radial wells or Ranney wells to intercept and collect groundwater derived principally from surface water infiltration. They can also be used for deeper recharge applications where confining soil layers are present, preventing recharge by shallow galleries as previously described. For this concept, a large-diameter transmission pipeline conveys gravity-fed water from a canal turn-out structure to multiple vertical shafts that feed the radial laterals. Since the exact location or placement of the shallow injection wells is not yet known, it is assumed that the injection wells are approximately one-half mile from the diversion at the CVC (see Figure 3-5).

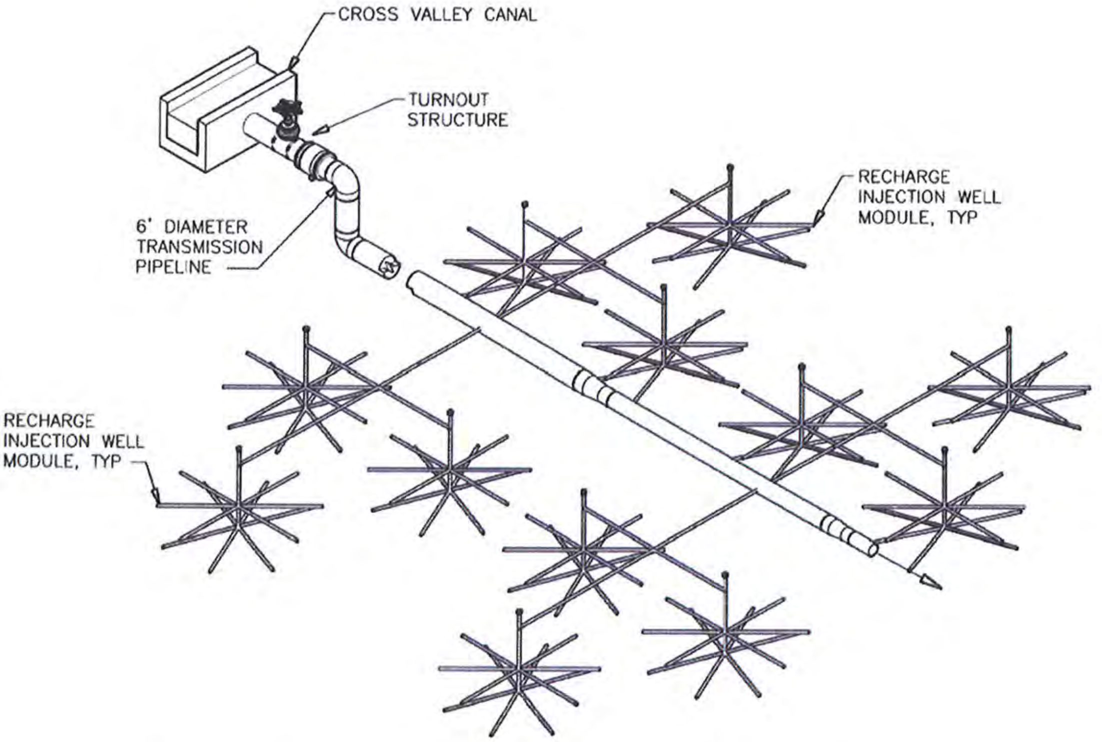


Figure 3-5: Concept 3 – Shallow Injection Wells Concept

Management of flows can either be controlled manually through valves, or easily automated. Similar to Concept 2, accessibility for maintenance activities is more challenging due to the subsurface nature and configuration of this system, when compared to other alternatives.

Sizing of the shallow injection wells based on a uniform infiltration rate of 4 inches per square foot per day requires approximately 250 acres of wetted area to recharge 10,000 acre-feet over a 4-month period. The spacing between laterals depends on the hydraulic conductivity of the soil, which may vary with location. For purposes of this study, it is assumed that the hydraulic conductivity is uniform throughout. Additionally the analysis assumes that soils are such that the wetted area includes 5 feet on either side of the center of the lateral pipeline. However, because the laterals move further apart as they extend out, more total land is required for easement purposes than is actually required for the 250 acres of wetted area.

This preliminary concept includes multiple 'modules' that each contain 12, 200-foot, 12-inch diameter screened or perforated lateral pipelines connected to a 24-inch diameter vertical shaft and caisson that can be connected to other modules and to the large-diameter transmission pipeline. The vertical shaft is installed to a depth approximately 12 feet below the surface. It should be noted that because of the circumference of the vertical shaft and limited space to connect in the 12-inch diameter laterals, 6 laterals are installed approximately 6 feet above the other 6 laterals, and rotated to maximize the wetted area. The deepest 6 laterals are installed 12 feet deep in trenches backfilled with one foot of gravel and 11 feet of compacted native soils. The shallowest 6 laterals are installed approximately 6 feet deep in trenches backfilled with one foot of gravel and the other 5 feet of compacted native soils. All of the lateral trenches utilize a filter fabric layer in between the gravel and native soils to prevent sediment and fine particles from penetrating and clogging the native soil, thus reducing the hydraulic conductivity. This concept is depicted in Figure 3-6. In order to encompass the required 250 acres of wetted area, approximately 454 modules need to be installed.

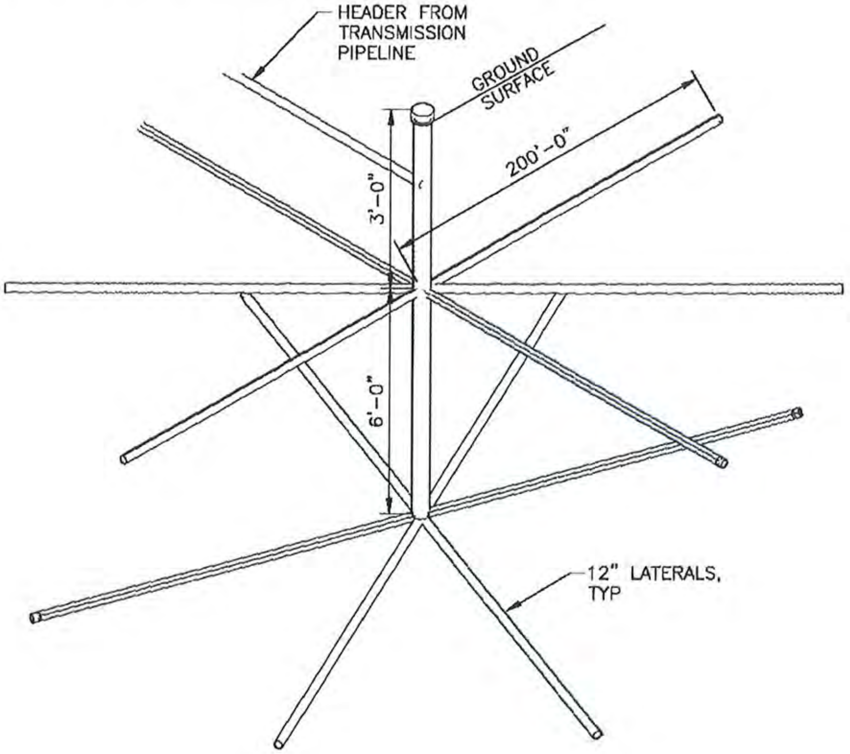


Figure 3-6: Concept 3 – Shallow Injection Wells Module

3.4 CULTEC Engineered Systems

CULTEC Engineered Systems are commercially-available units that are typically used to collect and recharge storm water flows, however may also be used for subsurface infiltration and retention/detention systems. The CULTEC Recharger® system consists of a dome-shaped, fully open bottom corrugated chamber with perforated sidewalls. This chamber stores water until it can infiltrate into the ground to the aquifer below. The bottom of the unit consists of a gravel pack and filter fabric in order to allow percolation while preventing sediment from clogging the native soils. The dome chambers may be installed in trench or bed configurations. Manholes can be installed to allow for maintenance access for periodic cleaning and replacement of the filter fabric.

Sizing of the CULTEC system is based on the recommendations provided by the manufacturer. For a project of this size, the CULTEC Recharger® V8™ is recommended. The V8™ is approximately 34 inches tall, 54 inches wide and 7.5 feet long and is manufactured of high molecular weight high-density polyethylene. Each chamber provides approximately 100 cubic feet of storage. Multiple chambers can be joined using an interlocking rib method. The manufacturer recommends that for the 10,000 AFY system (based on recharge over 4 months), only two-thirds of the wetted area needs to be provided based on the unit storage volume. Note that this storage volume credit is not included for any of the other concepts evaluated herein. Based on the information received from the manufacturer, and consideration of the infiltration criteria established in Section 3.0, it is anticipated that 322,667 V8™ units are required. It should also be noted that CULTEC is currently designing a larger unit that may be available in the future if this concept is utilized. This concept is depicted in Figures 3-7 and 3-8. Note that Figure 3-8 depicts a "cut-away" view of the asphalt surface above in order to more clearly show the subsurface installation of the system. Since the exact location or placement of the CULTEC Engineered System is not yet known, it is assumed that they are installed approximately one-half mile from the diversion at the CVC.

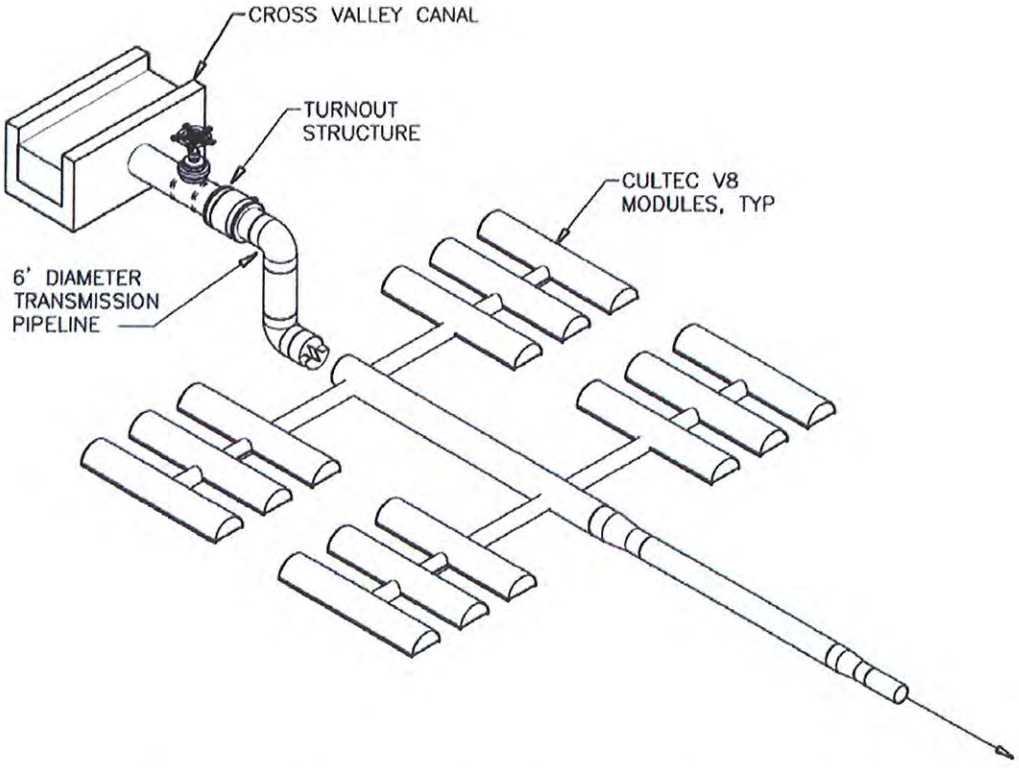


Figure 3-7: Concept 4 – CULTEC Engineered Systems

Figure 3-8: Concept 4 – CULTEC Engineered Systems Photo

3.5 Subsurface Conveyance Concept

The subsurface conveyance system concept consists of a large inverted trench box with gravel bottom in order to convey the source water while percolating a portion of the water into the ground as the water and associated sediments continue to flow through the length of the system. This concept is similar to the CULTEC system described in Concept 4 with the intent of conveying and infiltrating the source water in large underground structures. The primary difference between concepts is that the CULTEC system tends to capture and percolate the water under near-static conditions (i.e., vertical percolation in large, underground storage tanks), while Concept 5 maintains a horizontal flow through the system. Source water is diverted from the canal turn-out structure and transported through the inverted trench box at sufficient velocity to keep the sediment suspended and carried through the underground conveyance system, while recharging a portion of the source water through the bottom of the trench. The remaining portion of the source water that does not recharge in the inverted trench box is recharged via a smaller surface recharge basin similar to those described in Section 3.1.

Sizing of the subsurface conveyance concept based on a uniform infiltration rate of 4 inches per square foot per day, requires approximately 250 acres of combined wetted area to recharge 10,000 acre-feet over a 4-month period. More detailed hydraulic modeling will refine the length and diameter of the inverted trench box necessary to maintain the velocity at the speed needed to keep a large percentage of the sediment suspended while allowing the source water recharge. However, for purposes of this study, this concept is evaluated such that the inverted trench box provides half of the required wetted area (125 acres). The other half of the required wetted area is provided by a surface recharge pond. This approach assumes that the soils are such that the wetted area includes 5 feet on either side of the sides of the inverted trench box (see Figure 3-9).

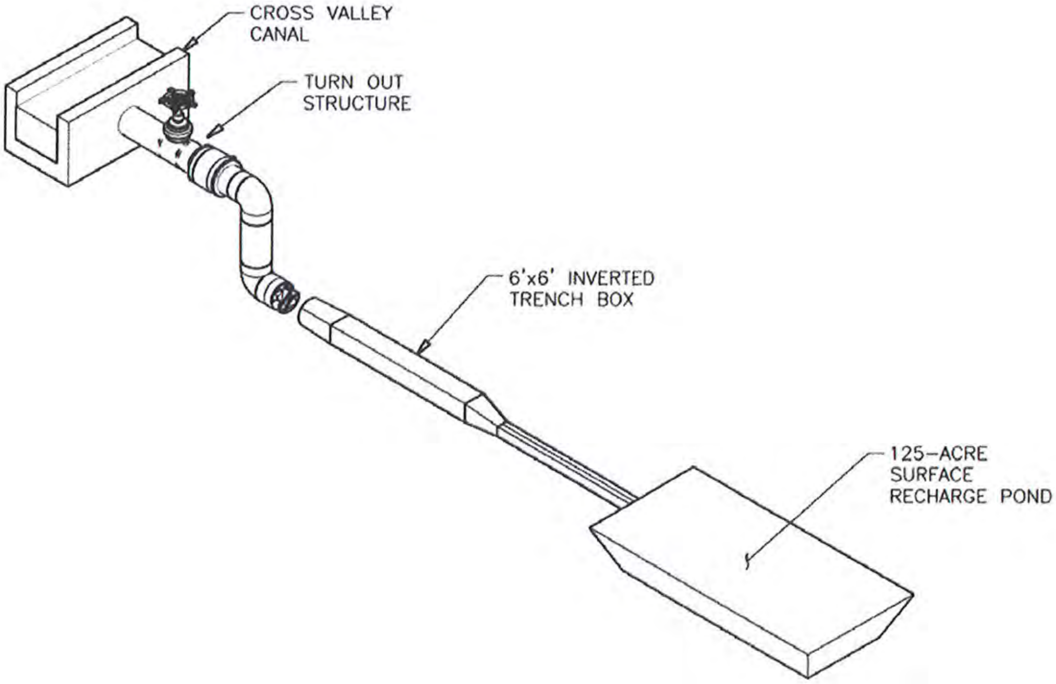


Figure 3-9: Concept 5 – Subsurface Conveyance System

A preliminary hydraulic analysis assumes a 65-mile, 6-foot by 6-foot inverted trench box will convey the source water to an approximately 125-acre surface recharge pond. For purposes of this study, it is assumed that the trench box is installed in a 10-foot deep trench, allowing 3 feet of cover over the top of the conveyance system. The bottom foot of the trench is filled with gravel and covered with a layer of filter fabric to help filter out fine particles and prevent these sediments from filling and clogging the native soils. Native soils are used to backfill the remaining trench (refer to Figure 3-10). The concept will include manholes spaced at appropriate intervals in order to facilitate accessibility for periodic cleaning and filter fabric replacement.

Representative section of the proposed 65-mile conveyance system

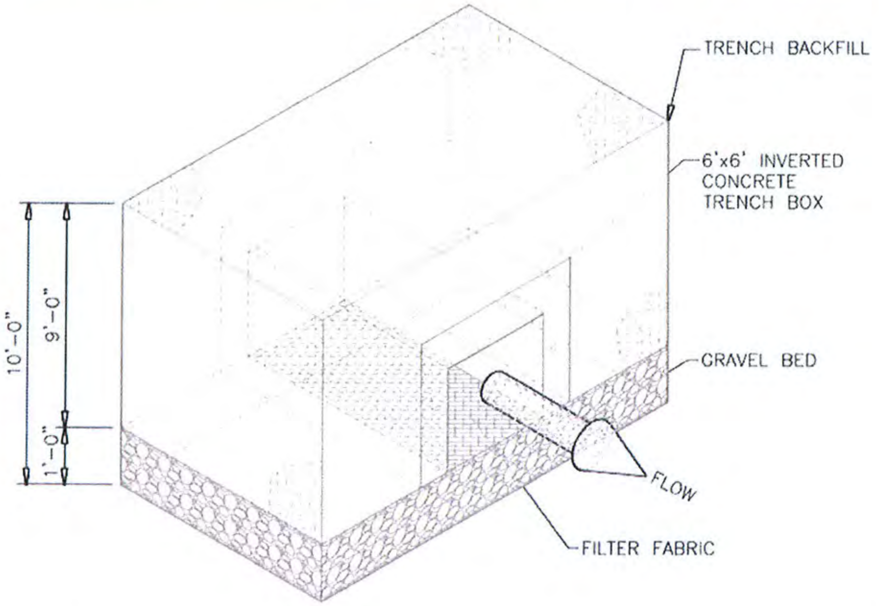


Figure 3-10: Concept 5 – Subsurface Conveyance System – Trench Cut View

4.0 Characteristics of Clogging During Artificial Recharge of Groundwater

Both surface and subsurface recharge concepts may be subject to clogging depending on the quality of the source water, changing environmental factors, or recharge facility mode of operation. Clogging occurs when sediments or biological material (such as algae or plankton) collect over time within the small pore spaces of the sand or gravel interface between the recharge concept (i.e., recharge pond, subsurface recharge gallery, etc.) and the aquifer below, thus restricting the amount of water able to be recharged. Organic and inorganic silts and clays that may be native to the source waters (or within the rivers and canals that convey the water) are typically the primary contributors to clogging. These silts and clays have a tendency to accumulate over time and establish a confining layer that reduces the rate of percolation.

Biological elements can also contribute to the clogging depending on the environmental conditions and availability of nutrients to sustain or proliferate biological activity. Biological growth can occur in both autotrophic (growth within direct sunlight) and heterotrophic (growth in the absence of light) conditions. Biological fouling can further decrease percolation rates due to additional plating or plugging of the interstitial spaces between the pores. A conceptual model of clogging is further described within this section. It should be noted that currently, the groundwater recharge projects in Kern County have not experienced significant percolation impacts as a result of clogging, based on Rosedale Conjunctive Use Partnership operational experience to date. This may be due, in part, to the current mode of operation which limits recharge activities to approximately 4 months. The seasonal loading and drainage of the basins may help control clogging potential as the accumulated silts dry and contract (i.e., crack), however the impacts may be realized in the future as the foulants continue to accumulate within the recharge basins.

4.1 Causes of Clogging

The formation of a clogging layer within groundwater recharge basins has been observed by other area agencies such as the Orange County Water District (OCWD). Clogging causes a decrease in recharge or infiltration (percolation rates) by reducing the hydraulic conductivity of the soil materials. Hydraulic conductivity is a quantitative measure of the soil's ability to transmit water when subjected to a given hydraulic gradient and essentially describes how easily water can move through the soil pores under a given driving force. Sometimes the reduction of hydraulic conductivity due to clogging can be as high as five orders of magnitude.

The clogging layer is often very thin, ranging from just a few millimeters up to approximately 4 centimeters. Clogging layers may consist of suspended solids, algae, microbes, dust and salts, and may be caused by different physical, chemical and biological factors. The causes of the development and extent of clogging are complex, but are influenced by recharge water quality, basin (or recharge concept) soil texture, mounding depth, hydraulic loading rate and cycle and vegetation.

Determination of the clogging layer can be challenging because the three different types of processes (physical, biological, and chemical) can work collectively or independently to reduce infiltration. Physical factors include the deposition and accumulation of organic and inorganic solids (such as clay and silt particles, algae cells and microorganisms) at the soil surface. If the suspended particles are smaller than the pore size of the media, and/or if the suspended solids are colloidal in size and if flocculating conditions exist, they can clog larger pores and form thick deposits on the pore walls. Biological factors include microbial cells and their metabolic byproducts (gas entrapped in pores or exopolymers that clog pores) that can alter soil properties (i.e., pore size, pore volume, flow path interconnectedness), and in turn affect the hydraulic conductivity of the media. Chemical factors include chemical precipitation and deposition in the pores. Chemical properties of soil particles and the infiltrating water, such as electrolyte concentration, pH, redox potential, and mineralogical composition of the soil, may influence the geometry of the pore space and may affect the shape and stability of the pores, which in turn determines the hydraulic conductivity of the media.

Research suggests that total suspended solids (TSS) and biological oxygen demand are the most important water quality components that influence the formation of a clogging layer. Additionally, extended mounding periods enhance soil clogging, whereas wetting and drying cycles tend to degrade the clogging layer. Prior to the start and during water recharge operations, IRWD may find it beneficial to monitor TSS levels in the source water, to help trend water quality constituent data with clogging rates.

4.2 Description of Phases of the Clogging Process

There are a number of effects which occur during artificial recharge that result in "clogging" and the accompanying decrease in percolation rates. A conceptual model is presented in Figures 4-1 and 4-2 to assist in understanding the clogging process. The model divides the clogging process into 6 phases and steps through the clogging process by starting with a clean recharge basin initially filled with recharge water and ending with a clogged recharge basin. Each phase corresponds to distinct physical phenomena which are characteristic of that phase of the recharge process. Conceptually, these phases occur in the sequence listed below and illustrated in Figure 4-2. In reality, not all phases may be present or important, and the phases are not as distinct as the model implies. It should also be noted that although Figure 4-1 illustrates a surface recharge basin, the concepts described below can also be applied to subsurface recharge alternatives.

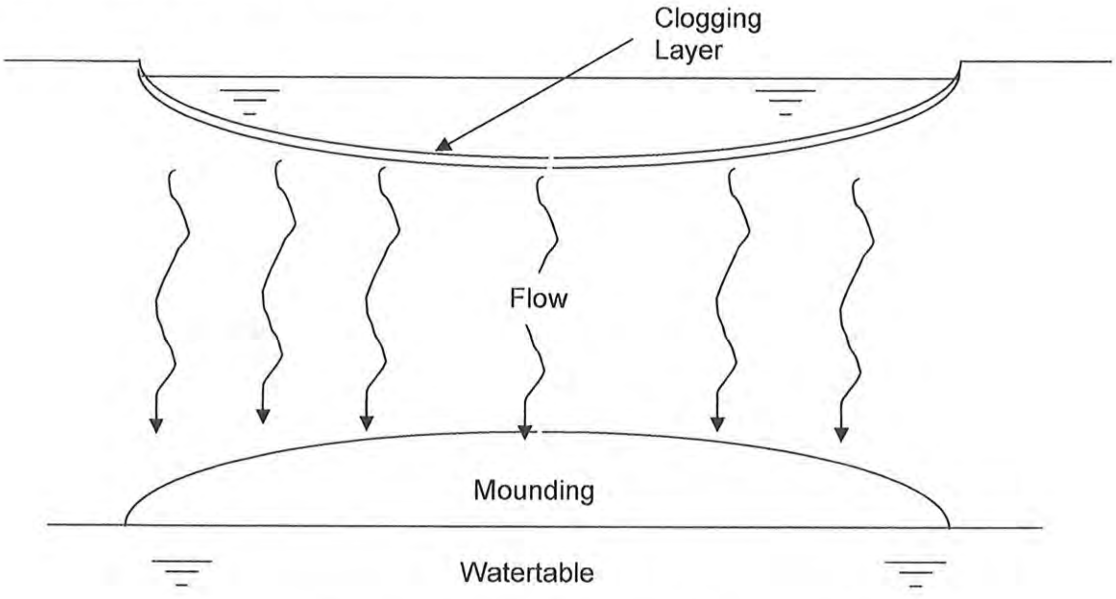


Figure 4-1: General Context of Clogging

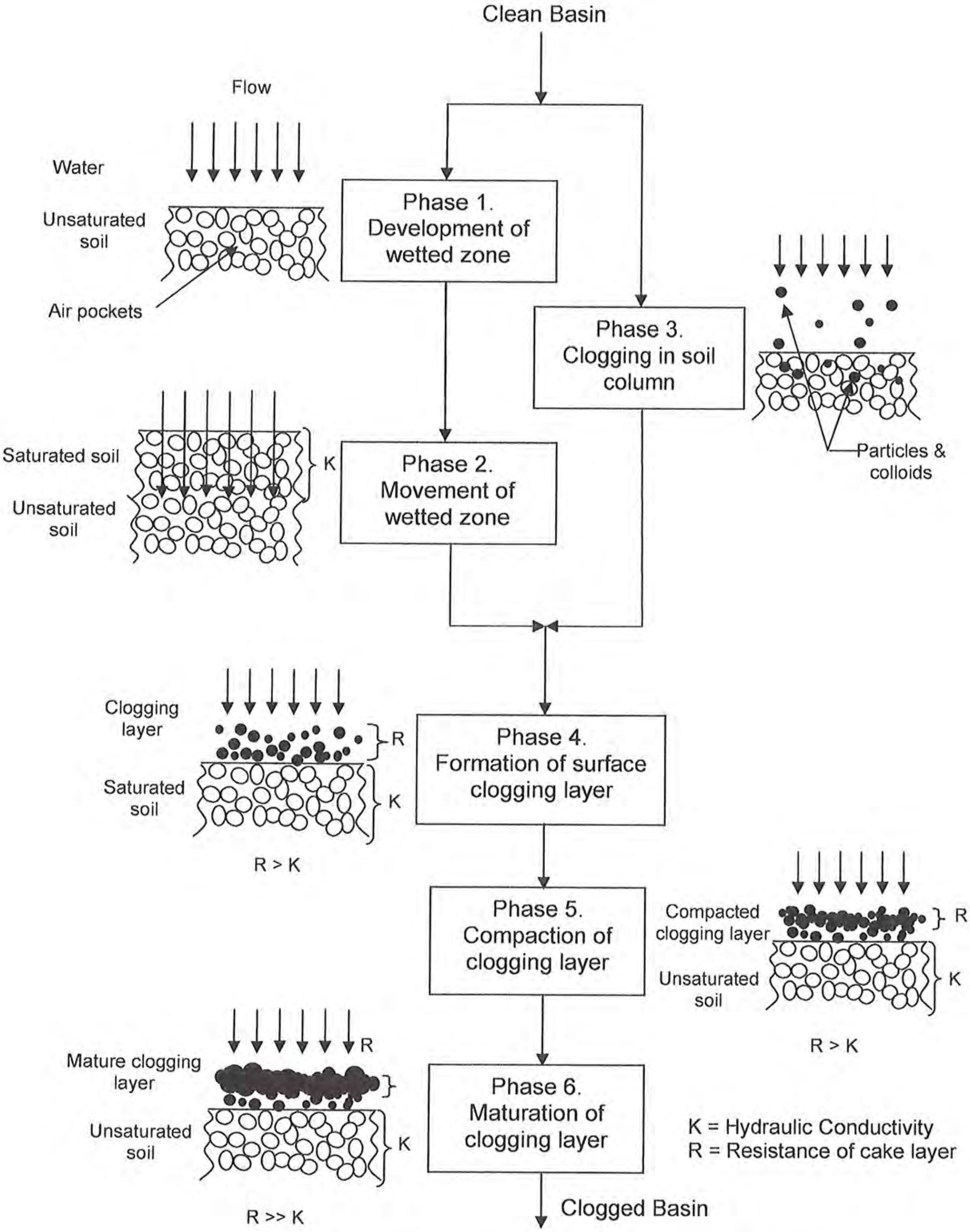


Figure 4-2: Phases of Clogging During Artificial Recharge

4.2.1 Phase 1 - Development of Wetted Zone in Soil

During Phase 1, water enters the soil from the recharge basin (or subsurface recharge concept), developing a wetted zone. The movement of the water results in the creation of flow paths in the soil matrix, but saturation of the soil is limited by entrapped air. Characteristics of Phase 1 include an increase or decrease in the percolation rate as entrapped air is released from the soil matrix.

4.2.2 Phase 2 - Movement of Wetted Zone in Soil

During Phase 2, the top portion of the soil becomes fully wetted and flow paths are developed. Flows respond to Darcy's law (flow proportional to head and inversely proportional to flow distance, the proportionality constant is the hydraulic conductivity (*K*)). Characteristics of Phase 2 include an initial high percolation rate, followed by a decrease in percolation rate as the length of the flow path in the wetted zone increases, and an eventual equal percolation rate and hydraulic conductivity. The hydraulic conductivity of the soil sets the maximum sustainable percolation rate for the system without clogging.

4.2.3 Phase 3 - Initial Clogging in Soil

Phase 3 is distinguished by the beginning of the entrance of colloids and particulates into the soil blocking pores in the soil. Characteristics of Phase 3 include an initial decrease in soil hydraulic conductivity near the surface of the soil while the lower soil is not impacted by clogging. This effect becomes less important as the clogging layer develops on the surface of the soil.

4.2.4 Phase 4 - Formation of Surface Clogging Layer

During Phase 4, particulates accumulate on the surface of the soil forming a cake clogging layer. Colloids penetrate into cake layer increasing hydraulic resistance. Characteristics of Phase 4 include formation of a thin, low hydraulic conductivity layer at the surface of soil, resulting in particulates and colloids that become trapped by the cake layer, and can no longer penetrate into the soil. Additionally, the system percolation rate is now controlled by the cake layer resistance (R) rather than the hydraulic conductivity of the soil and the wetted zone in the soil becomes unsaturated since flow is now controlled by cake layer resistance.

4.2.5 Phase 5 - Compaction of clogging layer

Phase 5 occurs when the clogging layer is compressed under hydraulic head. Characteristics of Phase 5 include an increase in intergranular pressure as unsaturated flow below the cake layer increases, causing compaction of the cake layer and thus increasing the hydraulic resistance of the cake layer. This becomes the dominant effect controlling the percolation rate.

4.2.6 Phase 6 - Maturation of Compacted Clogging Layer

During the final phase, Phase 6, biological and chemical interaction occurs in the clogging layer further increasing resistance and decreasing permeability. Characteristics of Phase 6 include further reduction of percolation rates by biological activity, through clogging, changes in pH, oxidation reduction reactions, or respiration. Additionally, chemical precipitation of carbonates, sulfates, phosphates may occur, increasing hydraulic resistance. Inter-particle effects related to surface charge may also occur, increasing hydraulic resistance. Phase 6 is a long-term development, typically developing after one or more months of recharge operation.

5.0 Sediment Removal Strategies

Previous sections of this report described various surface and subsurface recharge concepts without consideration of the impacts of clogging. Although clogging has not been identified as a problem on existing IRWD recharge projects, long-term accumulation of sediments and biological activity can reduce percolation rates over time and adversely impact the annual recharge and storage potential. The impacts due to clogging can be actively managed within recharge concepts that allow for easy access for cleaning, handling and removal of the associated foulants; however recharge concepts that are not readily accessible will exhibit diminished percolation rates over prolonged usage. As mentioned in Section 4.1, the causes of clogging are complex, but are often related to TSS or sediment load of the source water quality, and to a lesser extent, the nutrients within the source water that may lead to biological activity. For this reason, potential sediment removal strategies capable of removing these constituents are evaluated in this section as potential pretreatment options. Pretreatment is recommended for those recharge concepts where accessibility for maintenance is limited. Specific to this study, it is recommend that Concepts 2, 3 and 4 include pretreatment due to inaccessible or limited access to these recharge alternatives. Concept 1 – Surface Recharge Ponds are readily accessible for maintenance and cleaning activities, thus the IRWD recharge goals can reasonable be achieved without additional pretreatment. Concept 5 – Subsurface Conveyance System also provides the ability of access via manholes, which facilitate cleaning opportunities, albeit a more complex maintenance approach, allowing for a means of managing clogging potential while achieving the recharge goals.

The primary functional objectives for the sediment removal strategies are to remove sediment from the source water to be used in IRWD's potential recharge projects as a means to assist IRWD in optimizing the performance of its recharge facilities and in reaching long-term water banking goals.

Sediment removal alternatives were identified by HDR based on previous project experience and categorized as follows:

- Chemical/Physical Removal:
  - High Rate Sedimentation (HRS)
  - Ballasted Sedimentation (HRC)
  - Dissolved Air Flotation (DAF)
- Mechanical Removal
  - Cloth Filter
  - Membrane Technology
- Passive Treatment Systems

It should be noted that all of the chemical/physical sediment removal strategies stated above require the addition of a chemical coagulant. Mechanical sediment removal strategies typically do not require coagulant addition. The more chemical coagulant that is added to a process, the more precipitants are formed and must be dealt with during the residuals handling process. Typical chemical coagulants contain metals, which could add challenges to disposal options.

Each of the potential sediment removal strategies identified above are described in greater detail throughout this chapter.

5.1 Chemical/Physical Removal Strategies

Chemical/Physical removal technologies utilize a chemical or physical process to reduce the amount of sediments carried in the source water. The strategies described below are distinguished by several different criteria including:

- Surface Loading Rate (SLR) – Flow of water applied to a square foot of surface area
- Detention Time – Amount of time a fluid element remains within a particular basin
- Side Water Depth – Height of water required for process
- Anticipated Percent Solids – Percent of solid residuals within process waste stream
- Anticipated Footprint – Total land area required for entire sediment removal strategy (including all structures, equipment pads, pumping stations, etc.)

The typical design criteria indicated in the following sections are based on a combination of manufacturer input, literature searches and previous project experience. The design criteria included are for a potential IRWD system of 27 mgd or 10,000 AFY (over four months) and are based on scaled values from a recent project that HDR has performed for OCWD (refer to Section 6.0). Each of the potential chemical/physical removal strategies (High Rate Sedimentation, Ballasted Sedimentation, and Dissolved Air Flotation) is described in the sections below.

5.1.1 High Rate Sedimentation

High Rate Sedimentation is a modified version of the conventional sedimentation process that involves the installation of tubes or plates in the settling basin to increase the settling surface area, while reducing the footprint. Tube settlers are installed in the sedimentation zone at an angle (typically 60°), thus providing a larger surface area for the settled floc to accumulate. Flow enters through the bottom of the tubes and moves up to an effluent collection device such as a launder or submerged pipe lateral orifice. As the water moves up the pipe, floc settle on the inclined surface and gradually gain mass until sliding down the angled tube wall to the sludge zone. Figure 5-1 provides an example of typical flocculation-sedimentation basins and Figure 5-2 illustrate the tube settlers associated with the high rate sedimentation process.

Plate settlers are similar to tube settlers in that they are installed in the sedimentation zone at an angle (typically 55°), allowing the solids to slide down the angled plate into the sludge zone below. Flow typically enters the plates from the side near the bottom and moves up to an effluent collection device.

Figure 5-1: Typical Flocculation-Sedimentation Basins

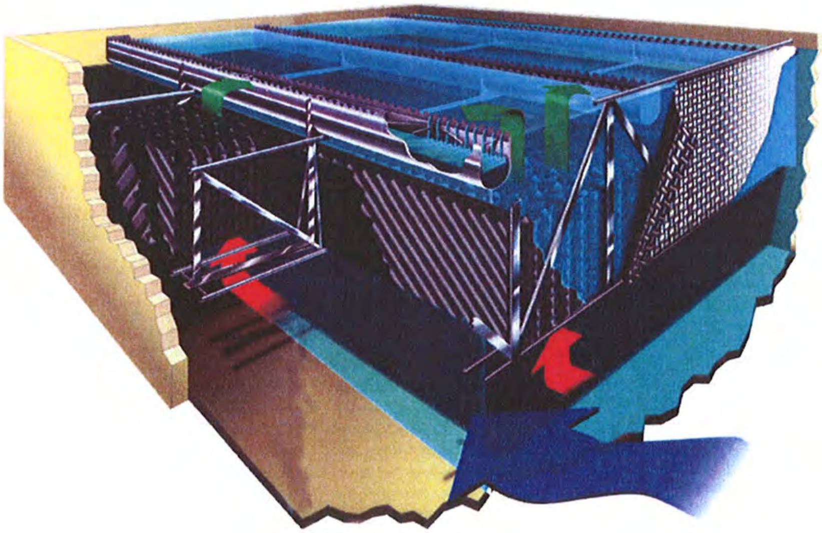


Figure 5-2: High Rate Sedimentation

Table 5-1 provides a summary of the typical design criteria associated with High Rate Sedimentation:

Table 5-1: High Rate Sedimentation Typical Design Criteria

Description	Criteria	Units
Surface Loading Rate	2.0- 3.5	gpm/ft^2
Detention Time		
Flocculation Zone	30 – 45	min
Sedimentation Zone	45-60	min
Side Water Depth	13 - 15	ft
Anticipated Percent Solids	0.8 – 1.5	%
Anticipated Footprint (27 mgd)	13,000-16,000	ft^2

5.1.2 Ballasted Sedimentation

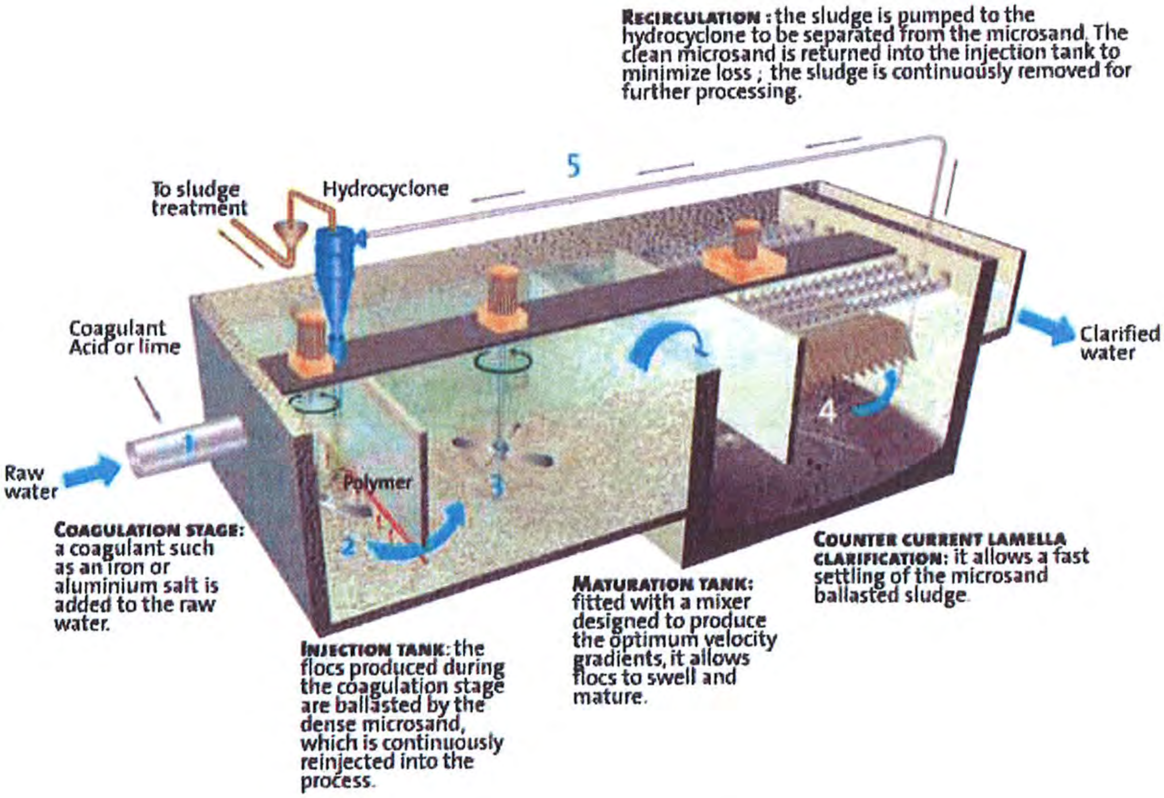
Ballasted sedimentation, also referred to as high rate clarification (HRC) is a treatment process that utilizes microsand as a ballast or nucleus to form a dense floc that readily settles. The process uses a coagulant and polymer to assist the removal efficiency. A hydrocylone is used to separate the microsand from the sludge for reuse. Lamella plate settlers are installed in the clarifier, allowing high surface loading rates.

Table 5-2 provides a summary of the typical design criteria associated with Ballasted Sedimentation:

Table 5-2: Ballasted Sedimentation Typical Design Criteria

Description	Criteria	Units
Surface Loading Rate	20-40[a]	gpm/ft^2
Side Water Depth	26-28	ft
Anticipated Percent Solids	0.1-0.5	%
Anticipated Footprint (27 mgd)	3,000-4,500	ft^2

Figure 5-3 illustrates the HRC process. This proprietary process, known as Actiflo®, is manufactured by Krüger.



RECIRCULATION : the sludge is pumped to the hydrocyclone to be separated from the microsand. The clean microsand is returned into the injection tank to minimize loss ; the sludge is continuously removed for further processing.

COAGULATION STAGE: a coagulant such as an iron or aluminium salt is added to the raw water.

INJECTION TANK: the flocs produced during the coagulation stage are ballasted by the dense microsand, which is continuously reinjected into the process.

MATURATION TANK: fitted with a mixer designed to produce the optimum velocity gradients, it allows flocs to swell and mature.

COUNTER CURRENT LAMELLA CLARIFICATION: it allows a fast settling of the microsand ballasted sludge.

Figure 5-3: Krüger Actiflo® Ballasted Sedimentation Process

5.1.3 Dissolved Air Flotation (DAF)

Dissolved Air Flotation (DAF) is an alternative to conventional clarification that achieves removal by creating smaller floc particles that can be floated to the surface. This is accomplished by dissolving air in the water under pressure and then releasing the air at atmospheric pressure in a flotation tank or basin. The released air forms tiny bubbles with a size range of 10 to 100 µm that adhere to the suspended matter causing the floc to float to the surface of the water where they may then be removed by a skimming device. If left at the surface, the floating floc layer can thicken to approximately 3% to 6% dry solids.

Table 5-3 provides a summary of the typical design criteria associated with DAF:

Table 5-3: Dissolved Air Flotation Typical Design Criteria

Description	Criteria	Units
Surface Loading Rate	12[a]	gpm/ft^2
Side Water Depth	12-16	ft
Anticipated Percent Solids	3.0-6.0	%
Anticipated Footprint (27 mgd)	6,800	ft^2

Figure 5-4 illustrates the DAF process. Manufacturers of proprietary DAF units include Leopold and Siemens.

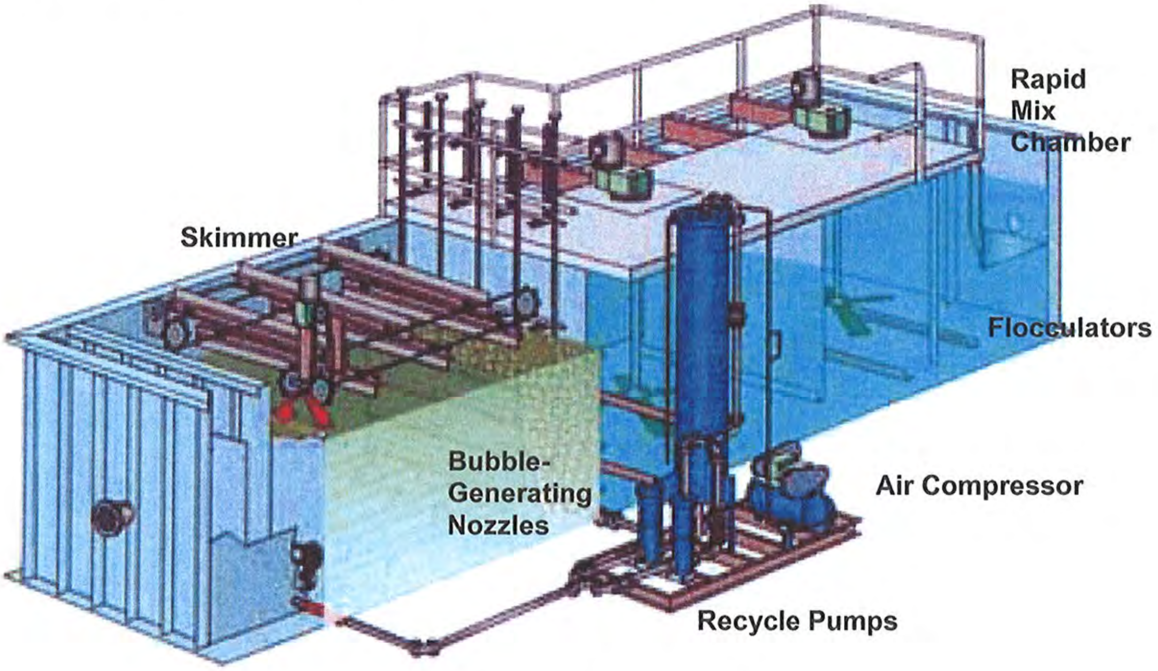


Figure 5-4: Leopold Clari-DAF® Process

5.2 Mechanical Removal Strategies

Mechanical removal strategies utilize a mechanical process to reduce the amount of sediments carried in source water. The strategies described below are distinguished by several different criteria including:

- Filter Loading Rate – Flow of water applied to a square foot of filter
- Flux Rate – Flow of permeate or filtrate through an MF membrane
- Side Water Depth – Height of water required for process
- Anticipated Percent Solids – Percent of solid residuals within process waste stream
- Anticipated Footprint – Total land area required for entire sediment removal strategy (including all structures, equipment pads, pumping stations etc.)

The typical design criteria indicated in the following tables are based on a combination of manufacturer input, literature searches and previous project experience. The design criteria included are for a potential IRWD system of 27 mgd or 10,000 AFY (over four months) and are based on scaled values from the OCWD project. Each of the potential mechanical removal strategies (Cloth Filter, Membrane Technology) is described in the sections below.

5.2.1 Cloth Media Filters

Cloth filters utilize a cloth fabric media to trap sediments as water is pushed through the fabric. The cloth media is completely submerged in the influent stream, while sediment is deposited on the outside of the cloth as the influent stream flows through the media. Effluent flows are collected via laterals inside the media and discharged by gravity. Backwash occurs periodically and involves vacuuming of the solids off the outside of the cloth media. Cloth Filters are low head systems, and typically do not require additional pump stations. Several configurations of cloth media filters exist including disk and diamond formation.

Table 5-4 provides a summary of the typical design criteria associated with Cloth Filters:

Table 5-4: Cloth Filters Typical Design Criteria

Description	Criteria	Units
Filter Loading Rate	2.0-4.0	gpm/ft^2
Side Water Depth	8.0	ft
Anticipated Percent Solids	0.5-1.0	%
Anticipated Footprint (27 mgd)	5,800	ft^2

Manufacturers of these filters include Aqua-Aerobics (AquaDisk®, AquaDiamond®) Parkson (Dynadisc®), and Krüger (Hydrotech Discfilter®). The AquaDiamond® is shown in Figures 5-5 and 5-6.

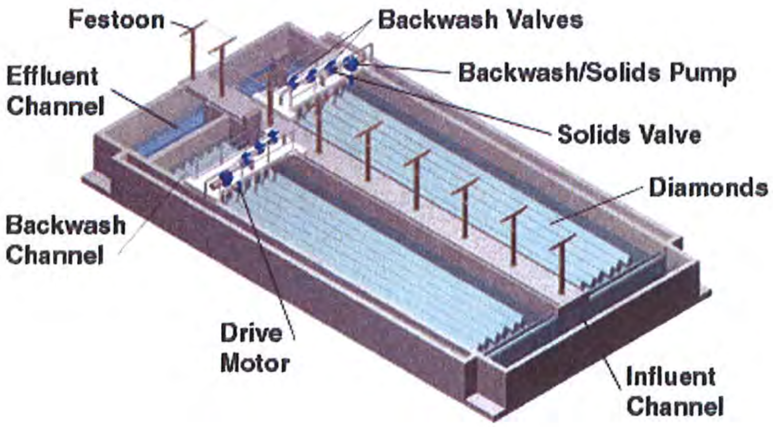


Figure 5-5: AquaDiamond Cloth Filter Process


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Figure 5-6: AquaDiamond Cloth Filter Installation

5.2.2 Microfiltration (MF)

Immersed membranes can produce effluent with virtually no suspended solids and can remove some microorganisms such as bacteria and cysts. In some situations, this process can be effective for removing certain organic species. This process will produce high quality finished water.

Immersed membranes use hollow fibers bundled into a cassette arrangement. The cassettes are then immersed in the effluent and operate under a vacuum created within the hollow membrane fibers by a permeate pump. Water is drawn through the membrane pores and enters the inside of the hollow fibers. Filtered material is kept on the exterior surface of the fibers. Air is introduced at the bottom of the membrane cassettes to create turbulence, scour and clean the outside surface of the membrane fibers. The filter cell is periodically backwashed to remove filtered material from the membrane surface. Periodic chemical cleaning is required to remove deposits of materials entrained on the membrane surface that is not removed by backwashing.

It is anticipated that this process will not require chemical pretreatment due to the tighter membrane pore size, thus simplifying residuals handling associated with this alternative.

Table 5-5 provides a summary of the typical design criteria associated with Microfiltration:

Table 5-5: Microfiltration Typical Design Criteria

Description	Criteria	Units
Flux Rate	37	$g/d/ft^2$
Side Water Depth	11-12	ft
Anticipated Percent Solids	0.5	%
Anticipated Footprint (27 mgd)	8,800	ft^2

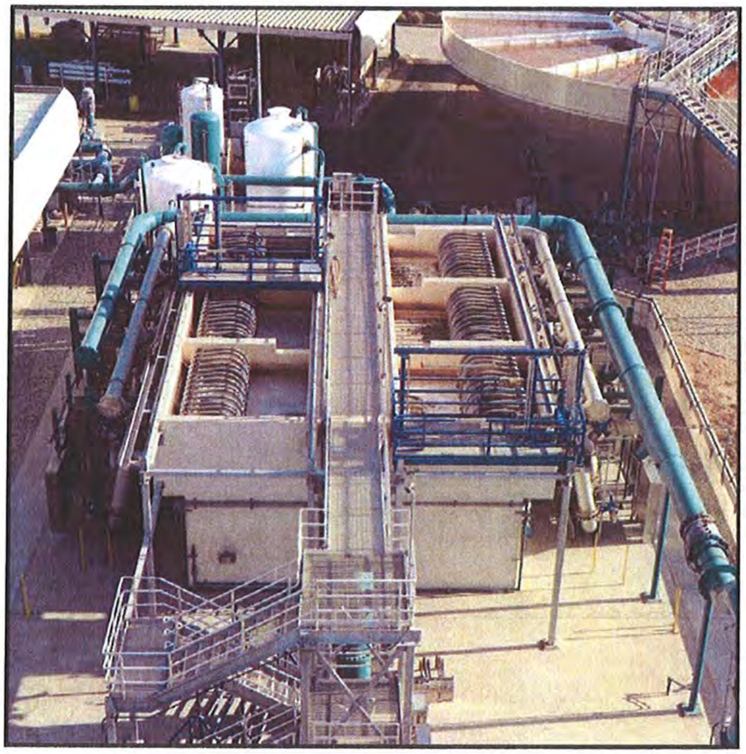

Figure 5-7: Immersed Microfiltration Membranes at West Basin MWD

5.3 Passive Treatment Systems

Passive treatment systems (i.e., river-bed filtration systems) can be installed within the river itself, or within close proximity to the river, utilizing the natural sand as a means of filtering sediment from the source waters in order to optimize recharge. Shallow Ranney wells (wells drilled vertically to a particular depth with horizontal perforated pipes or laterals extending radially outward) are employed to naturally filter water in the river bed, collect the filtered water via perforated pipes, and transport to recharge facilities. In-channel bank filtration systems with dedicated conveyance ditches or top-slotted pipelines (basically, reverse French drains) are used in a similar manner, with the potential advantage of conveying water by gravity in lieu of pumping, provided that there is sufficient grade difference from the location of the passive underdrain system and the receiving recharge basin or facility.

Passive treatment for sediment removal may not be a viable option for IRWD's Kern Fan project where the recharge facilities are a considerable distance from the source water. Additionally, stringent permitting requirements may deter construction within the river.

6.0 Summary of OCWD Study/Results

IRWD's Kern Fan area recharge objectives and goals are similar to other agencies that are actively pursuing recharge projects, such as the Orange County Water District (OCWD). Both agencies are currently focused on mitigating the increasing demands on California's water resources, in part, by implementing methods to capture and store (via underground aquifers) surplus storm waters that would otherwise be lost to other watersheds or the ocean. Also, both agencies are actively investigating available methods and technologies to enhance or optimize their recharge potential. This section provides a brief insight into OCWD's recent evaluation of optimizing their recharge spreading basins, and identifies the relevance to IRWD's current recharge program.

OCWD has been involved with groundwater recharge since the 1930's. Since inception, OCWD has built over 1,000 acres of recharge spreading facilities located in and adjacent to the Santa Ana River. OCWD has operated recharge basins to augment its groundwater supply to provide water for more than 2.3 million people served by more than 20 water providers that pump water for domestic purposes. One of the most plentiful supplies for groundwater replenishment is the Santa Ana River, the base flow of which has increased over time as the upper river basin has been urbanized and yields more runoff. However, recharge of the aquifer with available water supplies is limited by a number of factors, including clogging of the recharge facilities by a combination of organic and inorganic sediments in the Santa Ana River. Currently, the operable storage of the aquifer is not being fully utilized and increasing quantities of available renewable water supplies cannot be recharged because of the limitations caused, in part, by clogging due to the sediment carried in the Santa Ana River and local runoff.

It is OCWD's goal to capture and recharge as much Santa Ana River water as possible on an annual basis through its facilities, with long-term goals of achieving 700 cfs winter/spring and 500 cfs summer/fall recharge capacities. In an effort meet these goals without adding additional recharge facilities, OCWD recently embarked on a study in cooperation with HDR, Inc. to evaluate and determine effective alternatives to remove sediment from the Santa Ana River, in order to optimize and sustain "clean bed" percolation rates for extended durations and minimize the impacts due to clogging.

6.1 Pilot Testing of Sediment Removal Technologies

The OCWD study began with a preliminary investigation and pre-screening of potential sediment removal technologies. Technologies evaluated and piloted tested include; chemical/physical removal, mechanical removal and passive treatment strategies. Sediment removal strategies were evaluated at a base flow rate of 40 million gallons per day (mgd), or 62 cfs. Depending on the amount of water deemed necessary to meet OCWD's recharge goals, the base flow rate/sediment removal strategies could be scaled up to a larger system for further evaluation.

Based on the results of the preliminary evaluation of the sediment removal strategies, the project team determined that pilot testing of pre-screened technologies was necessary in order to observe the performance of each technology on treating varying water quality of the Santa Ana River and the resulting impacts to percolation. The primary objective of the pilot testing study was to demonstrate the ability of the processes to reliably remove sediment from the Santa Ana River water in an effort to reduce the clogging potential and to sustain the percolation rates within OCWD's recharge basins for longer periods of time. This primary objective would assist OCWD in optimizing the performance of the existing recharge facilities as one of the approaches to reaching their long-term recharge capacity goals.

Other objectives associated with the pilot testing included collection of data for each sediment removal process in order to develop specific design criteria to meet the production goals of the selected treatment technologies.

The pre-screened technologies selected for pilot testing included; ballasted sedimentation, dissolved air flotation, conventional flocculation-sedimentation, cloth filters, and passive (in-river) underdrain systems, similar to the technologies described in Section 5.0. The project team decided to pilot test conventional flocculation-sedimentation rather than high rate sedimentation since the two processes are essentially the same and differ only in footprint and settling tubes. Microfiltration was removed as a candidate for pilot testing due to budget constraints.

Pilot testing began in January 2009 and continued for approximately eight weeks. Water quality data was collected on raw source water as well as treated water from each technology throughout the duration of the pilot testing. Each sediment removal technology was compared to the others based on pre-determined evaluation methods which included; lab column percolation tests, larger percolation test cells, membrane fouling index (MFI), reduction in particle size distribution, and reduction of TSS and turbidity. Data from the study was reduced and evaluated. Section 6.2 summarizes the primary conclusions and recommendations.

6.2 OCWD Study Conclusions and Recommendations

Results from the pilot testing phase generally indicated that sediment removal technologies which did not rely on chemicals to induce coagulation, such as the cloth filter and passive system, performed the best. It was determined that chemical addition to the OCWD source water resulted in faster percolation decay than the untreated source water. Although the scope of the study did not include a thorough investigation into the mechanism causing the chemical fouling, it was theorized that the clogging could be attributed to destabilization and agglomeration of particles within the recharge basin media as a result of chemical carry-over.

The passive system performed the best in all of the evaluation methods, followed by cloth filters. Percolation testing results indicated that both the passive system and the cloth filter technologies have the potential to improve overall recharge performance by reducing the percolation decay rates currently exhibited by untreated Santa Ana River water.

From an operational viewpoint, both the passive and cloth filter systems were determined to be relatively simple to operate and, as stated above, did not involve the use of chemicals. Based on the results of the pilot test, the following recommendations were made for the OCWD recharge project:

1) The cloth filter and passive systems should be considered for additional evaluation.
2) Treatment systems that involve the use of chemical systems to aid in coagulation/flocculation of the water should not be further investigated.
3) Demonstration level testing is needed to address performance issues over time periods representative of clogging, rather than on an accelerated time scale. To the extent possible, the demonstration test should be performed under hydraulic conditions in a basin whose hydraulic residence time is similar to OCWD recharge basins, and under similar environmental conditions as the current OCWD recharge facilities.

6.3 Relevance of OCWD Study to IRWD Kern Fan Project

The Irvine Ranch and Orange County Water Districts both currently own and operate existing recharge facilities, and both agencies are actively investigating innovative and economical means of optimizing recharge potential and maximizing effective land use. Although IRWD does not currently experience clogging problems within their surface recharge ponds, OCWD's study evaluates strategies to reduce clogging in their own surface recharge ponds in order to optimize recharge performance. These same sediment removal strategies may also be considered useful for IRWD's Kern Fan project in order to enhance recharge within the concepts considered in this report. Additionally, results from the OCWD study and associated pilot testing offer additional insight related to expected treatment performance and operational parameters that may also be considered by IRWD as the District continues to pursue recharge opportunities.

7.0 Non-Economic Evaluation of Recharge/Infiltration Concepts and Sediment Removal Strategies

Sections 3.0 and 5.0 of this report have identified and described potential recharge alternatives and sediment removal technologies, respectively, that could be considered for future implementation for IRWD's Kern Fan water banking program. The following section provides a qualitative, non-economic evaluation of the identified recharge alternatives and sediment removal technologies by establishing comparative criteria from which each concept or technology can be weighed against the other.

7.1 Non-Economic Evaluation of Recharge/Infiltration Concepts

A qualitative evaluation of the recharge/infiltration concepts using the non-economic criteria presented below are summarized in this section.

- Performance – A recharge concept's ability to infiltrate water into the soils and aquifer below. Also considers proven performance and extent of use within the industry in the field of recharge or similar application.
- Constructability – Considers the complexity of construction and level of difficulty associated with the permitting process for each of the recharge concept.
- Operations and Maintenance – Considers the level of operational attention required by each concept, frequency and difficulty of maintenance activities, accessibility to the working parts of the system, and complexity of operation.

7.1.1 Evaluation of Concept 1 – Surface Recharge Ponds

Benefits or advantages associated with Surface Recharge Ponds include proven performance, simple construction, and accessibility for operations and maintenance, including periodic scraping to manage sediment accumulation within the basin. Surface recharge is widely used throughout the arid southwest for the purpose of reclamation and aquifer storage. These systems have a proven track record for recharge performance and are simple to operate. Construction activities have a relatively low complexity since most of the construction is dedicated to shallow earthwork to construct the berms of the ponds.

Disadvantages of this type of recharge system include the potential of biological fouling in shallow basins due to the daily exposure to the sun. There is potential for a faster rate of fouling caused by phytoplankton or algal blooms. The daily exposure to higher temperatures also results in additional evaporation losses, when compared to the other subsurface alternatives. Another disadvantage of this concept is use of land. Because the ponds are constructed at grade, beneficial use of the land is limited when compared to the other alternatives.

7.1.2 Evaluation of Concept 2 – Subsurface Recharge Galleries

The primary benefit of utilizing the subsurface recharge gallery concept is that it can be constructed beneath parks, greenbelt areas or areas with existing improvements in which a less expensive lease or easement for the site could replace ownership, as well as facilitate beneficial use of the land. Additional advantages of this concept include a reduction (or potential elimination) of evaporation losses attributed to sun exposure, and a potential reduction of biological fouling (i.e., reduction of autotrophic biological activity as described in Section 4.0).

Disadvantages include less proven performance, more difficult construction, limited accessibility for maintenance and more difficult O&M because of the size and complexity of the system. Based on literature searches, this type of recharge system is not widely utilized for systems of the magnitude considered for the IRWD Kern Fan water banking project. The most common use of this type of infiltration system is with respect to leach fields associated with septic systems. Construction is anticipated to be somewhat more difficult when compared to the surface ponds, due to the installation and placement of the multiple laterals and header piping. Although algal growth is not expected to be an issue due to the absence of sunlight, other biological growth (heterotrophic activity) is expected to occur in the benthic zone (soil near the soil/water interface) which could contribute to fouling. However, since the anticipated system usage in the Kern Fan area is limited to four months out of the year, drainage of the system during the off-season may help to mitigate biological fouling. Due to the inaccessibility of this option, the potential for irreversible sediment clogging over time presents significant challenges.

7.1.3 Evaluation of Concept 3 – Shallow Injection Wells

Concept 3 shares the same benefits as described for Concept 2, with respect to easements, beneficial use of the land, reduced evaporation, and potential reduction in biological fouling impacts due to intermittent use. Additionally, if a confining layer exists in selected recharge location, this alternative has the ability to develop the point of recharge below the confining layer.

Disadvantages include less proven performance, more difficult construction, limited accessibility for maintenance and more difficult O&M because of the size and complexity of the system. Similar to Concept 2, this infiltration concept is not widely used for large recharge systems, and is more commonly utilized for deep injection. Due to the depth of the laterals and central caisson associated with this concept, the construction will be more difficult and include the need for shoring and potential dewatering activities. The system, once installed, is also inaccessible for maintenance and cleaning which will present clogging challenges as sediment accumulates within the laterals over time.

7.1.4 Evaluation of Concept 4 – CULTEC Engineered Systems

Concept 4 shares the same benefits as described for Concepts 2 and 3, regarding easements, beneficial use of the land, reduced evaporation and potential reduction in biological fouling due to intermittent use. Additionally, the systems have proven performance, specific to storm water management, and are of a modular construction for relatively easy expansion. The CULTEC systems can be accessed for periodic maintenance, however it would be considered a confined space and the manufacturer recommends limiting access.

Disadvantages include more difficult construction, requiring shoring and anticipated dewatering activities due to the depth of the system. Clogging as a result of accumulated sediment and heterotrophic biological activity is anticipated. Although access is provided with this system, it is more challenging for cleaning and maintenance operations when compared to some of the other systems considered in this section.

7.1.5 Evaluation of Concept 5 – Subsurface Conveyance Concept

Similar to Concepts 2, 3, and 4, benefits associated with the Subsurface Conveyance concept include easements, beneficial use, reduced evaporation and potential reduction in biological fouling due to intermittent use. The subsurface conveyance system also poses the added benefit of potentially flushing much of the suspended sediment through the system, provided that the system is hydraulically modeled and designed to keep the velocities at appropriate speeds to prevent settling. Additionally, the large size of the inverted trench box will allow for accessibility via manholes located at reasonable distances along the conveyance system. Accessibility can also allow for periodic cleaning of portions of the system.

The primary disadvantage of this concept is that it is a unique approach to recharge and the performance and suitability of this concept is currently unknown. Detailed hydraulic modeling should be considered, as well as further studies such as pilot and/or demonstration testing in order to gain a better understanding of the anticipated performance and detailed design criteria associated with this concept.

The construction of Concept 5 will include some challenges due to the anticipated 65-mile length of pipeline needed to provide 50% of the overall percolation, with a smaller surface recharge basin providing for the remaining recharge as described in Section 3.0. The large width and depth of trench required may result in significant impacts to the public right of way, including prolonged traffic disruptions during construction. Due to the depth of the large trench box system, shoring and dewatering activities are anticipated. Depending on the actual alignment location, the construction may pose some environmental and/or public impacts. Because of the large length of conveyance required, the system is expected to require multiple bends in an effort to follow existing roadways and accessible right-of-ways. These bends may create eddies and "dead zones" in the flow stream, causing the sediment to drop out and accumulate at these locations. Additionally, because the system will utilize non-conventional conveyance methods (i.e., inverted trench box or half-pipe), availability of segments for bends, etc, will be limited. Most likely these segments need to be specially precast or cast in place.

Although this concept assumes that much of the sediment will be carried through the system, it is unlikely that all silts and sediment will pass through without some impacts to clogging. As a percentage of the flow percolates into the soils, the flow vectors will tend to carry some quantity of fine silts into the pours of the filter fabric, contributing to clogging. Additionally, heterotrophic biological activity, similar to Concepts 2, 3 and 4, may also contribute to clogging over time. Periodic cleaning through access manholes will help mitigate the impacts of clogging.

7.1.6 Comparison of the Non-Economic Criteria

The advantages and disadvantages of each concept, as identified above, are consolidated into a comparative format in Table 7-1. Each of the three non-economic criteria established earlier (i.e., Performance, Constructability, and O&M) are independently considered in this table, from which an overall comparison and scoring can be derived as established in Table 7-2.

Table 7-1: Recharge Conce

Concept	Performance	Constr
Concept 1 – Surface Recharge Ponds	• Proven performance for large scale recharge projects	• Sim req • Lea con • Sim • Re
Concept 2 – Subsurface Recharge Galleries	• Not as common for large scale recharge projects • Pretreatment is recommended to optimize performance	• Mo per • Mo • Ca
Concept 3 – Shallow Injection Wells	• Proven track record for deep bed injection • Pretreatment is recommended to optimize performance	• Mo wit • Lar late • Mo • Ca
Concept 4 – CULTEC Engineered Systems	• Unproven performance for large-scale recharge projects (Typically used for storm water storage and infiltration.) • Pretreatment is recommended to optimize performance	• Mo (sh • Mo • Ca
Concept 5 – Subsurface Conveyance	• Unproven performance for large scale recharge projects • Long term performance is unknown	• Tra • Mo wit • No • Lim • Ca

Considering the information in the previous sections, the recharge concepts were numerically rated from 1 to 5 for each of the non-economic evaluation criteria. Results of this ranking are shown in Table 7-2.

Table 7-2: Non-Economic Recharge Concept Evaluation

Concept	Performance	Constructability	Operations & Maintenance	Overall Ranking
Concept 1 – Surface Recharge Ponds	5	5	5	5.0
Concept 2 – Subsurface Recharge Galleries	4	3	2	3.0
Concept 3 – Shallow Injection Wells	3	1	1	1.7
Concept 4 – CULTEC Engineered Systems	3	3	4	3.3
Concept 5 – Subsurface Conveyance	2	2	4	2.7

1 = Least favorable
5 = Most favorable

Taking into account only this preliminary non-economic evaluation, Surface Recharge Ponds appear to be the most favorable choice, followed by CULTEC Engineered Systems and then Subsurface Recharge Galleries. The Surface Recharge Ponds received the highest comparative ranking due to their proven performance in the industry, simple construction, and ease of operation. The Subsurface Conveyance Concept and Shallow Injection Wells appear to be least favorable choices when evaluated by these non-economic criteria.

7.2 Non-Economic Evaluation of Sediment Removal Strategies

A qualitative evaluation of the sediment removal strategies identified in Section 5.0 is summarized in this section based on the following non-economic criteria.

- Performance – A sediment removal system's ability to remove sediment from a source water to effectively increase recharge into the soils and aquifer below. Also considers proven performance and use within the industry.
- Constructability – Considers the complexity of construction and level of difficulty associated with the permitting process for each of the treatment concepts.
- Operations and Maintenance – Considers the level of operational attention required by each concept, frequency and difficulty of maintenance activities, accessibility to the working parts of the system, and complexity of operation.

As discussed in Section 5.0, pretreatment is recommended for those recharge concepts that are not accessible, or provide limited access for maintenance and cleaning; specifically Concepts 2, 3 and 4.

7.2.1 Evaluation of Concept 1 – High Rate Sedimentation

The primary benefit of high rate sedimentation is that it is a robust process with a proven track record for performance, and is widely used in water treatment. The system is capable of providing reliable treatment during variations in flow rate or water quality. The process is also relatively simple to operate, has minimal equipment to control, and is fairly simple to maintain.

Disadvantages of high rate sedimentation include larger land requirements than some of the other treatment technologies, more challenging construction due to the larger footprint and the reliance on chemicals for coagulation. The use of chemicals will require additional storage and feed facilities, and require an additional level of training of personnel for proper handling and safety.

7.2.2 Evaluation of Concept 2 – Ballasted Sedimentation

The advantages of ballasted sedimentation are that it is a compact process requiring a much smaller footprint than high rate sedimentation and is capable of producing high quality treated water, even during variation in flow rates and water qualities. The system has a proven track record and is frequently used in water treatment. Additionally, the system is modular, which allows for ease of expansion in the future.

The primary disadvantage associated with ballasted sedimentation when compared to the other technologies is that it is a more complex system to operate. As described earlier in the report, the system includes the use of a coagulant (typically ferric chloride or alum), polymer, and microsand as the ballast, of which doses and quantities need to be monitored and maintained. The system requires a higher level of operator attention and associated maintenance when compared to some of the other technologies.

7.2.3 Evaluation of Concept 3 – DAF

The primary benefit of utilizing the DAF concept is that it is also a compact process requiring a much smaller footprint than high rate sedimentation and is capable of producing high quality treated water, even during variation in flow rates and water qualities. Additionally, the system is modular, which allows for easier expansion in the future.

Disadvantages include its complexity, with more operator attention and maintenance required similar to ballasted sedimentation. Also, this system relies on a chemical coagulant as part of the process, of which dose and quantities need to be monitored and maintained.

7.2.4 Evaluation of Concept 4 – Cloth Filtration

The cloth filtration technology provides for a relatively small, modular footprint similar to Concepts 2 & 3, above. In addition, the cloth filter system is a simple process, easy to operate and maintain with simply automation. An additional benefit of the cloth filter system is that it does not rely on chemicals to facilitate the process as the other technologies evaluated above.

Some disadvantages of the cloth filtration technology are that it may be limited to wide variations in flow rate and solids loading. Although the system is automated to initiate backwashes as the solids build up on the filter, excessive solids loading or flow rates may result in some breakthrough or carry-over of material into the downstream side of the process. The cloth filter process also does not currently possess the proven track record in water treatment, as do the other technologies, primarily as a result of being a fairly new technology. However, it should be noted that during the OCWD pilot testing, the data indicated that this process performed better than the other technologies (except passive) when comparing the percolation test results.

7.2.5 Evaluation of Concept 5 – Passive Treatment

The primary benefit of utilizing the passive treatment concept is that it can be used within the river itself and requires no moving mechanical components or chemicals. Once installed, the passive treatment system needs minimal maintenance, except for potential routine scraping or tilling of the riverbed, if solids tend to accumulate and impact performance over time. Additionally, this system also performed well during the OCWD pilot testing previously discussed.

Disadvantages include difficult construction in the river bed, such as shoring and potentially significant dewatering activities in order to install the laterals and collection pipeline to the depths necessary for proper performance. Environmental issues and the permitting process may also prove to be difficult. It is unknown if the system could potential clog over time due to accumulation of sediment. It may be necessary to excavate and replace laterals over many years of prolonged use. Also, with respect to the IRWD Kern Fan area, this concept may not be suitable, since it requires installation in the river, or directly next to the river.

7.2.6 Comparison of the Non-Economic Criteria for Sediment Removal

The advantages and disadvantages of each sediment removal concept, as identified above, are consolidated into a comparative format in Table 7-3. A comparative scoring of the alternatives is established in Table 7-4.

Table 7-3: Sediment Removal S

Concept	Performance	Constru
Concept 1 – High Rate Sedimentation	• Produces high quality treated water; Large reductions in TSS typical • Capable of handling variation in flow rates; Robust process • Capable of treating varying influent water qualities; Slow start up time	• Som • Not
Concept 2 – Ballasted Sedimentation	• Produces high quality treated water; Large reductions in TSS and algae typical • Capable of handling variation in flow rates; Robust process • Capable of treating varying influent water qualities; Quick start up time	• Com • Mod
Concept 3 – DAF	• Produces high quality treated water; Large reductions in TSS and algae typical • Capable of handling variation in flow rates; Robust process • Capable of treating varying influent water qualities; Somewhat quick start up time	• Som • Som addi
Concept 4 – Cloth Filtration	• Produces high quality treated water; Large reductions in TSS and algae typical • Capable of handling variation in flow rates; Robust process • Capable of treating varying influent water qualities; Quick start up time	• Som • Mod
Concept 5 – Passive Treatment	• Produces high quality treated water; Large reductions in TSS typical	• Som river • Not

Considering the information in the previous sections, the sediment removal strategies were numerically rated from 1 to 5 for each of the non-economic evaluation criteria. Results of this ranking are shown in 7-4.

Table 7-4: Non-Economic Sediment Removal Strategy Evaluation

Concept	Performance	Constructability	Operations & Maintenance	Overall Ranking
Concept 1 – High Rate Sedimentation	2	1	3	2.0
Concept 2 – Ballasted Sedimentation	3	5	3	3.7
Concept 3 – DAF	3	4	3	3.3
Concept 4 – Cloth Filtration	4	5	4	4.3
Concept 5 – Passive Treatment[a]	5	1	4	3.3

1 = Least favorable
5 = Most favorable

a. Although passive treatment systems are evaluated in the table above, this strategy is not considered feasible for the IRWD Kern Fan project, unless IRWD were granted access to a portion of the river, or land immediately adjacent to the river.

Of the sediment removal strategies that were evaluated for this exercise, cloth media filters scored the highest, followed by ballasted sedimentation. High rate sedimentation scored the lowest. It should be noted that although passive systems were evaluated in this section, this strategy is not considered feasible for the IRWD Kern Valley project, unless IRWD owned a portion of the river or land immediately next to the river. This option could also raise questions as to the feasibility of conveying and recharging water that has already percolated below grade.

8.0 Economic Evaluation of Recharge/Infiltration Concepts and Sediment Removal Strategies

For purposes of this study, an appraisal-level, economic evaluation of each of the five recharge concepts and the sediment removal strategies identified is presented in this section. This cost analysis is based on the 10,000 AFY treatment volume (over 4 months) established by IRWD as the evaluation/comparison baseline.

The capital costs presented are comparative planning-level opinions of construction costs based on conceptual sizing, including preliminary layouts of major structures and rough sizing of critical equipment. Capital costs have been established in 2009 dollars, with escalation to 2012. Estimates of this type can be expected to vary from 50 percent less than to 30 percent more than actual final project costs.

The sources of construction cost data are:

- R.S. Means
- IRWD Strand Ranch Construction Cost Data
- Construction cost data for other similar facilities, adjusted to regional market conditions and 2009 dollars.
- Equipment pricing from manufacturers, with installation costs based on similar projects.

Additionally, capital costs for each of the five recharge concepts were developed based on the following assumptions developed collectively by HDR and IRWD:

- Cost of land purchase - $14,000/acre.
- Cost of easement - $1,400/acre.
- All excavated fill will be reused onsite, thus no hauling costs are included.
- All recharge concepts are assumed to be installed approximately 0.5 miles from the diversion of source water at the CVC.
- Each recharge cost includes a 35% project contingency.
- Unit costs are inclusive of prevailing wages.

8.1 Recharge Concepts – Capital Cost Analysis

Table 8-1 summarizes opinion of probable cost for the recharge concepts discussed within this report. The capital costs include a high and low range based on a 35% contingency. This table accounts for the cost of each recharge system only, and does not include cost of pretreatment. The pretreatment cost is established in subsequent tables within this section. Complete detailed capital cost estimates for each of the recharge concepts can be found in the Appendix.

Table 8-1: Opinion of Probable Cost – 27 mgd Recharge Concepts

Recharge Concept	Recharge Concept Capital Cost Range	
	Low Range	High Range
Concept 1 – Surface Recharge Ponds	$9,800,000	$11,600,000
Concept 2 – Subsurface Recharge Galleries	$16,700,000	$21,800,000
Concept 3 – Shallow Injection Wells	$61,700,000	$80,300,000
Concept 4 – CULTEC Engineered Systems	$105,300,000	$138,000,000
Concept 5 –Subsurface Conveyance System	$69,400,000	$89,200,000

Based on the information shown in Table 8-1, the following observations are made:

- Concept 4 – CULTEC Engineered Systems has the highest projected capital cost
- Concept 1 – Surface Recharge Ponds has the lowest projected capital cost.

8.2 Sediment Removal Concepts – Capital Cost Analysis

Table 8-2 summarizes the opinion of probable cost for the sediment removal technologies evaluated within this report. Costs for the passive system sediment removal technology have been excluded from this evaluation since the passive system is not recommended for the IRWD Kern Fan project.

Table 8-2: Opinion of Probable Cost – 27 mgd Sediment Removal Systems

Sediment Removal Strategy	Sediment Removal Strategy Estimated Capital Cost
Dissolved Air Flotation	$8,900,000
Sand Ballasted Sedimentation	$8,000,000
Cloth Filter	$9,500,000
High Rate Sedimentation	$10,800,000

Based on the information shown in Table 8-2, these cost estimates indicate that:

- High Rate Sedimentation has the highest projected capital cost.
- Sand Ballasted Sedimentation has the lowest projected capital cost.

8.3 Cost Analysis with Recommended Pretreatment

As mentioned in Section 4.0, pretreatment would help optimize the recharge potential by maintaining the "clean bed" percolation rates for extended periods of time before decay of the percolation rate begins to occur as solids accumulate at the water/soil interface. However, even with pretreatment, there will be a small percentage of particles that will pass through the treatment system (via break-through in mechanical separation such as filters or carry-over in the chemical/physical treatment alternatives). Over time, the particles that pass through the pretreatment system will accumulate within the recharge system, inducing clogging and a reduced percolation rate.

For purposes of this study, it is recommended that pretreatment be considered for all subsurface recharge concepts, with exception of Concept 5 – Subsurface Conveyance System. For Concept 5, one of the underlying assumptions is that much of the sediment will be carried through the system, provided the velocities are maintained throughout. As previously stated, this assumption will need to be validated via additional hydraulic modeling and pilot testing. Additionally, the subsurface conveyance concept will be accessible for periodic maintenance and removal of sediment without the need for pretreatment. It is anticipated that some portion of the sediment will accumulate within the system over time, and that the filter fabric will need to be replaced after prolonged usage of the system.

Sediment removal pretreatment is not anticipated for the surface recharge alternative established under Concept 1. The anticipated recharge operation of four months out of the year will allow for periodic management of residuals in the basins without the need for pretreatment. The basins will experience a faster decay of the "clean bed" percolation rate than will be experienced with pretreatment; nevertheless, it is assumed that this mode of operation is acceptable as a result of current operating experience of other recharge operations within the Kern Fan area. Additional data from IRWD's current Strand Ranch operations will help determine the average basin recharge capacity over the typical operating duration, which can then be applied to future studies.

Table 8-3 provides a summary of the opinion of probable cost for each of the recharge concepts, including the cost for sediment removal treatment as recommended for Concepts 2, 3 and 4. For purposes of this study, the cloth filter system is considered as the preferred method of pretreatment. Although the cloth filter system is not the most economical alternative as indicated in Table 8-2, it appears to be the best choice when considering the benefits identified in the non-economic evaluation, as well as its positive performance during the OCWD pilot testing compared to the other treatment alternatives.

Table 8-3: Opinion of Probable Capital and O&M Costs – 27 mgd Recharge Concept Including Recommended Pretreatment

Recharge Concept	Total Recharge and Pretreatment Cost Range		O&M Cost per year
	Low Range	High Range	
Concept 1 – Surface Recharge Ponds	$9,800,000	$11,600,000	$38,000
Concept 2 – Subsurface Recharge Galleries	$26,200,000	$31,300,000	$80,000
Concept 3 – Shallow Injection Wells	$71,200,000	$ 89,800,000	$80,000
Concept 4 – CULTEC Engineered Systems	$114,800,000	$147,500,000	$80,000
Concept 5 –Subsurface Conveyance System	$69,400,000	$89,200,000	$19,000

Table 8-3 also includes a column that establishes O&M costs. The values indicated in this column specifically pertain to the anticipated annual O&M cost associated with each of the recharge concepts and include:

- Annual pretreatment O&M costs for cloth filter including filter replacement, labor, power and equipment replacement.

- Periodic access and maintenance of the surface recharge ponds, including periodic tilling or mowing.
- Periodic access and maintenance of the subsurface conveyance system.

These O&M costs do not include residual management and hauling/disposal from either the pretreatment system or from scraping activities in the case of surface recharge ponds. As additional data is collected from the current Strand Ranch recharge basins, the extent of annual residual accumulation can be further assessed in order to determine the effort required for cleaning the recharge ponds and potential volumes of silt that will require hauling and disposal.

As previously mentioned, all of the evaluated recharge concepts are expected to experience some amount of clogging. Some of this clogging will be mitigated by use of a sediment removal pretreatment system, but surface and subsurface recharge systems that are accessible for periodic maintenance will require rehabilitation and subsurface recharge systems that are inaccessible for periodic maintenance will eventually need to be replaced. Table 8-4 includes recharge concept rehabilitation and replacement costs. This analysis assumes the following:

- In addition to the periodic maintenance stated above, the surface recharge ponds will require rehabilitation via thorough cleaning on a 20 year cycle by bulk removal and hauling of accumulated silt and sediments.
- Filter fabric will be replaced on a 20 year cycle for the CULTEC Engineered Systems and Subsurface Conveyance concepts.
- The perforated laterals and filter fabric associated with the subsurface recharge galleries and shallow injection wells will be completely replaced every 20 years. It is assumed that the new systems will be constructed on the same land and no new easements or land purchases will be required.

Table 8-4: Sediment Removal 20-Year Rehabilitation and Replacement Costs – 27 mgd

Recharge Concept	20 Year Rehabilitation and Replacement Costs
Concept 1 – Surface Recharge Ponds	$2,700,000
Concept 2 – Subsurface Recharge Galleries	$11,100,000
Concept 3 – Shallow Injection Wells	$48,500,000
Concept 4 – CULTEC Engineered Systems	$2,200,000
Concept 5 –Subsurface Conveyance System	$2,200,000

8.4 Cost Recovery Analysis

A capital recovery analysis was applied to each of the systems based on a 5% discount rate over a 40-year project life for the estimated recharge and pretreatment concept capital and O&M costs, including the 20-year rehabilitation and replacement costs. The annualized cost of each system is shown in Table 8-5. Costs per acre foot were calculated based on the 10,000 acre-feet of water recharged per year and are also shown in Table 8-5.

Table 8-5: Annualized Cost

Recharge Concept	Annualized Recharge and Treatment Cost	Annualized Cost per Acre Foot
Concept 1 – Surface Recharge Ponds	$800,000	$80
Concept 2 – Subsurface Recharge Galleries	$2,300,000	$230
Concept 3 – Shallow Injection Wells	$6,600,000	$660
Concept 4 – CULTEC Engineered Systems	$8,700,000	$870
Concept 5 –Subsurface Conveyance System	$5,300,000	$530

Based on the capital recovery analysis shown in Table 8-5, Concept 1 – Surface Recharge Ponds is the least expensive annualized recharge and treatment cost, and cost per acre-foot of water recharged, with each acre foot of water recharged costing approximately $80. Concept 4 – CULTEC Engineered Systems is the most expensive annualized recharge and treatment cost and cost per acre foot of water recharged, with each acre foot of water recharged costing approximately $870.

Each of the recharge concepts evaluated in this study involves the purchase or lease of additional land. The evaluation assumes that the surface recharge alternative requires the purchase of land to implement, while the subsurface recharge alternatives benefit by the lower cost of leased land. Presently, with the downturn of the economy, land purchase prices are low, but are expected to increase as the economy improves. The following tables present an evaluation of escalating land cost over time in an effort to determine the potential "break even" cost between concepts as a result of real estate escalation. The results of this analysis are included in Tables 8-6, 8-7, and 8-8. Table 8-6 establishes anticipated escalation of land on a per acre basis as well as for the 250 acre system, based on assumed escalation rates of 1%, 3% and 5%. Tables 8-7 and 8-8 indicate the low and high capital cost, respectively, for each of the Concepts evaluated in this report. These tables also establish the differential cost when compared to the lowest priced option (Concept 1), for which the years to "break even" cost can be extracted from Table 8-6.

Table 8-6: Land Escalation Analysis

Year	Land Escalation			Cost of 250 Acres		
	5%	3%	1%	5%	3%	1%
0	$ 14,000	$14,000	$14,000	$ 3,500,000	$ 3,500,000	$ 3,500,000
5	$ 17,868	$16,230	$14,714	$ 4,466,985	$ 4,057,459	$ 3,678,535
10	$ 22,805	$18,815	$15,465	$ 5,701,131	$ 4,703,707	$ 3,866,177
15	$ 29,105	$21,812	$16,254	$ 7,276,249	$ 5,452,886	$ 4,063,391
25	$ 47,409	$29,313	$17,954	$ 11,852,242	$ 7,328,223	$ 4,488,512
30	$ 60,507	$33,982	$18,870	$ 15,126,798	$ 8,495,419	$ 4,717,471
35	$ 77,224	$39,394	$19,832	$ 19,306,054	$ 9,848,519	$ 4,958,110
40	$ 98,560	$45,669	$20,844	$ 24,639,960	$ 11,417,132	$ 5,211,023
45	$ 125,790	$52,942	$21,907	$ 31,447,527	$ 13,235,585	$ 5,476,838
50	$ 160,544	$61,375	$23,025	$ 40,135,899	$ 15,343,671	$ 5,756,211
55	$ 204,899	$71,150	$24,199	$ 51,224,708	$ 17,787,520	$ 6,049,836
60	$ 261,509	$82,482	$25,434	$ 65,377,151	$ 20,620,611	$ 6,358,438
65	$ 333,759	$95,620	$26,731	$ 83,439,652	$ 23,904,940	$ 6,682,783
70	$ 425,970	$110,850	$28,095	$ 106,492,489	$ 27,712,377	$ 7,023,672
75	$ 543,658	$128,505	$29,528	$ 135,914,401	$ 32,126,240	$ 7,381,950
80	$ 693,860	$148,972	$31,034	$ 173,465,044	$ 37,243,117	$ 7,758,503
85	$ 885,561	$172,700	$32,617	$ 221,390,237	$ 43,174,980	$ 8,154,265
90	$1,130,225	$200,207	$34,281	$ 282,556,278	$ 50,051,635	$ 8,570,214
95	$1,442,485	$232,094	$36,030	$ 360,621,368	$ 58,023,563	$ 9,007,381
100	$1,841,018	$269,061	$37,867	$ 460,254,402	$ 67,265,212	$ 9,466,848

Table 8-7: Land Escalation Analysis – Comparison of Capital Cost (Low Range)

Concept	Concept Cost (low range)	Cost Difference to Concept 1	Estimated Years to Breakeven at Percent Land Escalation		
			5%	3%	1%
Concept 1	$9,767,227	$ -	-	-	-
Concept 2	$26,188,951	$16,421,724	31	51	>100
Concept 3	$71,155,970	$61,388,743	59	97	>100
Concept 4	$114,734,331	$104,967,104	70	>100	>100
Concept 5	$69,329,069	$59,561,842	58	95	>100

Table 8-8: Land Escalation Analysis – Comparison of Capital Cost (High Range)

Concept	Concept Cost (High range)	Cost Difference to Concept 1	Estimated Years to Breakeven at Percent Land Escalation		
			5%	3%	1%
Concept 1	$11,564,934	$ -	-	-	-
Concept 2	$31,277,982	$19,713,048	34	57	>100
Concept 3	$89,767,152	$78,202,218	64	>100	>100
Concept 4	$147,496,543	$135,931,609	75	>100	>100
Concept 5	$89,142,504	$77,577,570	63	>100	>100

Evaluating the low and high capital cost ranges between Concept 1 (Surface Recharge) and the next lowest priced alternative, Concept 2 (Subsurface Recharge Galleries), results in a perceived cost difference of $16.4 million to $19.7 million. Dividing these differences by the anticipated 250 acres to accommodate the 10,000 AFY recharge goal, indicates that the assumed cost of land ($14,000) would need to increase to $65,000-$79,000 before Concept 2 will be viable on an economic basis. The tables above suggest that if real estate escalates annually at 5%, it will take between 31 and 34 years before the cost of Concept 1 equals the cost of Concept 2. It should also be noted that the tables above do not account for future rehabilitation and replacement costs as discussed in Section 8.3. If these costs are included in the land escalation analysis, the time until Concept 1 equals Concept 2 is increased even more significantly. For example, considering rehabilitation costs for Concept 1 and replacement costs for Concept 2, with 5% land escalation, it will take between 41 and 43 years before the cost of Concept 1 equals the cost of Concept 2. Considering the results of the land escalation analysis and the large difference in capital cost between Concept 1 and the other concepts, the surface recharge concept is decisively the best economic alternative.

9.0 Conclusions and Recommendations

Taking into consideration both the non-economic and economic evaluations, the following conclusions were made:

- Concept 1 – Surface Recharge Ponds are the most favorable recharge concept from both the non-economic and economic evaluations.
- Surface recharge ponds provide the benefit of simple access, operation and maintenance, which allows for easy cleaning of the basins in order to mitigate the effects of sediment clogging without the additional cost of treatment.
- Even when considering the potential escalation of real estate, Concept 1 still stands out as the better economic option.
- Concept 1 has a higher residual value considering the additional land as an asset.

Additional data collection specific to the Kern Valley area will be necessary in order to further evaluate the cost/benefit ratio of alternative recharge systems. Based on this conceptual-level analysis, it is recommended that IRWD focus future studies on Concept 1 - Surface Recharge Ponds and Concept 2- Subsurface Recharge Galleries. Although Concept 2 was identified as having a higher cost than Concept 1 under this initial evaluation, the collection of further data may allow for refinement of the assumptions, resulting in a more cost effective alternative. One concern with any of the subsurface alternatives is the potential for clogging over time, even if pretreatment is incorporated. The potential for clogging of subsurface systems should be further investigated through long-term pilot testing.

More extensive geotechnical and hydrologic studies will help refine the assumptions used in determining percolation rates and recharge system sizing. Soil porosity and hydraulic conductivity can vary widely within localized regions. Additional characterization of the soils through boring logs and infiltration tests will provide for more accurate assumptions during future studies. In addition, further geotechnical analysis will help isolate areas that may include confining layers that will adversely impact the shallow surface or subsurface recharge approaches described in this report. These analyses should be specific to potential recharge sites. Additionally, a water quality sampling plan is recommended in order to further evaluate the potential mechanisms for clogging. Measured constituents should include total suspended solids, turbidity, phosphorous, total nitrogen, total organic carbon, and particle size distribution.

Pilot level testing, followed by larger demonstration testing of the recharge concepts and sediment removal treatment technologies should be considered prior to investing in full-scale construction. Pilot testing will allow IRWD to compare some of the preferred recharge and pretreatment alternatives in a side-by-side venue, at the potential project site under similar environmental and source water conditions as the full scale operations. Pilot testing will also provide for collection of necessary data, such as variations in source water quality, initial percolation rates and rate decay over time, "scaled" performance of various alternatives, and other operating and maintenance information in order to develop more accurate sizing, capital and O&M estimates. Based on the outcome of the pilot testing, it may be necessary to conduct larger scale demonstration testing over a longer period of time, in order to accumulate a minimum of 2 years of solid data. IRWD has indicated that water may only be available every 3 years, therefore the actual duration of testing required in order to collect 2 years worth of data, may be closer to a 6 to 9-year duration. Pilot testing alone, may not adequately capture long-term impacts associated with the recharge alternatives or the pretreatment systems. Some of these factors may include; potential biological fouling which may develop over longer durations, long-term clogging impacts as a result of residual accumulation and compaction over time, and in the case of pretreatment or residual management, it may take additional time to determine the extent of accumulated material that will need to be managed and disposed.

With the increased recurrence of severe droughts within the region, and California's increased efforts associated with water conservation and water reclamation, the importance of water conservation and water banking is critical during these current times. IRWD should continue its pursuit with cost effective approaches to water banking and recharge opportunities. In addition, it may be prudent for IRWD to continue working with OCWD as they further develop their own local recharge programs. OCWD currently has many on-going studies that are evaluating similar conditions and impacts to recharge as IRWD. A collaborative effort may help both agencies efficiently and effectively collect the necessary data required to make informed decisions in the field of surface water recharge.

10.0 References

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Appendix A – Cost Estimates

HDR

Date: September 2009
Prepared by: K. Streams
Reviewed by: S. Toland

Irvine Ranch Water District
Kern Valley Groundwater Recharge Evaluation
Concept Cost Summary

Capital Cost Summary of Recharge Alternatives

Technology	Direct Cost Estimate (Above the Line Costs)	Contingency	Land Purchase Costs	Land Easement Costs	Total Escalated Capital Cost Range (including contingency)	
Concept 1 - Surface Recharge Ponds	$ 4,300,000	35%	$ 3,675,000	$ 2,000	$ 9,800,000	$ 11,600,000
Concept 2 - Subsurface Recharge Galleries	$ 12,100,000	35%	$ -	$ 351,000	$ 16,700,000	$ 21,800,000
Concept 3 - Shallow Injection Wells	$ 44,100,000	35%	$ -	$ 1,854,000	$ 61,700,000	$ 80,300,000
Concept 4 - Cultec Engineered Systems	$ 77,600,000	35%	$ -	$ 233,800	$ 105,300,000	$ 138,000,000
Concept 5 - Subsurface Conveyance System	$ 47,000,000	35%	$ -	$ 54,000	$ 69,400,000	$ 89,200,000

Irvine Ranch Water District
Kern Valley Groundwater Recharge Evaluation
Concept Cost Summary

Date: September 2009
Prepared by: K. Streams
Reviewed by: S. Toland

Capital Cost Summary of Recharge Alternatives Plus Sediment Pretreatment

Technology	Direct Cost Estimate (Above the Line Costs)	Contingency	Land Purchase Costs	Land Easement Costs	Treatment Costs	Total Escalated Capital Cost Range (including contingency)	
Concept 1 - Surface Recharge Ponds	$ 4,300,000	35%	$ 3,675,000	$ 2,000	$ -	$ 9,800,000	$ 11,600,000
Concept 2 - Subsurface Recharge Galleries	$ 12,100,000	35%	$ -	$ 351,000	$ 9,500,000	$ 26,200,000	$ 31,300,000
Concept 3 - Shallow Injection Wells	$ 44,100,000	35%	$ -	$ 1,854,000	$ 9,500,000	$ 71,200,000	$ 89,800,000
Concept 4 - Cultec Engineered Systems	$ 77,600,000	35%	$ -	$ 233,800	$ 9,500,000	$ 114,800,000	$ 147,500,000
Concept 5 - Subsurface Conveyance System	$ 47,000,000	35%	$ -	$ 54,000	$ -	$ 69,400,000	$ 89,200,000

Irvine Ranch Water District
Kern Valley Groundwater Recharge Evaluation
Concept Cost Summary

Date: September 2009
Prepared by: K. Streams
Reviewed by: S. Toland

i = 0.05
n = 40
f = 0.058

$$f = \frac{i(1+i)^n}{(1+i)^n - 1}$$

Annualized Cost - 40 Year Recovery

Technology	Direct Cost Estimate (Above the Line Costs)	Contingency	Land Purchase Costs	Land Easement Costs	Treatment Costs	Total Escalated Capital Cost Range (including contingency)		Total Annualized Capital Cost	Annual O&M Costs	20-YR Replacement Cost	Total Annualized Cost	Annualized Cost Per AF
Concept 1 - Surface Recharge Ponds	$ 4,300,000	35%	$ 3,675,000	$ 2,000	$ -	$ 9,800,000	$ 11,600,000	$ 700,000	$ 38,000	$ 2,709,435	$ 800,000	$ 80
Concept 2 - Subsurface Recharge Galleries	$ 12,100,000	35%	$ -	$ 351,000	$ 9,500,000	$ 26,200,000	$ 31,300,000	$ 1,900,000	$ 80,000	$ 11,122,313	$ 2,300,000	$ 230
Concept 3 - Shallow Injection Wells	$ 44,100,000	35%	$ -	$ 1,854,000	$ 9,500,000	$ 71,200,000	$ 89,800,000	$ 5,300,000	$ 80,000	$ 48,522,860	$ 6,600,000	$ 660
Concept 4 - Cultec Engineered Systems	$ 77,600,000	35%	$ -	$ 233,800	$ 9,500,000	$ 114,800,000	$ 147,500,000	$ 8,600,000	$ 80,000	$ 2,160,468	$ 8,700,000	$ 870
Concept 5 - Subsurface Conveyance System	$ 47,000,000	35%	$ -	$ 54,000	$ -	$ 69,400,000	$ 89,200,000	$ 5,200,000	$ 49,000	$ 2,188,390	$ 5,300,000	$ 530

HDR

Irvine Ranch Water District
Kern Valley Groundwater Recharge Evaluation
Concept Cost Summary

Date: July 2009
Prepared by: K. Streams
Reviewed by: S. Toland

LAND ESCALATION: 100 - YEAR ANALYSIS

Year	Land Escalation			Cost of 250 Acres				
	5%	3%	1%	5%	3%	1%	3%	1%
0	$ 14,000	$ 14,000	$ 14,000	$ 3,500,000	$ 3,500,000	$ 3,500,000	$ 3,500,000	$ 3,500,000
1	$ 14,700	$ 14,420	$ 14,140	$ 3,675,000	$ 3,605,000	$ 3,535,000	$ 3,605,000	$ 3,535,000
2	$ 15,435	$ 14,853	$ 14,281	$ 3,858,750	$ 3,713,150	$ 3,570,350	$ 3,713,150	$ 3,570,350
3	$ 16,207	$ 15,298	$ 14,424	$ 4,051,688	$ 3,824,545	$ 3,606,054	$ 3,824,545	$ 3,606,054
4	$ 17,017	$ 15,757	$ 14,568	$ 4,254,272	$ 3,939,281	$ 3,642,114	$ 3,939,281	$ 3,642,114
5	$ 17,868	$ 16,230	$ 14,714	$ 4,466,985	$ 4,057,459	$ 3,678,535	$ 4,057,459	$ 3,678,535
6	$ 18,761	$ 16,717	$ 14,861	$ 4,690,335	$ 4,179,183	$ 3,715,321	$ 4,179,183	$ 3,715,321
7	$ 19,699	$ 17,218	$ 15,010	$ 4,924,851	$ 4,304,559	$ 3,752,474	$ 4,304,559	$ 3,752,474
8	$ 20,684	$ 17,735	$ 15,160	$ 5,171,094	$ 4,433,695	$ 3,789,998	$ 4,433,695	$ 3,789,998
9	$ 21,719	$ 18,267	$ 15,312	$ 5,429,649	$ 4,566,706	$ 3,827,898	$ 4,566,706	$ 3,827,898
10	$ 22,805	$ 18,815	$ 15,465	$ 5,701,131	$ 4,703,707	$ 3,866,177	$ 4,703,707	$ 3,866,177
11	$ 23,945	$ 19,379	$ 15,619	$ 5,986,188	$ 4,844,819	$ 3,904,839	$ 4,844,819	$ 3,904,839
12	$ 25,142	$ 19,961	$ 15,776	$ 6,285,497	$ 4,990,163	$ 3,943,888	$ 4,990,163	$ 3,943,888
13	$ 26,399	$ 20,559	$ 15,933	$ 6,599,772	$ 5,139,868	$ 3,983,326	$ 5,139,868	$ 3,983,326
14	$ 27,719	$ 21,176	$ 16,093	$ 6,929,761	$ 5,294,064	$ 4,023,160	$ 5,294,064	$ 4,023,160
15	$ 29,105	$ 21,812	$ 16,254	$ 7,276,249	$ 5,452,886	$ 4,063,391	$ 5,452,886	$ 4,063,391
16	$ 30,560	$ 22,466	$ 16,416	$ 7,640,061	$ 5,616,473	$ 4,104,025	$ 5,616,473	$ 4,104,025
17	$ 32,088	$ 23,140	$ 16,580	$ 8,022,064	$ 5,784,967	$ 4,145,066	$ 5,784,967	$ 4,145,066
18	$ 33,693	$ 23,834	$ 16,746	$ 8,423,167	$ 5,958,516	$ 4,186,516	$ 5,958,516	$ 4,186,516
19	$ 35,377	$ 24,549	$ 16,914	$ 8,844,326	$ 6,137,271	$ 4,228,381	$ 6,137,271	$ 4,228,381
20	$ 37,146	$ 25,286	$ 17,083	$ 9,286,542	$ 6,321,389	$ 4,270,665	$ 6,321,389	$ 4,270,665
21	$ 39,003	$ 26,044	$ 17,253	$ 9,750,869	$ 6,511,031	$ 4,313,372	$ 6,511,031	$ 4,313,372
22	$ 40,954	$ 26,825	$ 17,426	$ 10,238,413	$ 6,706,362	$ 4,356,506	$ 6,706,362	$ 4,356,506
23	$ 43,001	$ 27,630	$ 17,600	$ 10,750,333	$ 6,907,553	$ 4,400,071	$ 6,907,553	$ 4,400,071
24	$ 45,151	$ 28,459	$ 17,776	$ 11,287,850	$ 7,114,779	$ 4,444,071	$ 7,114,779	$ 4,444,071
25	$ 47,409	$ 29,313	$ 17,954	$ 11,852,242	$ 7,328,223	$ 4,488,512	$ 7,328,223	$ 4,488,512
26	$ 49,779	$ 30,192	$ 18,134	$ 12,444,854	$ 7,548,069	$ 4,533,397	$ 7,548,069	$ 4,533,397
27	$ 52,268	$ 31,098	$ 18,315	$ 13,067,097	$ 7,774,512	$ 4,578,731	$ 7,774,512	$ 4,578,731
28	$ 54,882	$ 32,031	$ 18,498	$ 13,720,452	$ 8,007,747	$ 4,624,518	$ 8,007,747	$ 4,624,518
29	$ 57,626	$ 32,992	$ 18,683	$ 14,406,475	$ 8,247,979	$ 4,670,764	$ 8,247,979	$ 4,670,764
30	$ 60,507	$ 33,982	$ 18,870	$ 15,126,798	$ 8,495,419	$ 4,717,471	$ 8,495,419	$ 4,717,471
31	$ 63,533	$ 35,001	$ 19,059	$ 15,883,138	$ 8,750,281	$ 4,764,646	$ 8,750,281	$ 4,764,646
32	$ 66,709	$ 36,051	$ 19,249	$ 16,677,295	$ 9,012,790	$ 4,812,292	$ 9,012,790	$ 4,812,292
33	$ 70,045	$ 37,133	$ 19,442	$ 17,511,160	$ 9,283,173	$ 4,860,415	$ 9,283,173	$ 4,860,415
34	$ 73,547	$ 38,247	$ 19,636	$ 18,386,718	$ 9,561,669	$ 4,909,019	$ 9,561,669	$ 4,909,019
35	$ 77,224	$ 39,394	$ 19,832	$ 19,306,054	$ 9,848,519	$ 4,958,110	$ 9,848,519	$ 4,958,110
36	$ 81,085	$ 40,576	$ 20,031	$ 20,271,356	$ 10,143,974	$ 5,007,691	$ 10,143,974	$ 5,007,691
37	$ 85,140	$ 41,793	$ 20,231	$ 21,284,924	$ 10,448,293	$ 5,057,768	$ 10,448,293	$ 5,057,768
38	$ 89,397	$ 43,047	$ 20,433	$ 22,349,171	$ 10,761,742	$ 5,108,345	$ 10,761,742	$ 5,108,345
39	$ 93,867	$ 44,338	$ 20,638	$ 23,466,629	$ 11,084,594	$ 5,159,429	$ 11,084,594	$ 5,159,429
40	$ 98,560	$ 45,669	$ 20,844	$ 24,639,960	$ 11,417,132	$ 5,211,023	$ 11,417,132	$ 5,211,023
41	$ 103,488	$ 47,039	$ 21,053	$ 25,871,959	$ 11,759,646	$ 5,263,133	$ 11,759,646	$ 5,263,133
42	$ 108,662	$ 48,450	$ 21,263	$ 27,165,556	$ 12,112,436	$ 5,315,765	$ 12,112,436	$ 5,315,765
43	$ 114,095	$ 49,903	$ 21,476	$ 28,523,834	$ 12,475,809	$ 5,368,922	$ 12,475,809	$ 5,368,922
44	$ 119,800	$ 51,400	$ 21,690	$ 29,950,026	$ 12,850,083	$ 5,422,612	$ 12,850,083	$ 5,422,612
45	$ 125,790	$ 52,942	$ 21,907	$ 31,447,527	$ 13,235,585	$ 5,476,838	$ 13,235,585	$ 5,476,838
46	$ 132,080	$ 54,531	$ 22,126	$ 33,019,904	$ 13,632,653	$ 5,531,606	$ 13,632,653	$ 5,531,606
47	$ 138,684	$ 56,167	$ 22,348	$ 34,670,899	$ 14,041,633	$ 5,586,922	$ 14,041,633	$ 5,586,922
48	$ 145,618	$ 57,852	$ 22,571	$ 36,404,444	$ 14,462,882	$ 5,642,791	$ 14,462,882	$ 5,642,791
49	$ 152,899	$ 59,587	$ 22,797	$ 38,224,666	$ 14,896,768	$ 5,699,219	$ 14,896,768	$ 5,699,219
50	$ 160,544	$ 61,375	$ 23,025	$ 40,135,899	$ 15,343,671	$ 5,756,211	$ 15,343,671	$ 5,756,211

LAND ESCALATION: 100 - YEAR ANALYSIS

Year	Land Escalation			Cost of 250 Acres				
	5%	3%	1%	5%	3%	1%	3%	1%
51	$ 168,571	$ 63,216	$ 23,255	$ 42,142,694	$ 15,803,981	$ 5,813,773	$ 15,803,981	$ 5,813,773
52	$ 176,999	$ 65,112	$ 23,488	$ 44,249,829	$ 16,278,101	$ 5,871,911	$ 16,278,101	$ 5,871,911
53	$ 185,849	$ 67,066	$ 23,723	$ 46,462,320	$ 16,766,444	$ 5,930,630	$ 16,766,444	$ 5,930,630
54	$ 195,142	$ 69,078	$ 23,960	$ 48,785,436	$ 17,269,437	$ 5,989,937	$ 17,269,437	$ 5,989,937
55	$ 204,899	$ 71,150	$ 24,199	$ 51,224,708	$ 17,787,520	$ 6,049,836	$ 17,787,520	$ 6,049,836
56	$ 215,144	$ 73,285	$ 24,441	$ 53,785,944	$ 18,321,146	$ 6,110,334	$ 18,321,146	$ 6,110,334
57	$ 225,901	$ 75,483	$ 24,686	$ 56,475,241	$ 18,870,780	$ 6,171,438	$ 18,870,780	$ 6,171,438
58	$ 237,196	$ 77,748	$ 24,933	$ 59,299,003	$ 19,436,903	$ 6,233,152	$ 19,436,903	$ 6,233,152
59	$ 249,056	$ 80,080	$ 25,182	$ 62,263,953	$ 20,020,011	$ 6,295,484	$ 20,020,011	$ 6,295,484
60	$ 261,509	$ 82,482	$ 25,434	$ 65,377,151	$ 20,620,611	$ 6,358,438	$ 20,620,611	$ 6,358,438
61	$ 274,584	$ 84,957	$ 25,688	$ 68,646,008	$ 21,239,229	$ 6,422,023	$ 21,239,229	$ 6,422,023
62	$ 288,313	$ 87,506	$ 25,945	$ 72,078,309	$ 21,876,406	$ 6,486,243	$ 21,876,406	$ 6,486,243
63	$ 302,729	$ 90,131	$ 26,204	$ 75,682,224	$ 22,532,698	$ 6,551,105	$ 22,532,698	$ 6,551,105
64	$ 317,865	$ 92,835	$ 26,466	$ 79,466,335	$ 23,208,679	$ 6,616,617	$ 23,208,679	$ 6,616,617
65	$ 333,759	$ 95,620	$ 26,731	$ 83,439,652	$ 23,904,940	$ 6,682,783	$ 23,904,940	$ 6,682,783
66	$ 350,447	$ 98,488	$ 26,998	$ 87,611,635	$ 24,622,088	$ 6,749,611	$ 24,622,088	$ 6,749,611
67	$ 367,969	$ 101,443	$ 27,268	$ 91,992,216	$ 25,360,750	$ 6,817,107	$ 25,360,750	$ 6,817,107
68	$ 386,367	$ 104,486	$ 27,541	$ 96,591,827	$ 26,121,573	$ 6,885,278	$ 26,121,573	$ 6,885,278
69	$ 405,686	$ 107,621	$ 27,817	$ 101,421,418	$ 26,905,220	$ 6,954,130	$ 26,905,220	$ 6,954,130
70	$ 425,970	$ 110,850	$ 28,095	$ 106,492,489	$ 27,712,377	$ 7,023,672	$ 27,712,377	$ 7,023,672
71	$ 447,268	$ 114,175	$ 28,376	$ 111,817,114	$ 28,543,748	$ 7,093,909	$ 28,543,748	$ 7,093,909
72	$ 469,632	$ 117,600	$ 28,659	$ 117,407,970	$ 29,400,060	$ 7,164,848	$ 29,400,060	$ 7,164,848
73	$ 493,113	$ 121,128	$ 28,946	$ 123,278,368	$ 30,282,062	$ 7,236,496	$ 30,282,062	$ 7,236,496
74	$ 517,769	$ 124,762	$ 29,235	$ 129,442,286	$ 31,190,524	$ 7,308,861	$ 31,190,524	$ 7,308,861
75	$ 543,658	$ 128,505	$ 29,528	$ 135,914,401	$ 32,126,240	$ 7,381,950	$ 32,126,240	$ 7,381,950
76	$ 570,840	$ 132,360	$ 29,823	$ 142,710,121	$ 33,090,027	$ 7,455,769	$ 33,090,027	$ 7,455,769
77	$ 599,383	$ 136,331	$ 30,121	$ 149,845,627	$ 34,082,728	$ 7,530,327	$ 34,082,728	$ 7,530,327
78	$ 629,352	$ 140,421	$ 30,423	$ 157,337,908	$ 35,105,210	$ 7,605,630	$ 35,105,210	$ 7,605,630
79	$ 660,819	$ 144,633	$ 30,727	$ 165,204,804	$ 36,158,366	$ 7,681,686	$ 36,158,366	$ 7,681,686
80	$ 693,860	$ 148,972	$ 31,034	$ 173,465,044	$ 37,243,117	$ 7,758,503	$ 37,243,117	$ 7,758,503
81	$ 728,553	$ 153,442	$ 31,344	$ 182,138,296	$ 38,360,410	$ 7,836,088	$ 38,360,410	$ 7,836,088
82	$ 764,981	$ 158,045	$ 31,658	$ 191,245,211	$ 39,511,223	$ 7,914,449	$ 39,511,223	$ 7,914,449
83	$ 803,230	$ 162,786	$ 31,974	$ 200,807,471	$ 40,696,559	$ 7,993,594	$ 40,696,559	$ 7,993,594
84	$ 843,391	$ 167,670	$ 32,294	$ 210,847,845	$ 41,917,456	$ 8,073,530	$ 41,917,456	$ 8,073,530
85	$ 885,561	$ 172,700	$ 32,617	$ 221,390,237	$ 43,174,980	$ 8,154,265	$ 43,174,980	$ 8,154,265
86	$ 929,839	$ 177,881	$ 32,943	$ 232,459,749	$ 44,470,229	$ 8,235,808	$ 44,470,229	$ 8,235,808
87	$ 976,331	$ 183,217	$ 33,273	$ 244,082,736	$ 45,804,336	$ 8,318,166	$ 45,804,336	$ 8,318,166
88	$ 1,025,147	$ 188,714	$ 33,605	$ 256,286,873	$ 47,178,466	$ 8,401,347	$ 47,178,466	$ 8,401,347
89	$ 1,076,405	$ 194,375	$ 33,941	$ 269,101,217	$ 48,593,820	$ 8,485,361	$ 48,593,820	$ 8,485,361
90	$ 1,130,225	$ 200,207	$ 34,281	$ 282,556,278	$ 50,051,635	$ 8,570,214	$ 50,051,635	$ 8,570,214
91	$ 1,186,736	$ 206,213	$ 34,624	$ 296,684,092	$ 51,553,184	$ 8,655,917	$ 51,553,184	$ 8,655,917
92	$ 1,246,073	$ 212,399	$ 34,970	$ 311,518,296	$ 53,099,779	$ 8,742,476	$ 53,099,779	$ 8,742,476
93	$ 1,308,377	$ 218,771	$ 35,320	$ 327,094,211	$ 54,692,773	$ 8,829,900	$ 54,692,773	$ 8,829,900
94	$ 1,373,796	$ 225,334	$ 35,673	$ 343,448,921	$ 56,333,556	$ 8,918,199	$ 56,333,556	$ 8,918,199
95	$ 1,442,485	$ 232,094	$ 36,030	$ 360,621,368	$ 58,023,563	$ 9,007,381	$ 58,023,563	$ 9,007,381
96	$ 1,514,610	$ 239,057	$ 36,390	$ 378,652,436	$ 59,764,270	$ 9,097,455	$ 59,764,270	$ 9,097,455
97	$ 1,590,340	$ 246,229	$ 36,754	$ 397,585,058	$ 61,557,198	$ 9,188,430	$ 61,557,198	$ 9,188,430
98	$ 1,669,857	$ 253,616	$ 37,121	$ 417,464,311	$ 63,403,914	$ 9,280,314	$ 63,403,914	$ 9,280,314
99	$ 1,753,350	$ 261,224	$ 37,492	$ 438,337,526	$ 65,306,031	$ 9,373,117	$ 65,306,031	$ 9,373,117
100	$ 1,841,018	$ 269,061	$ 37,867	$ 460,254,402	$ 67,265,212	$ 9,466,848	$ 67,265,212	$ 9,466,848

LAND ESCALATION ANALYSIS: COMPARISON OF CAPITAL COST (LOW RANGE)

	(low range)	to Concept 1	Escalation		
			5%	3%	1%
Concept 1	$ 9,767,227	$ -	-	-	-
Concept 2	$ 26,188,951	$ 16,421,724	31	51	>100
Concept 3	$ 71,155,970	$ 61,388,743	59	97	>100
Concept 4	$ 114,734,331	$ 104,967,104	70	>100	>100
Concept 5	$ 69,329,069	$ 59,561,842	58	95	>100

LAND ESCALATION ANALYSIS: COMPARISON OF CAPITAL COST (HIGH RANGE)

	(low range)	to Concept 1	Escalation		
			5%	3%	1%
Concept 1	$ 11,564,934	$ -	-	-	-
Concept 2	$ 31,277,982	$ 19,713,048	34	57	>100
Concept 3	$ 89,767,152	$ 78,202,218	64	>100	>100
Concept 4	$ 147,496,543	$ 135,931,609	75	>100	>100
Concept 5	$ 89,142,504	$ 77,577,570	63	>100	>100

Irvine Ranch Water District
Kern Valley Groundwater Recharge Evaluation
Concept 1 - Surface Recharge Ponds

Date: September 2009
Prepared by: K. Streams
Reviewed by: S. Toland

Key Assumptions:
1) All pipes are gravity
2) Unit cost based on 2008 reference. Not yet adjusted with CCI.

SPEC SECTION AND DESCRIPTION	QUANTITY	UNITS	UNIT COST	INSTALLATION	TOTAL COST	DIVISION SUBTOTALS	NOTES
DIVISION 2 - SITE WORK							
Clearing and Grubbing	250	ACRE	$ 240.00	included	$ 60,000		Unit Cost based on previous IRWD Strand Ranch Construction cost. (10% of RS Means published unit cost. RS Means 2008, 31 11 10.10 - 0020, pg. 207)
Excavation, Bulk, Scraper	1,210,097	BCY	$ 0.90	included	$ 1,089,087		Unit Cost based on previous IRWD Strand Ranch Construction cost. (35% of RS Means published unit cost. RS Means 2008, 31 23 16.13 -5110, pg. 211)
Backfill - For Berm Around Pond	1,210,097	CY	$ 0.75	included	$ 907,573		Unit Cost based on previous IRWD Strand Ranch Construction cost. (34% of RS Means published unit cost. RS Means 2008, 31 23 23.14 -2400, pg. 223; Assuming reuse of excavated materials for trapezoidal berm around pond)
Site Dewatering	-	CY	$ 6.26	included	$ -		RS Means 2008, 31 23 19.20 - 0100, pg. 221; Assuming excavation is shallow & dewatering is not required
Hauling	-	CY	$ 7.48	included	$ -		RS Means 2008, 31 23 23.18 - 1250, pg. 225; 20 CY Dump Trailer; 10 mile round trip; Assume all fill reused on site
						$ 2,056,660	
DIVISION 3 - CONCRETE							
Canal Tie-In Structure	1	LS	$ 150,000.00	included	$ 150,000		Per Prior project experience
Basin Headwall/Distribution Channel	1	LS	$ 150,000.00	included	$ 150,000		Per Prior project experience
						$ 300,000	
DIVISION 5 - METALS N/A							
DIVISION 11 - EQUIPMENT N/A Assuming Gravity Flow - No pump station							
DIVISION 13 - SPECIAL CONSTRUCTION N/A							
DIVISION 15 - MECHANICAL Transmission Piping (6-foot diameter)	2,640	LF	$ 720.00	included	$ 1,900,800	*$ 1,900,800*	Assuming Unit cost $10/InchDiam/LF pipe & 0.5 mile to recharge pond; Includes piping installation, trench excavation, backfill, and speed shoring
DIRECT COSTS						**$4,257,460**	
Field Overhead & Mobilization (% of Construction Total)				7%		$298,022	
Subtotal 1						*$4,555,482*	
Contractor Profit (% of Subtotal 1)				10%		$455,548	
Subtotal 2						*$5,011,030*	
Insurance & Bonds (% of Subtotal 2)				2.5%		$125,276	
Subtotal 3						*$5,136,306*	
Contingency (% of Subtotal 3)				35%		$1,797,707	
Subtotal 4						*$6,934,013*	
Land Purchase Costs	**262.50**	ACRE		$14,000	$ 3,675,000	*$10,609,013*	Per IRWD Kickoff Meeting; Includes cost of pond +5% additional land for berms and access
Easement Purchase Costs	**0.73**	ACRE		$1,400	$ 1,018	*$10,610,031*	Per IRWD Kickoff Meeting; Includes cost of easement for Distribution Piping
Escalation to 2012 (% of Subtotal with Land Costs)				9%		$954,903	

TOTAL		**$11,564,934**
Range (with and without contingency)	**$9,767,227**	**$11,564,934**

O&M COST

DESCRIPTION	QUANTITY	UNITS	UNIT COST	TOTAL COST	NOTES
Annual Maintenance per Rosedale GM (ratio to 250 acres)	1	LS	$ 38,000.00	$ 38,000	Cost based on 9/1/09 email from Kellie Welch per discussion with Rosedale's GM.
20-Yr Scraping Activity (assume 4" material removal)	-			$ 2,709,435	
Excavation, Bulk, Scraper	*134,444*	*BCY*	*$ 0.90*	*$ 121,000*	Unit cost based on HDR CCI division.
Hauling - 20 mile RT	*134,444*	*BCY*	*$ 11.50*	*$ 1,546,111*	Unit cost based on HDR CCI division.
Tipping Fees	*6,002*	*Ton*	*$ 100.00*	*$ 600,198*	Unit cost based on HDR CCI division.
Scraping Indirects (overhead, profit, insurance, bonds)				*$ 442,125*	Based on percentages used for Capital Cost indirects, above. Excludes contingency and escalation.
Total Annualized O&M (40-YR life cycle)				$ 105,736	

Irvine Ranch Water District
Kern Valley Groundwater Recharge Evaluation
Concept 2 - Subsurface Recharge Galleries

Date: September 2009
Prepared by: K. Streams
Reviewed by: S. Toland

Key Assumptions:
1) All pipes are gravity
2) Does not include the cost of pretreatment
3) Unit cost based on 2008 reference. Not yet adjusted with CCI.

SPEC SECTION AND DESCRIPTION	QUANTITY	UNITS	UNIT COST	INSTALLATION	TOTAL COST	DIVISION SUBTOTALS	NOTES
DIVISION 2 - SITE WORK							
Clearing and Grubbing	250	ACRE	$ 240.00	included	$ 60,000		Unit Cost based on previous IRWD Strand Ranch Construction cost. (10% of RS Means published unit cost. RS Means 2008, 31 11 10.10 - 0020, pg. 207)
Excavation, Trench	549,539	BCY	$ 1.09	included	$ 598,998		Unit Cost based on previous IRWD Strand Ranch Construction cost. (35% of RS Means published unit cost. RS Means 2008, 31 23 16.13 -5110, pg. 211). Assuming total depth of trench to be excavated is 5 ft
Backfill (gravel pipe bedding zone)	109,919	CY	$ 17.72	included	$ 1,948,207		RS Means 2008, 31 23 23.17 - 1300, pg. 225; Assuming 12" deep of gravel. Includes 40% discount for economics of scale
Backfill (native material)	439,620	CY	$ 0.75	included	$ 329,715		Unit Cost based on previous IRWD Strand Ranch Construction cost. (34% of RS Means published unit cost. RS Means 2008, 31 23 23.14 -2400, pg. 223). Assuming using native backfill for 4 of the 5 feet; Rest to be used onsite
Site Dewatering	-	CY	$ 6.26	included	$ -		RS Means 2008, 31 23 19.20 - 0100, pg. 221; Assuming excavation is shallow & dewatering is not required
Hauling	-	CY	$ 7.48	included	$ -		RS Means 2008, 31 23 23.18 - 1250, pg. 225; 20 CY Dump Trailer; 10 mile round trip; Assume all fill reused on site
Filter Fabric	302,470	SY	$ 1.65	included	$ 499,075		
						$ 3,435,994	
DIVISION 3 - CONCRETE							
Canal Tie-In Structure	1	LS	$ 150,000.00	included	$ 150,000	*$ 150,000*	Per Prior project experience
DIVISION 5 - METALS							
N/A							
DIVISION 11 - EQUIPMENT							
N/A Assuming Gravity Flow - No pump station							
DIVISION 13 - SPECIAL CONSTRUCTION							
N/A							
DIVISION 15 - MECHANICAL							
Transmission Piping (6-foot diameter)	2,640	LF	$ 720.00	included	$ 1,900,800		Assuming Unit cost $10/InchDiam/LF pipe & 0.5 mile to recharge gallery; Includes piping installation, trench excavation, backfill, and speed shoring
Perforated Drain Pipe (6-inch diameter) - Laterals	1089000	LF	$ 5.21	included	$ 5,671,512		RS Means 2008, 33 46 16.35 - 0060, pg. 316; Does not include excavation and backfill. Includes 30% discount for economics of scale.
Perforated Drain Pipe (8-inch diameter) - Headers	91790	LF	$ 7.31	included	$ 670,801		RS Means 2008, 33 46 16.35 - 0080, pg. 316; Does not include excavation and backfill. Includes 30% discount for economics of scale.
Valving	137	EA	$ 1,628.50	included	$ 223,105		RS Means 2008, 33 12 16.10 -3180, pg. 302; 1 isolation valve per module
						$ 8,466,218	
DIRECT COSTS						$12,052,212	
Field Overhead & Mobilization (% of Construction Total)				7%		$843,655	
Subtotal 1						*$12,895,867*	
Contractor Profit (% of Subtotal 1)				10.0%		$1,289,587	
Subtotal 2						*$14,185,454*	
Insurance & Bonds (% of Subtotal 2)				2.5%		$354,636	
Subtotal 3						*$14,540,090*	
Contingency (% of Subtotal 3)				35%		$5,089,032	
Subtotal 4						*$19,629,122*	
Land Purchase Costs		0	ACRE	**$14,000**	$ -	*$19,629,122*	
Easement Purchase Costs		250	ACRE	**$1,400**	$ 350,679	*$19,979,800*	Per IRWD Kickoff Meeting. Includes cost of easement for Module Laterals, Headers and Distribution Piping
Escalation to 2012 (% of Subtotal with Land Costs)				9%		$1,798,182	

TOTAL		$21,777,982
Range (with and without contingency)	$16,688,951	$21,777,982

O&M COST

DESCRIPTION	QUANTITY	UNITS	UNIT COST	TOTAL COST	NOTES
Annual Sediment Treatment System O&M	1	LS	$ 80,000	$ 80,000	
20-Yr Replacement Cost of Perforated Laterals	1	LS	$ 11,122,313	$ 11,122,313	Accounts for excavation, replacement of gravel, perforated piping and backfill. Also includes Contractor indirects (overhead, profit, insurance, bonds)
Total Annualized O&M (40-YR life cycle)				$ 358,058	

HDR

Irvine Ranch Water District
Kern Valley Groundwater Recharge Evaluation
Concept 3 - Shallow Injection Wells

Date: September 2009
Prepared by: K. Streams
Reviewed by: S. Toland

Key Assumptions:
1) All pipes are gravity
2) Does not include the cost of pretreatment
3) Unit cost based on 2008 reference. Not yet adjusted with CCI.

SPEC SECTION AND DESCRIPTION	QUANTITY	UNITS	UNIT COST	INSTALLATION	TOTAL COST	DIVISION SUBTOTALS	NOTES
DIVISION 2 - SITE WORK							
Clearing and Grubbing	1,323	ACRE	$ 240.00	included	$ 317,520		Unit Cost based on previous IRWD Strand Ranch Construction cost. (10% of RS Means published unit cost. RS Means 2008, 31 11 10.10 - 0020, pg. 207)
Excavation, Trench	1,457,985	CY	$ 1.09	included	$ 1,592,120		Unit Cost based on previous IRWD Strand Ranch Construction cost. (35% of RS Means published unit cost. RS Means 2008, 31 23 16.13 - 5200, pg. 211)
Backfill (gravel pipe bedding zone)	121,499	CY	$ 17.72	included	$ 2,153,444		RS Means 2008, 31 23 23.17 - 1300, pg. 225; Assuming 12" deep of gravel. Includes 40% discount for economics of scale
Backfill (native material)	1,336,487	CY	$ 0.75	included	$ 1,002,365		Unit Cost based on previous IRWD Strand Ranch Construction cost. (34% of RS Means published unit cost. RS Means 2008, 31 23 23.14 -2400, pg. 223). Assuming reusing 11' of original backfill; rest to be used onsite
Site Dewatering	218,698	CY	$ 6.26	included	$ 1,369,048		RS Means 2008, 31 23 19.20 - 0100, pg. 221; Assuming appox 15% of trench excavation must be dewatered
Hauling	-	CY	$ 7.48	included	$ -		RS Means 2008, 31 23 23.18 - 1250, pg. 225; 20 CY Dump Trailer; 10 mile round trip; Assume all fill reused on site
Speed Shoring	26,136,000	SF	$ 1.00	included	$ 26,136,000		Speed Shoring Per J. Moncrief; Assuming shoring is required for all lateral trench installation
Filter Fabric	362,964	SY	$ 1.65	included	$ 598,890		RS Means 2008, 33 46 26.10 0100, pg. 317
						$ 32,570,497	
DIVISION 3 - CONCRETE							
Concrete Caisson	5,448	VLF	$ 36.00	included	$ 196,128		RS Means 2008, 31 63 26.13 - 0200, pg. 248; Assuming 12 feet deep
Canal Tie-In Structure	1	LS	$ 150,000.00	included	$ 150,000		Per Prior project experience
						$ 346,128	
DIVISION 5 - METALS							
N/A							
DIVISION 11 - EQUIPMENT							
N/A Assuming Gravity Flow - No pump station							
DIVISION 13 - SPECIAL CONSTRUCTION							
N/A							
DIVISION 15 - MECHANICAL							
Transmission Piping (6-foot diameter)	2,640	LF	$ 720.00	included	$ 1,900,800		Assuming Unit cost $10/InchDiam/LF pipe & 0.5 mile to recharge wells; Includes piping installation, trench excavation, backfill, and speed shoring
Perforated Drain Pipe (12-inch diameter) - Laterals	1089600	LF	$ 7.82	included	$ 8,519,582		RS Means 2008, 33 46 16.30 -2140, pg. 316; Does not include excavation and backfill. Includes 30% discount for economics of scale.
Valving	454	EA	$ 1,628.50	included	$ 739,339		RS Means 2008, 33 12 16.10 -3180, pg. 302; 1 isolation valve per module
						$ 11,159,721	
DIRECT COSTS						**$44,076,347**	
Field Overhead & Mobilization (% of Construction Total)				7%		$3,085,344	
Subtotal 1						*$47,161,691*	
Contractor Profit (% of Subtotal 1)				10%		$4,716,169	
Subtotal 2						*$51,877,860*	
Insurance & Bonds (% of Subtotal 2)				2.5%		$1,296,947	
Subtotal 3						*$53,174,807*	
Contingency (% of Subtotal 3)				35%		$18,611,182	
Subtotal 4						*$71,785,989*	
Land Purchase Costs	0	ACRE		$14,000	$ -	*$71,785,989*	Per IRWD Kickoff Meeting
Easement Purchase Costs	1,324	ACRE		$1,400	$ 1,853,600	*$73,639,589*	Per IRWD Kickoff Meeting
Escalation to 2012 (% of Subtotal with Land Costs)				9%		$6,627,563	

TOTAL		**$80,267,152**
Range (with and without contingency)	$61,655,970	$80,267,152

O&M COST

DESCRIPTION	QUANTITY	UNITS	UNIT COST	TOTAL COST	NOTES
Annual Sediment Treatment System O&M	1	LS	$ 80,000	$ 80,000	
20-Yr Replacement Cost of Perforated Laterals	1	LS	$ 48,522,860	$ 48,522,860	Accounts for excavation, dewatering, shoring, replacement of gravel, filter fabric, perforated piping and backfill. Also includes Contractor indirects (overhead, profit, insurance, bonds).
Total Annualized O&M (40-YR life cycle)				$ 1,293,072	

Irvine Ranch Water District
Kern Valley Groundwater Recharge Evaluation
Concept 4 - CULTEC Engineered Systems

Date: September 2009
Prepared by: K. Streams
Reviewed by: S. Toland

Key Assumptions:
1) All pipes are gravity
2) Does not include the cost of pretreatment
3) Unit cost based on 2008 reference. Not yet adjusted with CCI

SPEC SECTION AND DESCRIPTION	QUANTITY	UNITS	UNIT COST	INSTALLATION	TOTAL COST	DIVISION SUBTOTALS	NOTES
DIVISION 2 - SITE WORK							
Clearing and Grubbing	167	ACRE	$ 240.00	included	$ 40,080		Unit Cost based on previous IRWD Strand Ranch Construction cost. (10% of RS Means published unit cost. RS Means 2008, 31 11 10.10 - 0020, pg. 207)
Excavation	1,345,786	CY	$ 1.09	included	$ 1,466,907		Unit Cost based on previous IRWD Strand Ranch Construction cost. (35% of RS Means published unit cost. RS Means 2008, 31 23 16.13 -5110, pg. 211). Assuming total depth of trench to be excavated is 5 ft
Backfill (native material)	1,076,629	CY	$ 0.75	included	$ 807,472		Unit Cost based on previous IRWD Strand Ranch Construction cost. (34% of RS Means published unit cost. RS Means 2008, 31 23 23.14 -2400, pg. 223; Assuming reusing 7' of original backfill; rest to be reused on site.)
Backfill (gravel pipe bedding zone)	269,157	CY	$ 17.72	included	$ 4,770,543		RS Means 2008, 31 23 23.17 - 1300, pg. 225; Assuming 12" deep of gravel. Includes 40% discount for economics of scale
Site Dewatering	-	CY	$ 6.26	included	$ -		RS Means 2008, 31 23 19.20 - 0100, pg. 221; Assuming excavation is shallow & dewatering is not required
Hauling	-	CY	$ 7.48	included	$ -		RS Means 2008, 31 23 23.18 - 1250, pg. 225; 20 CY Dump Trailer; 10 mile round trip; Assume all fill reused on site
						$ 7,085,002	
DIVISION 3 - CONCRETE							
Canal Tie-In Structure	1	LS	$ 150,000.0	included	$ 150,000		Per Prior project experience
						$ 150,000	
DIVISION 5 - METALS							
N/A							
DIVISION 11 - EQUIPMENT							
N/A Assuming Gravity Flow - No pump station							
DIVISION 13 - SPECIAL CONSTRUCTION							
N/A							
DIVISION 15 - MECHANICAL							
Transmission Piping (6-foot diameter)	2,640	LF	$ 720.00	included	$ 1,900,800		Assuming Unit cost $10/InchDiam/LF pipe & 0.5 mile to system; Includes piping installation, trench excavation, backfill, and speed shoring
CULTEC RECHARGER V8	322,667	EA	$ 185.00		$ 59,693,395		Per unit cost from CULTEC quote
CULTEC Feed F-110 Connectors	29,041	EA	$ 40.00		$ 1,161,640		Per unit cost from CULTEC quote
CULTEC Poly Liner	29,041	roll	$ 200.00		$ 5,808,200		Per unit cost from CULTEC quote
CULTEC 410 Filter Fabric	322,667	EA	$ 5.55		$ 1,790,802		Per unit cost from CULTEC quote
						$ 70,354,837	
DIRECT COSTS						$77,589,838	
Field Overhead & Mobilization (% of Construction Total)				7%		$5,431,289	
Subtotal 1						*$83,021,127*	
Contractor Profit (% of Subtotal 1)				10%		$8,302,113	
Subtotal 2						*$91,323,240*	
Insurance & Bonds (% of Subtotal 2)				2.5%		$2,283,081	
Subtotal 3						*$93,606,321*	
Contingency (% of Subtotal3)				35%		$32,762,212	
Subtotal 4						*$126,368,533*	
Land Purchase Costs	0	ACRE		$14,000	$ -	*$126,368,533*	Per IRWD Kickoff Meeting
Easement Purchase Costs	167	ACRE		$1,400	$ 233,800	*$126,602,333*	Per IRWD Kickoff Meeting
Escalation to 2012 (% of Subtotal with Land Costs)				9%		$11,394,210	

TOTAL		$137,996,543
Range (with and without contingency)	$105,234,331	$137,996,543

O&M COST

DESCRIPTION	QUANTITY	UNITS	UNIT COST	TOTAL COST	NOTES
Annual Sediment Treatment System O&M	1	LS	$ 80,000	$ 80,000	
20-Yr Replacement of Filter Fabric	1	LS	$ 2,160,468	$ 2,160,468	Accounts for filter fabric replacement based on assumptions that the Cultec system is accessible. Also accounts for contractor indirects.
Total Annualized O&M (40-YR life cycle)				$ 134,012	

Irvine Ranch Water District
Kern Valley Groundwater Recharge Evaluation
Concept 5 - Subsurface Conveyance System

Date: September 2009
Prepared by: K. Streams
Reviewed by: S. Toland

Key Assumptions:
1) All pipes are gravity
2) Does not include the cost of treatment and recharge basin for remaining flows
3) Assumes 1/2 of flow is recharged via a recharge basin
4) Unit cost based on 2008 reference. Not yet adjusted with CCI.

SPEC SECTION AND DESCRIPTION	QUANTITY	UNITS	UNIT COST	INSTALLATION	TOTAL COST	DIVISION SUBTOTALS	NOTES
DIVISION 2 - SITE WORK							
Clearing and Grubbing	38	ACRE	$ 240.00	included	$ 9,231		Unit Cost based on previous IRWD Strand Ranch Construction cost (10% of RS Means published cost. RS Means 2008, 31 11 10.10 - 0020, pg. 207)
Excavation, Trench	620,562	BCY	$ 1.09	included	$ 677,654		Unit Cost based on previous IRWD Strand Ranch Construction cost. (35% of RS Means published unit cost. RS Means 2008, 31 23 16.13 - 5200, pg. 211)
Backfill (gravel pipe bedding zone)	93,084	CY	$ 17.72	included	$ 1,649,827		RS Means 2008, 31 23 23.17 - 1300, pg. 225; Assuming 12" deep of gravel. Includes 40% discount for economics of scale.
Backfill (native material)	527,478	CY	$ 0.75	included	$ 395,609		Unit Cost based on previous IRWD Strand Ranch Construction cost. (34% of RS Means published unit cost. RS Means 2008, 31 23 23.14 -2400, pg. 223; Assuming reusing 9' of original backfill; rest to be reused on site.)
Site Dewatering	9,308	CY	$ 6.26	included	$ 58,271		RS Means 2008, 31 23 19.20 - 0100, pg. 221; Assuming appox 15% of trench excavation must be dewatered
Hauling	-	CY	$ 5.24	included	$ -		RS Means 2008, 31 23 23.18 - 1250, pg. 225; 20 CY Dump Trailer; 10 mile round trip. Includes 30% discount for economics of scale.
Shoring	4,188,462	SF	$ 1.00	included	$ 4,188,462		Speed Shoring Per J. Moncrief; Assuming shoring is required for all lateral trench installation
Filter Fabric	418,804	SY	$ 1.65	included	$ 691,027		RS Means 2008, 22 46 26.10 0100, pg. 317
						$ 7,670,080	
DIVISION 3 - CONCRETE							
Canal Tie-In Structure	1	LS	$ 150,000.00	included	$ 150,000		Per Prior project experience
Basin Headwall/Distribution Channel	1	LS	$ 150,000.00	included	$ 150,000		Per Prior project experience
Concrete Manholes	419	EA	$ 1,652.00	included	$ 691,934		RS Means 2008, 33 39 13.10 1130, pg. 318, Assuming manhole every 1,000 feet
						$ 991,934	
DIVISION 5 - METALS N/A							
DIVISION 11 - EQUIPMENT N/A Assuming Gravity Flow - No pump station							
DIVISION 13 - SPECIAL CONSTRUCTION N/A							
DIVISION 15 - MECHANICAL Transmission Channel - Assumes 6-ft x 10-ft tall inverted trench box	209,423	LF	$ 182.70	included	$ 38,261,596	*$ 38,261,596*	RS Means 2008, 31 11 13.10 -3070, pg. 296 (Extrapolating for 1/2 Pipe Costs) Includes 30% discount for economics of scale.
DIRECT COSTS						**$46,923,610**	
Field Overhead & Mobilization (% of Construction Total)				7%		$3,284,653	
Subtotal 1						*$50,208,263*	
Contractor Profit (% of Subtotal 1)				10%		$5,020,826	
Subtotal 2						*$55,229,089*	
Bonds (% of Subtotal 2)				2.5%		$1,380,727	
Subtotal 34						*$56,609,817*	
Contingency (% of Subtotal 3)				35%		$19,813,436	
Subtotal 4						*$76,423,252*	
Land Purchase Costs		0.00	ACRE	$14,000	$ -	*$76,423,252*	Per IRWD Kickoff Meeting
Easement Purchase Costs		38	ACRE	$1,400	$ 53,846	*$76,477,099*	Per IRWD Kickoff Meeting
Recharge Basin Costs		1	LS	$5,305,016	$ 5,305,016	*$81,782,114*	Assume 0.5 of Total Cost of Concept 1
Escalation to 2012 (% of Subtotal with Land Costs)				9%		$7,360,390	

TOTAL		$89,142,504
Range (with and without contingency)	$69,329,069	$89,142,504

O&M COST

DESCRIPTION	QUANTITY	UNITS	UNIT COST	TOTAL COST	NOTES
Annual Surface Recharge Basin O&M (one-half of Concept 1 O&M cost)	1	LS	$ 19,000	$ 19,000	
Annual Subsurface Conveyance O&M (Periodic Vactor Cleaning)	1	LS	$ 30,000	$ 30,000	
20-Yr Surface Recharge Scraping (one-half of Concept 1)	1	LS	$ 1,354,717	$ 1,354,717	
20-Yr Replacement of Filter Fabric	1	LS	$ 833,672	$ 833,672	Accounts for filter fabric replacement, including contractor indirects.
Total Annualized O&M (40-YR life cycle)				$ 103,710	

Irvine Ranch Water District
Kern Valley Groundwater Recharge Evaluation
Treatment Costs

Date: July 2009
Prepared by: K. Streams
Reviewed by: S. Toland

Key Assumptions
1) All pipes are gravity
2) Does not include the cost of treatment and recharge basin for remaining flows
3) Assumes 1/2 of flow is recharged via a recharge basin
4) Unit cost based on 2008 reference. Not yet adjusted with CCI

SPEC SECTION AND DESCRIPTION	QUANTITY	UNITS	UNIT COST	INSTALLATION	TOTAL COST	DIVISION SUBTOTALS	NOTES
DAF	1	LS	$ 8,938,321	included	$ 8,938,321	*$ 8,900,000*	OCWD Project Reference
Actiflo	1	LS	$ 7,977,855	included	$ 7,977,855	*$ 8,000,000*	OCWD Project Reference
Aqua Diamond	1	LS	$ 9,480,206	included	$ 9,480,206	*$ 9,500,000*	OCWD Project Reference
High Rate Sedimentation	1	LS	$ 10,784,050	included	$ 10,784,050	*$ 10,800,000*	OCWD Project Reference
Memcor Microfiltration	1	LS	$ 20,152,578	included	$ 20,152,578	*$ 20,200,000*	OCWD Project Reference
Conventional Sedimentation	1	LS	$ 12,736,106	included	$ 12,736,106	*$ 12,700,000*	OCWD Project Reference

HDR

Irvine Ranch Water District
Kern Valley Groundwater Recharge Evaluation
27 MGD Aqua Diamond - Operations & Maintenance Cost

Date: July 2009
Prepared by: K. Streams
Reviewed by: S. Toland

Pre-Treatment Only

ITEM	QUANTITY	UNIT	UNIT COST	TOTAL COST
Facility Operations & Maintenance				
Filter Replacement (Every 7 years)	32	EA	$798.92	$ 25,565
Labor	1	Staff Person	$80,000	$ 80,000
Equipment Replacement	1	LS	$25,000	$ 25,000
Aqua Diamond Facility Power	79935	kWh	$0.14	$ 11,191
TOTAL				**$ 116,191**
				0.68
				$ 78,429