Paso Robles Groundwater Subbasin Water Banking Feasibility Study

Hydrogeologic Feasibility Progress Report

San Luis Obispo County Flood Control
And Water Conservation District

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1 Introduction

The Paso Robles Groundwater Basin (Basin) located in northern San Luis Obispo County (County) is one of the largest groundwater basins in the County (Figure 1). The Coastal Branch of the California State Water Project (SWP) enters the County and the Central Coast just east of the Basin near the town of Shandon and continues southwest across the Basin. These two features along with the County's unused allocation of SWP water led local water leaders to want to explore the feasibility of banking water in the Basin for the benefit of County residents.

This Feasibility Study Progress Report (Progress Report):

- Summarizes the information and approach used to develop the water banking alternatives; and
- Presents the results of the groundwater modeling conducted to determine the hydrogeologic feasibility of developing a water bank within the Basin.

Recommendations on the water banking feasibility will be presented in the Draft Report pending completion of the engineering analysis and evaluation of other issues such as environmental and permitting considerations and groundwater mangement options.

This work was completed by the project team, which was lead by GEI Consultants, Inc., with hydrogeologic support by Fugro West and Cleath & Associates.

1.1 Project Background

The Water Banking Feasibility Study (Feasibility Study) for the Paso Robles Groundwater Basin is being led by the San Luis Obispo County Flood Control and Water Conservation District (District) in coordination with the Groundwater Banking Subcommittee (GBSC) of the Water Resources Advisory Committee (WRAC). Additional stakeholders invited to participate include the North County Water Forum, the Shandon Advisory Committee, the Creston Advisory Body, and San Luis Obispo County State Water Subcontractors.

The San Luis Obispo County Integrated Regional Water Management Plan (IRWM Plan) identified the feasibility study of the groundwater banking potential of the Basin as a high-priority project. Funding for this study, as well as several other planning projects identified in the San Luis Obispo County IRWM Plan, was provided in part by a Proposition 50 Chapter 8 Integrated Regional Water Management Program Fiscal Year 2005-2006 Planning Grant.

1.2 Project Goal

The goal of the Feasibility Study is to determine the water banking potential in the Basin. If feasible water banking opportunities are identified, they can be compared to other water management options identified by the District to improve the long-term water supply reliability for the residents of the County and the Central Coast. Potential benefits of a water bank may include the following:

- Improving local groundwater conditions within the Basin.
- Increasing dry-year water supply reliability for local water users and possibly the residents of the County and the Central Coast.
- Improving local groundwater quality in the Basin.
- Providing greater flexibility of water resources management in the County and the Central Coast.
- Reducing the County's dependence on imported water supplies in below-normal years.

1.3 Supporting Information

The following documents have been prepared during the completion of this project and provide the approach and assumptions used in this study:

- Preliminary Engineering Technical Memorandum (PETM).
- Presentations to the GBSC, which are available on the SLOC water resources website under the IRWM Quicklink at: www.slocountywater.org. These presentations were used to inform the GBWC and interested parties about the project progress and ellicit feedback.
- Description of Alternatives Technical Memorandum (TM), which was distributed to the Water Resource Advisory Committee (WRAC) and presented at the June 6, 2007 meeting. This TM described the alternatives and operational scenarios that were being considered for evaluation. Input received on the TM and responses from the June WRAC meeting were incorporated into the evaluated alternatives and operational scenarios.

1.4 Report Outline

This Progress Report is organized into the following sections:

- **Section 1, Introduction,** provides general background information about the project and an introduction to the Progress Report.
- **Section 2, Water Banking Project Components,** provides some general background information on project participants, water supply availability, existing infrastructure, and potential project operations.
- **Section 3, Water Banking Alternatives,** describes how the water banking alternative locations were selected and provides background information on the three preferred locations.
- **Section 4, Hydrogeologic Evaluation,** describes the modeling approach used to evaluate the selected alternatives and the results of the hydrogeologic feasibility analysis.

2 Water Banking Project Components

This section describes some of the background information used to develop the water banking alternatives and operational scenarios.

2.1 Project Participants

The project participants are identified below because they may have a role in the planning, implementation, and operation of water banking projects in the Paso Robles Groundwater Basin for the following reasons:

- They supply water for banking,
- They use banked water, or
- They may be involved or impacted by recharge and recovery operations.

Additional analyses will be needed to identify and codify the specific coordination, cooperation, and management of any future water banking activities among local and state agencies, as well as local land owners.

San Luis Obispo County Flood Control and Water Conservation District (SLOCFCWCD) – SLOCFCWCD has the SWP contract that is being used as the water supply for banking. It also has the contract with Central Coast Water Authority to treat and convey water to the existing M&I contractors in San Luis Obispo County.

Central Coast Water Authority (CCWA) – CCWA owns and operates the Coastal Branch Aqueduct and the Polonio Pass WTP. CCWA also represents potential urban water users that may be interested in receiving banked water.

Local Agricultural Water Users – Local agricultural water users are included to estimate local agricultural in-lieu recharge opportunities. The local agricultural areas are identified based on a 2006 San Luis Obispo County land use survey prepared by the San Luis Obispo County Agricultural Commissioner’s Office. Coordination with agricultural land owners that may choose to participate in a feasible water banking project would occur under future efforts.

Local Urban Water Users – Local urban water users are included because they may be affected by water banking operations. They may also be potential project participants that utilize banked water. Coordination with local cities and communities may be necessary in the future to evaluate the effects of a potential water banking project on their existing water supply wells and to evaluate opportunities for them to participate in any potential project.

Regional Urban Water Users – Regional urban water users are included to represent potential out-of-basin water users that may become partners in a water banking project.

2.2 Existing Core Infrastructure

This section briefly describes some of the major existing infrastructure that may be utilized in water banking project operations.

2.2.1 Coastal Branch Phase I

Coastal Branch Phase I branches off the California Aqueduct in southern Kings County near Kettleman City and extends as a 15-mile aqueduct into northern Kern County in the vicinity of Devils Den. Berrenda Mesa Water District and Castaic Lake Water Agency receive water through the Phase I facilities. There are two pumping plants within the Phase I Stage, Las Perillas and Badger Hill Pumping Plants.

2.2.2 Polonio Pass Water Treatment Plant

The section of the Coastal Branch from Devils Den Pumping Plant to Polonio Pass Water Treatment Plant (PPWTP) was constructed as part of Phase II. This section of the Coastal Branch Pipeline has an estimated capacity is 74,125 acre-feet over the course of 11 months per year.

The PPWTP has an existing capacity rating of 48 MGD for 11 months, equaling 49,286 acre-feet per year. Current demands for treated water on the Coastal Branch total about 44,000 acre-feet per year (4,830 acre-feet per year for San Luis Obispo County and 39,078 acre-feet per year for Santa Barbara County). Based upon these capacity estimates, the Coastal Branch between Devils Den and PPTWP has about 25,000 acre-feet more capacity than the current treatment capacity of the PPWTP.

2.2.3 Coastal Branch Phase II

The Phase II is a 101-mile buried pipeline extending from Devils Den (Phase I) to Vandenberg Air Force Base. To serve the other cities of southern Santa Barbara, CCWA built a 42-mile extension terminating at Lake Cachuma for a total length of 143 miles. The pipe diameter starts at 57 inches at Devils Den, reduces to 42 inches south of the City of Arroyo Grande, and reduces further to between 30 and 39 inches south of Vandenberg AFB. Two turnouts are located in San Luis Obispo County, Chorro Valley Pipeline and the Lopez Turnout. The coastal branch has a treated capacity of about 48,600 acre-feet per year – 45,486 acre-feet per year contracted capacity for CCWA and 4,830 acre-feet per year contracted capacity for the District.

2.3 Water Supply Availability

An analysis was completed to estimate the water supply available for a potential water banking project. The water supply for this water banking feasibility study is based in part upon the State Water Project (SWP) annual allocation for the District as defined in Table A of the District's contract with the Department of Water Resources (DWR). The Table A annual allocation identifies each agency's share of the total SWP supply available in a given year. The SWP has contracts with 29 contractors that total 4.173 million acre-feet (maf). *The State Water Project Delivery Reliability Report 2005* (Reliability Report) presents DWR's current information regarding the annual water delivery reliability of the SWP for existing and future levels of development in the water source areas, assuming historical patterns of precipitation. The actual availability of SWP is based upon annual hydrologic conditions. The Reliability Report provided an assessment of the existing SWP delivery capability of a range of hydrologic conditions that included an historic extended dry period.

The water supply availability for this analysis is based on the CalSim II model studies used in the Reliability Report. CalSim II is a planning model developed by the DWR and United States Bureau of Reclamation (USBR) to simulate the SWP and Central Valley Project (CVP) and areas tributary to the Sacramento-San Joaquin Delta. It uses historic rainfall and runoff data, which have been adjusted for changes to land and water use conditions that have occurred or may occur in the future, to simulate water resources operations in the Sacramento and San Joaquin River Basins on a month-to-month basis. The month-to-month simulations are based on the 73-year period (1922-1994) of the adjusted historical rainfall/runoff data. This assumption is based on the assumption that the next 73 years will have the same rainfall/snowmelt amount and pattern, within-year and from year to year, as the 1922 to 1994 period.

Table A Allocation – The Table A annual allocation for the District totals 25,000 acre-feet at an instantaneous rate of delivery of 35 cfs. This corresponds to a monthly delivery rate of 2,083 acre-feet. The County currently utilizes 4,830 acre-feet per year of the Table A annual allocation for urban water users in the County, leaving the remaining Table A supply available in any given year for water banking operations.

Article 21 – Article 21 refers to a provision in the SWP Contracts for delivering water that is available in addition to Table A amounts. SWP contractors are allowed to receive Article 21 water only under specific conditions, including the following:

- It is available only when it does not interfere with Table A allocations and SWP operations;
- It is available only when excess water is available in the Delta;
- It is available only when conveyance capacity is not being used for SWP purposes or SWP deliveries; and

- It cannot be stored within the SWP system.

Article 21 water can be stored directly in a reservoir or by offsetting other water that would have been withdrawn from storage, such as local groundwater. The Reliability Report states that,

> "In the absence of storage, Article 21 water is not likely to contribute significantly to local water supply reliability. Incorporating supplies received under Article 21 into the assessment of water supply reliability is a local decision based on specific local circumstances, facts and level of water supply reliability required."

Article 21 water represents an SWP water supply source that may be available in some years to SWP contractors.

Drought Buffer – Drought buffer is a portion of unused Table A allocation that has been contractually reserved to firm up the reliability of the contract allocation that is used in those years when full SWP deliveries are not available.

2.4 Water Banking Concepts

The October 5, 2005 CCWA memorandum regarding San Luis Obispo County Water Reliability Opportunities Update identified two potential groundwater banking concept alternatives for northern San Luis Obispo County.

Treated Water Banking Concept: This concept included creating a new turnout from the Coastal Branch Aqueduct to deliver treated water to a banking location for recharge (through injection, spreading, or in-lieu recharge). When SWP supplies exist in excess of current demand, water would be banked. When SWP water is not available, the previously banked water would be recovered and conveyed to the Coastal Branch for delivery water users.

Raw Water Banking Concept: This concept would require constructing a new pipeline to convey raw water from PPWTP (prior to treatment) to a banking location in the Paso Robles Groundwater Basin for recharge (through stream recharge, spreading, or in-lieu recharge). When SWP supplies exist in excess of current demand (4,830 acre-feet per year), water would be banked. When SWP water is not available, the previously banked water would be recovered and conveyed to the Coastal Branch for delivery water users, or, if necessary, pumped back to Polonio Pass WTP for treatment using the same pipeline.

The Raw Water Banking Concept is being evaluated in this feasibility study in part because the available supply for banking significantly exceeds the existing capacity of the PPWTP and treated water pipeline capacity.

2.5 Water Banking Operations

Three operational scenarios are being considered to evaluate the water banking feasibility in the Paso Robles Groundwater Subbasin. The three operational scenarios bookend the range of groundwater recharge and water banking opportunities that may be considered in the basin based in part upon SWP supply availability described in Section 2.3. They include:

- Baseline Condition (no groundwater recharge or recovery),
- Groundwater Recharge Scenario (groundwater recharge only), and
- Water Banking Scenario (groundwater recharge and recovery).

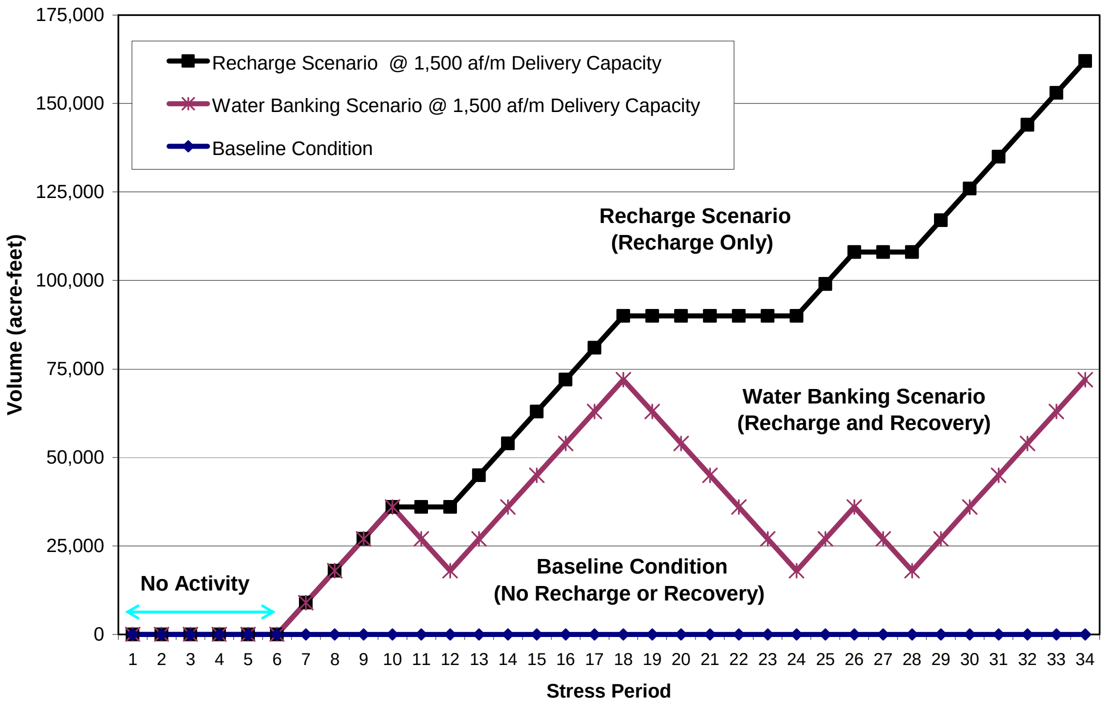
For purposes of this feasibility study, the recharge and recovery capacity was assumed to be 1,500 acre-feet per month (18,000 acre-feet per year). This value represents a potential water supply from the State Water Project that is available to the region in most years through a combination of sources, and is considered to be an appropriate magnitude to test the water banking potential in the Basin. These operational scenarios were evaluated in the previously developed groundwater model of the Paso Robles Groundwater Basin. The 17-year simulation period of the groundwater model is divided into 34 six-month stress periods, which represent alternating the growing season (April to September) and the non-growing season (October to March). Figure 2 shows the project operations for the Baseline Condition, Recharge Scenario, and the Groundwater Banking Scenario based upon the 1,500 acre-feet per month project capacity for the simulation period. Each of these operational scenarios is described below.

2.5.1 Baseline Condition

The Baseline Condition is used to represent the groundwater basin without groundwater recharge or water banking operations, and is therefore used to evaluate the effects of the Recharge Scenario and the Water Banking Scenario (described below) on the groundwater basin. The Baseline Condition for this analysis is the Buildout Scenario (Scenario 2 from the Phase II Groundwater Basin Study). The Buildout Scenario was developed to simulate the effects of urban growth build-out and maximum reasonable agricultural demand on groundwater elevations throughout the Paso Robles Groundwater Basin and to identify areas of special concern within the Basin. The Baseline Condition is described in more detail in the Phase II Groundwater Basin Study.

As shown in Figure 2, the Baseline Condition does not include any recharge or recovery operations during the 17-year simulation period.

Figure 2



2.5.2 Recharge Scenario

The Recharge Scenario focuses on improving local water supply conditions by supplementing existing groundwater supplies with an imported water supply. The imported supply may be used instead of pumping groundwater (in-lieu recharge) or by directly recharging the groundwater basin (direct recharge), thereby reducing the net demand on the groundwater system. Reducing the annual net groundwater demand results in higher groundwater levels than would have occurred without the recharge program. Existing (or new) groundwater wells are used to recover the recharged water for use on the overlying lands.

The purpose of the Recharge Scenario is to evaluate the effect of a recharge program on the Baseline Condition. This scenario includes only recharge operations; the groundwater pumping is the same as in the Baseline Condition to meet municipal, agricultural, and rural water demands. As shown in Figure 2, recharge occurs in nine years and totals about 162,000 acre-feet during the 17-year simulation period. These recharge periods were selected based upon SWP supply availability described in Section 2.3. Recharge occurs in years with above-average rainfall and runoff.

2.5.3 Groundwater Banking Scenario

A groundwater banking program differs from a groundwater recharge program by storing water for others that may or may not overlie the portion of the groundwater basin involved in the groundwater recharge activities. A groundwater banking program requires an accounting system to distribute the costs and benefits of the program among the participants (including the banking partners and overlying groundwater users). Groundwater levels in the area affected by water banking operations may have greater fluctuations than there would have been without the banking program. During periods of recharge, groundwater levels may be higher than they would have been without the project. During recovery periods, groundwater pumping may exceed that of what was normally used, resulting in localized drawdown at the recovery wells that would have been greater than without the banking project.

- The goal of water banking is to store and recover groundwater for an intended use. Imported water is ‘banked’ in wet years when surplus supplies are available and recovered in drier years when the banked water is needed.
- The groundwater bank may experience higher groundwater levels than would have been present without the bank in wet years (put years), and may experience lower groundwater levels in dry years during take operations (than would have occurred without the bank in place).
- The banking program may serve an outside interest that pays either water and/or money to store water in the bank for their time of need.

The purpose of the Water Banking Scenario is to evaluate the effect of a recharge and recovery program (for export) on the Baseline Condition and the Recharge Scenario. This scenario includes the same recharge operations as the Recharge Scenario. The recovery operations include the local demand (as in the Recharge Scenario) and an additional recovery component to represent pumping of banked water to meet an additional demand. The disposition of the water recovered from the basin has not been associated with any individual water user; e.g., the recovered water may be used to meet the dry year water needs of other SWP contractors.

For the Water Banking Scenario, the recharge operations are the same as the Recharge Scenario, as shown in Figure 2. During years when there is no supply for groundwater recharge, it is assumed that the banked water would be recovered and delivered for use outside of the basin. In the Water Banking Scenario, 90,000 acre-feet of groundwater is recovered during the simulation period. This represents about 55 percent of the total amount of recharged water. The recovery of banked water occurs in three periods, stress period 11-12, stress period 19-24 (3-year period), and stress period 27-28.

3 Water Banking Alternatives

The locations of the water banking alternatives to be evaluated in this feasibility study were identified in part based on the local hydrogeologic conditions. The following hydrogeologic considerations were used to identify appropriate areas to test water banking feasibility:

- Hydrogeologic conditions
- Near surface conditions
- Occurrence and movement of groundwater
- Groundwater storage capacity
- Water quality conditions

These hydrogeologic considerations were presented in the PETM and discussed at several GBSC meetings. The three selected alternatives presented below were developed based on review of the existing available information and field investigation to verify local conditions.

For evaluation purposes, each of the three alternatives consists of a combination of direct recharge and agricultural in-lieu recharge. The recharge area was evaluated to determine a combination of direct and in-lieu recharge based upon the existing land use and local hydrogeologic conditions as described above.

For the recovery of banked water, the new recovery wells were located to minimize drawdown interference during recovery operations with existing wells and other recovery wells while limiting infrastructure requirements. The actual number and distribution of recovery wells is based on existing well locations and local hydrogeologic conditions.

The alternatives represent the three different locations shown in Figure 3 where water banking feasibility projects will be evaluated using the existing groundwater model. These alternatives are described in the Draft Description of Water Banking Alternatives TM. The alternatives include:

- Shell Creek/Camatta Creek and Lower San Juan Creek Recharge Areas,
- Creston Recharge Area, and
- Salinas River/Hwy 46 Recharge Area.

3.1 Shell Creek/Camatta Creek and Lower San Juan Creek Recharge Areas

The purpose of this alternative is to evaluate the groundwater banking potential in the San Juan Subarea shown in Figure 4.

Potential areas that may support direct recharge have been located along Shell/Camatta Creeks and San Juan Creek. In addition, the agricultural areas (primarily vineyards) present in the Shandon area and along Shell Creek may provide in-lieu recharge opportunities.

The water banking alternatives would be simulated using a combination of agricultural in-lieu recharge and direct recharge. This combination of in-lieu and direct recharge would disperse the recharge activities over a large area in order to access as much of the aquifer system as possible. This area is not subject to current groundwater level declines.

Groundwater recovery would take place throughout the area receiving recharge water. Wells in this area can produce from 1,000 to 2,000 gallons per minute. It is expected that new groundwater recovery wells would be located along the conveyance pipeline to recover the banked water and return it to the Polonio Pass WTP.

This alternative would include approximately 23 miles of pipelines to deliver water to the recharge areas and return recovered water to the Polonio Pass WTP for treatment and distribution. The pipeline diameter would be reduced as needed to match the recharge and recovery operations.

3.1.1 Hydrogeologic Setting

The average thickness of the aquifer system in the San Juan Subarea is approximately 450 feet, with an average specific yield of about 10 percent, resulting in an estimated groundwater storage capacity of about 4.2 million acre-feet. The aquifer typically consists of sand and gravel interbedded with discontinuous clay horizons. In the Shell Creek/Camatta Creek area, the aquifer contains sequences of sand and gravel up to several hundred feet thick. Previous field investigations have noted significant stream recharge in Shell/Camatta Creek (Fugro, 2002).

Throughout most of the area, the Paso Robles Formation, which comprises the deep aquifer and primary producing geologic unit, is underlain by the Santa Margarita Formation. Within the stream valleys, the alluvium is thin but highly permeable, consisting of sand and gravel with very high transmissivity values.

In the lower San Juan Creek and Shell Creek/Camatta Creek area, well production typically ranges from 1,000 to 2,000 gallons per minute (gpm), with typical specific capacity values of about 26 gpm/ft.

Water levels in wells in the San Juan area have shown both rising and falling conditions over the past 25 years. Wells exhibiting both the greatest decline and the greatest water level increases can be found in Camatta Canyon, indicating the effects of localized heavy agricultural pumping as well as the impacts of significant stream recharge. In general, the lower San Juan Creek and upper Shell Creek areas experienced a long period of declining water levels from the early 1960s through the mid-1990s, followed by a marked increase from the mid-1990s to the present. Wells along Camatta Canyon appear not to have experienced the same period of recovery in the 1990s, however, resulting in a slight decline of water levels. Generally, groundwater flow in the area is to the north-northwest.

Groundwater quality in the subarea is variable, depending on the area and the depth of the well. Groundwater quality in the Shell Creek and Camatta Canyon areas is typically very good, with total dissolved solids (TDS) concentrations in the range of 150 to 300 mg/L, chloride concentrations less than 40 mg/L, and nitrates generally about 10 to 15 mg/L. Concentration levels of the major constituents of concern are relatively stable.

Groundwater quality in the lower San Juan Creek area is more variable. The shallow aquifer zones in the lower San Juan Creek area, above or below the confluence of Camatta Creek and San Juan Creek, have TDS concentrations greater than 2,000 mg/L with increasing nitrate levels that occasionally exceed 45 mg/L. In part because of the water quality, this shallow zone is not used to a large degree.

The deeper aquifer in the lower San Juan Creek area is more typical of the deep Paso Robles Formation, with TDS concentrations in the 500 to 700 mg/L range and chloride concentrations in the 40 to 60 mg/L range.

The aquifer in the Shell Creek/Camatta Creek area is unconfined, with an apparent high degree of hydraulic communication between the shallow alluvium and the underlying Paso Robles Formation. Streamflow in the Shell Creek/Camatta Creek alluvium directly recharges the underlying deep aquifer. To the north of the confluence of the Camatta Creek and San Juan Creek, however, the deep primary production aquifer is semi-confined to confined, with limited direct hydraulic communication between the aquifer and the shallow alluvial systems. Thus, direct recharge applications in the lower San Juan Creek appear to have limited deep aquifer recharge potential.

3.2 Creston Recharge Area

The purpose of this alternative is to evaluate the groundwater banking potential in the Creston Subarea shown in Figure 5. The sand and gravel zones of the Creston basin sediments appear to be in direct contact with the shallow alluvial sand and gravel deposits of the Huer Huero Creek, which may provide direct recharge to the basin. Groundwater quality is generally good in the shallow zones, with increased mineralization from the southwest to the northeast.

The East Branch of the Huer Huero Creek has been identified as a potential recharge area. In addition, the agricultural areas (primarily vineyards) present in the Creston area may provide in-lieu recharge opportunities.

The water banking alternatives would be simulated primarily using direct recharge along the Huer Huero recharge area and secondarily using agricultural in-lieu in the Creston Area. This combination of in-lieu and direct recharge would disperse the recharge activities over a large area in order to access as much of the aquifer system as possible. Groundwater levels in this area are relatively stable.

Groundwater recovery would take place throughout the area receiving recharge water from the shallow alluvial aquifer and the Paso Robles Formation. Wells in this area can produce from 300 to 400 gallons per minute. It is expected that new groundwater recovery wells would be located along the pipeline to recover the banked water and return it to the Polonio Pass WTP.

This alternative would include approximately 26 miles of pipelines to deliver water to the recharge areas and return recovered water to the Polonio Pass WTP for treatment and distribution. The pipeline diameter would be reduced as needed to match the recharge and recovery operations.

New recovery wells were located along the conveyance pipeline to minimize drawdown interference during recovery operations with existing wells and other recovery wells while limiting infrastructure requirements.

3.2.1 Hydrogeologic Setting

The average thickness of the aquifer system in the Creston Subarea is approximately 450 feet, with an average specific yield of about 9 percent, resulting in an estimated groundwater storage capacity of about 2 million acre-feet. This area has a two-layered aquifer system, with the shallow alluvial aquifer system overlying the Paso Robles Formation.

Throughout the Creston area, the deep basin sediments of the Paso Robles Formation are underlain predominantly by Tertiary-age marine sediments. In the southern portion of the area, the basin sediments are underlain by and in contact with the granitic rocks that form the groundwater basin boundary. The Paso Robles Formation sediments in the Creston area are typical of the rest of the basin, comprised of relatively thin, discontinuous sand and gravel layers interbedded with thicker layers of silt and clay.

Throughout most of the Creston area, alluvial deposits of variable thicknesses overlie the Paso Robles Formation beneath the flood plains and older stream terraces of Huer Huero Creek. These alluvial deposits reach depths as great as 100 feet in places and consist of much coarser and unconsolidated sedimentary layers than are typically found in the

Paso Robles Formation. Groundwater recharge to the Creston area occurs where the shallow alluvial deposits are in contact with (overlying) the coarse-grained Paso Robles Formation aquifer.

Producing water wells in the Creston area penetrate and extract groundwater from both the alluvium and the Paso Robles Formation. Wells producing from the unconfined and highly permeable alluvium typically pump in the range of 300 to 400 gpm, with specific capacities in the range of 60 to 70 gpm per foot. Wells producing from the Paso Robles Formation also typically pump in the range of 300 to 400 gpm, but with much lower specific capacities, generally in the 5 to 10 gpm per foot range.

Water levels in wells in the northern part of the Creston area showed a general decline from the mid-1960s into the early 1990s. From the early 1990s to about 2000, water levels in most wells in the area increased markedly, resulting in more than 50 feet of water-level rise in the 20-year period prior to about 2000. Since 2000, water levels appear to have stabilized or perhaps declined slightly.

Near the town of Creston, water levels have remained relatively stable for many years. Several wells, particularly along the course of the Huer Huero Creek south of town, experienced flowing conditions and historic high water levels in the late 1990s.

Groundwater and surface water flows northward out of the Creston area primarily along the Huer Huero Creek drainage. Groundwater flow is generally to the northwest at a regional hydraulic gradient of approximately 0.009 feet per foot.

Groundwater quality in the Creston area is generally very good for drinking and for direct agricultural application. Typical TDS concentrations are in the 250 to 500 mg/L range, with chloride concentrations about 50 mg/L and nitrates generally below 20 mg/L. Overall, water quality trends in the area are relatively stable.

The primary source of recharge to the deep aquifer in the Creston area appears to be Huer Huero Creek. The aquifer in the Creston area, particularly in the northern portion of the subarea, appears to be unconfined for the most part, with an apparent high degree of hydraulic communication between the shallow alluvium of the creek and its tributaries and the underlying Paso Robles Formation.

3.3 Salinas River/Highway 46 Recharge Area

The purpose of this alternative is to evaluate the groundwater banking potential along Highway 46 and in the Salinas River Area shown in Figure 6.

Within the Subarea, the Estrella River north of Highway 46 has some areas that may provide favorable surface recharge, but the connection of these areas to the main aquifer system is not clearly understood at this time.

The Salinas River just south of Paso Robles has been identified as a potential recharge area. In addition, the agricultural areas (primarily vineyards) present along Highway 46 may provide in-lieu recharge opportunities.

Groundwater levels along Highway 46 and near Paso Robles have experienced the greatest declines in the basin. It is expected that groundwater recharge alternatives in this area may reduce the rate of groundwater-level declines and may allow for the recovery of groundwater levels during recharge operations.

Groundwater recovery would take place throughout the area receiving recharge water from the shallow alluvial aquifer and the Paso Robles Formation. Wells in this area can produce up to 1,000 gpm. Groundwater recovery wells may have to be disbursed over a large area to reduce the impacts of recovery operations on existing groundwater users.

This alternative would include approximately 31 miles of pipelines to deliver water to the recharge areas and return recovered water to the Polonio Pass WTP for treatment and distribution. The pipeline diameter would be reduced as needed to match the recharge and recovery operations.

3.3.1 Hydrogeologic Setting

The aquifer system in the Estrella Subarea averages about 700 feet of thickness with an 8 percent specific yield resulting in an estimated groundwater storage capacity of about 8.8 million acre-feet. This area has a two-layered aquifer system, with the shallow alluvial aquifer system overlying the Paso Robles Formation. Groundwater quality is generally good east of the Salinas River; however, elevated nitrate levels are present in some areas.

In the area of potential in-lieu recharge opportunities along Highway 46, the Paso Robles Formation consists of interbedded sand and gravel zones with clay beds that retard vertical percolation of groundwater. The direct recharge potential appears to be limited in this area because of the prevalence of clay interbeds, relatively low conductivity of the near-surface soils, and the thin to nil alluvial cover.

The Salinas River aquifer is a Recent-age younger alluvium comprised of stream channel and flood plain sediments deposited by the Salinas River. The thickness of the alluvium varies, but in the potential direct recharge area, is typically 75 to 100 feet thick. Short-term specific capacities at discharge rates of 1,000 gpm range from 20 to 60 gpm per foot of drawdown, with transmissivity values of about 100,000 gallons per day per foot of aquifer.

Well production yields in the Salinas River alluvium typically range from 800 gpm to as high as 1200 gpm. Well yields in the Paso Robles Formation in the Estrella area vary widely, but average about 500 to 800 gpm.

Water levels in wells in the Estrella area have exhibited severe declines over the past 25 years, through a combination of the presence of older, less permeable sediments along with localized increased water demand in the area. Water level declines ranging from 50 feet to as high as 200 feet have been noted in wells in the area.

Groundwater flows into the Estrella area from the north and northeast, from the east from Shandon and the San Juan Creek area, and from the south out of the Huer Huero Creek drainage. Along the Salinas River, groundwater flow follows the river drainage northward across the western portion of the basin towards the basin outlet.

Groundwater quality in the Estrella area is generally good, with TDS concentrations ranging from 400 to 700 mg/L, chlorides in the range of 50 to 80 mg/L, and nitrates generally below 40 mg/L. In the area of potential in-lieu recharge opportunities, water quality trends are relatively stable.

4 Hydrogeologic Evaluation

This section describes the hydrogeologic evaluation of the recharge and water banking scenarios using a numerical groundwater flow model previously developed for the Paso Robles Groundwater Basin.

4.1 Model Background Information

The groundwater flow model used in this study to evaluate the recharge and water banking scenarios was previously developed for the County of San Luis Obispo Public Works Department by Fugro West, Inc. and ETIC Engineering (Fugro, 2005). The numerical groundwater model was developed in MODFLOW-2000 using the Groundwater Vistas graphical-user-interface for MODFLOW. The function of the model was to simulate groundwater level and storage changes in the Paso Robles Groundwater Basin for the 17-year simulation period representing the 1981 through 1997 historical period. In that study, the model was further adapted to evaluate three different scenarios of future water supply and demand in the Paso Robles Groundwater Basin.

The aquifer system in the Paso Robles Groundwater Basin is simulated in the groundwater flow model using four model layers.

- Model layer 1 represents the highly permeable unconfined, coarse-grained alluvial sediments associated with the channel corridors of the Salinas River and the Estrella River. Alternative 3 includes direct recharge into this layer.
- Model layer 2 represents the less permeable channel bed of the Salinas River and a low permeable fine-grained unit that underlies the modeled extent of the Estrella River and also extends to the north and south of the Estrella River by approximately 3 to 4 miles in each direction. None of the simulated alternatives include direct recharge into this layer.
- Model layers 3 and 4 represent the upper and lower portions of the confined to semi-confined Paso Robles Formation. Alternatives 1 and 2 include direct recharge into this layer. The project pumping associated with the groundwater recovery operations occur in these model layers.
- Reductions in groundwater pumping resulting from the in-lieu recharge operations were assigned to the individual model layer where the pumping occurs.

The model calculates the changes in groundwater levels and groundwater storage in each layer over the 17-year base period. Each year in the base period was divided into two 6-

month stress periods, resulting in a total of 34 stress periods over the 17 years. The stress period concept implies that the modeled groundwater recharge and discharge stresses have constant rates of application during each 6-month stress period. Although the rates are constant in time during a given stress period, the stresses may and often do vary spatially during the same stress period. The different recharge and discharge stresses frequently change from stress period to stress period. In the model, the recharge stresses included: 1) subsurface inflows, 2) percolation of precipitation, 3) streambed percolation, 4) percolation of irrigation water, and 5) percolation of wastewater discharge. Conversely, the discharge stresses included: 1) subsurface outflows, 2) urban, agricultural, and domestic groundwater pumping, 3) discharges to streams, and 4) extraction by phreatophytes.

4.2 Evaluation Criteria

Numerical evaluation of the recharge and water banking scenarios was performed by comparing the simulated groundwater levels, groundwater storage changes, and groundwater mass balance components (i.e., other recharge and discharge stresses) against those generated by the Baseline Condition. Other mass balance components include changes to evapotranspiration losses, stream flows, and subsurface flows through the boundary conditions caused by the recharge and water banking scenarios.

Finally, the efficiency of the recharge and water banking scenarios was evaluated by comparing the simulated volumes of recharge retained in the aquifer system under the various alternatives to the amounts of recharge actually implemented according to the recharge and water banking schedules.

4.3 Baseline Condition

In the groundwater modeling study performed for the Paso Robles Groundwater Basin (Fugro, 2005), Scenario 2 of that study was referred to as the “Build-Out Scenario.” The Build-Out Scenario evaluated the future impacts on basin groundwater resources of urban build-out and maximum reasonable agricultural water demand, which increases basin-wide groundwater pumping by about 33,000 acre-feet per year. The groundwater flow model that simulated the Build-Out Scenario is the same model that is used in this study to evaluate the recharge and water banking scenarios for the three alternatives. The simulated groundwater levels and storage changes from the original Build-Out Scenario were used as the baseline conditions (i.e., Baseline Condition) for this study for comparison of the impacts of the recharge and water banking scenarios . The Baseline Condition therefore represents the future scenario in which no recharge operations and no water banking operations are implemented in the Paso Robles Groundwater Basin.

The annual agricultural groundwater pumping demand for the Baseline Condition is assumed to be constant over the 34 stress periods. For each year, the total annual agricultural pumping demand is divided between the Fall-Winter stress period and the Spring-Summer stress period. Since the Spring-Summer stress period coincides with the predominant portion of the crop growing season during which agricultural water demands are greatest during the year, the pumping rate for the Spring-Summer stress period is always greater than the Fall-Winter stress period.

4.4 Simulation of Recharge and Water Banking Operations

The modifications to the Baseline Condition to account for recharge and recovery operations evaluated in the groundwater modeling are shown in Figure 2.

The recharge operations (i.e., direct recharge plus in-lieu recharge) are applied during the active recharge stress periods numbered 7-10, 13-18, 25-26, and 29-34. The in-lieu recharge potential for these areas occurs at specific wells within the model for each alternative. For these active recharge stress periods, pumping from these agricultural wells was disabled in the model simulations and the water demands for those agricultural areas were assumed to be met with available SWP water. During the stress periods when recharge was not active, agricultural pumping in the wells associated with the in-lieu recharge areas are once again active in the model. The total amount of agricultural pumping demand in the in-lieu recharge areas for each stress period was subtracted from the 9,000 acre-feet of available SWP for recharge operations. The remainder of the 9,000 acre-feet of SWP water is assumed to be available for direct recharge. The allotments of direct recharge and in-lieu recharge for each alternative are presented in Table 1.

During water banking operations, recharge operations and recovery operations do not occur during the same stress periods, but vary according to the water banking schedule shown in Figure 2 and in Table 1. Recovery wells for each alternative were located to maximize the recovery of the recharged water while being located no less than 2,500 feet from the nearest modeled urban, agricultural, or domestic well. Each recovery well is screened only in model layer 4 (i.e., the Paso Robles Formation).

Table 1

Summary of Groundwater Model Input Data

Stress Period	Groundwater Recharge Operations										Groundwater Recovery Operations		
	Alternative 1a and 1b			Alternative 2a and 2b			Alternative 3a and 3b			Cumulative Volume of Groundwater for Recharge Alternatives (acre-feet)	Alternative 1b, 2b, and 3b		Cumulative Volume of Groundwater for Banking Alternatives (acre-feet)
	Direct Groundwater Recharge (acre-feet)	In-Lieu Groundwater Recharge (acre-feet)	Total Groundwater Recharge (acre-feet)	Direct Groundwater Recharge (acre-feet)	In-Lieu Groundwater Recharge (acre-feet)	Total Groundwater Recharge (acre-feet)	Direct Groundwater Recharge (acre-feet)	In-Lieu Groundwater Recharge (acre-feet)	Total Groundwater Recharge (acre-feet)		Total Groundwater Recovery (acre-feet)	Cumulative Groundwater Recovery (acre-feet)	
1	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0
7	8,587	413	9,000	8,935	65	9,000	8,074	926	9,000	9,000	0	0	9,000
8	6,660	2,340	9,000	8,630	370	9,000	4,182	4,818	9,000	18,000	0	0	18,000
9	8,587	413	9,000	8,935	65	9,000	8,074	926	9,000	27,000	0	0	27,000
10	6,660	2,340	9,000	8,630	370	9,000	4,182	4,818	9,000	36,000	0	0	36,000
11	0	0	0	0	0	0	0	0	0	36,000	9,000	9,000	27,000
12	0	0	0	0	0	0	0	0	0	36,000	9,000	18,000	18,000
13	8,587	413	9,000	8,935	65	9,000	8,074	926	9,000	45,000	0	18,000	27,000
14	6,660	2,340	9,000	8,630	370	9,000	4,182	4,818	9,000	54,000	0	18,000	36,000
15	8,587	413	9,000	8,935	65	9,000	8,074	926	9,000	63,000	0	18,000	45,000
16	6,660	2,340	9,000	8,630	370	9,000	4,182	4,818	9,000	72,000	0	18,000	54,000
17	8,587	413	9,000	8,935	65	9,000	8,074	926	9,000	81,000	0	18,000	63,000
18	6,660	2,340	9,000	8,630	370	9,000	4,182	4,818	9,000	90,000	0	18,000	72,000
19	0	0	0	0	0	0	0	0	0	90,000	9,000	27,000	63,000
20	0	0	0	0	0	0	0	0	0	90,000	9,000	36,000	54,000
21	0	0	0	0	0	0	0	0	0	90,000	9,000	45,000	45,000
22	0	0	0	0	0	0	0	0	0	90,000	9,000	54,000	36,000
23	0	0	0	0	0	0	0	0	0	90,000	9,000	63,000	27,000
24	0	0	0	0	0	0	0	0	0	90,000	9,000	72,000	18,000
25	8,587	413	9,000	8,935	65	9,000	8,074	926	9,000	99,000	0	72,000	27,000
26	6,660	2,340	9,000	8,630	370	9,000	4,182	4,818	9,000	108,000	0	72,000	36,000
27	0	0	0	0	0	0	0	0	0	108,000	9,000	81,000	27,000
28	0	0	0	0	0	0	0	0	0	108,000	9,000	90,000	18,000
29	8,587	413	9,000	8,935	65	9,000	8,074	926	9,000	117,000	0	90,000	27,000
30	6,660	2,340	9,000	8,630	370	9,000	4,182	4,818	9,000	126,000	0	90,000	36,000
31	8,587	413	9,000	8,935	65	9,000	8,074	926	9,000	135,000	0	90,000	45,000
32	6,660	2,340	9,000	8,630	370	9,000	4,182	4,818	9,000	144,000	0	90,000	54,000
33	8,587	413	9,000	8,935	65	9,000	8,074	926	9,000	153,000	0	90,000	63,000
34	6,660	2,340	9,000	8,630	370	9,000	4,182	4,818	9,000	162,000	0	90,000	72,000
Total	**137,220**	**24,780**	**162,000**	**158,085**	**3,915**	**162,000**	**110,305**	**51,695**	**162,000**		**90,000**		
Average (Stress Period)	**4,036**	**729**	**4,765**	**4,650**	**115**	**4,765**	**3,244**	**1,520**	**4,765**		**2,647**		
Average (Annual)	**4,036**	**729**	**4,765**	**4,650**	**115**	**4,765**	**3,244**	**1,520**	**4,765**		**2,647**		
Percent of Total Recharge	**85%**	**15%**		**98%**	**2%**		**68%**	**32%**					

4.5 Model Implementation and Results

This section describes the application of the groundwater model to each alternative, and presents the resulting changes to the groundwater conditions compared to the Baseline Conditions.

4.5.1 Alternative 1 – Shell Creek/Camatta Creek and Lower San Juan Creek Recharge Areas

4.5.1.1 Alternative 1a: Recharge-Only Scenario

Alternative 1a involves the implementation of the recharge-only schedule in the Shell Creek/Camatta Creek and Lower San Juan Creek recharge areas shown in Figure 4. The southern site is located in the Shell Creek/Camatta Creek area and the northern site is located in the Lower San Juan Creek area. Preliminary model simulations of Alternative 1a indicated that the northern site would be inappropriate for recharge-only operations due to the existence of the semi-confining to confining layer. Consequently, all of the water available for direct recharge was directed to the southern recharge site (i.e., Shell Creek/Camatta Creek).

As shown on Table 1, the total in-lieu recharge potential for the Fall-Winter and Spring-Summer stress periods in Alternative 1 are 413 and 2,340 acre-feet, respectively, or 4.6 percent and 26 percent of the 9,000 acre-feet of the water available for recharge during active recharge stress periods. The remaining water available for direct recharge during the Fall-Winter and Spring-Summer stress periods in Alternative 1 was 8,587 and 6,660 acre-feet, respectively.

Direct recharge in the southern area of Alternative 1 was implemented in 18 grid cells in model layer 4, for a total recharge area of 180 acres (i.e., 10 acres per grid cell).

The model results comparing the changes in groundwater levels and storage between the Alternative 1a and the Baseline Condition following stress periods 18, 24, and 34 are shown in Figure 7. Direct recharge in the southern area resulted in groundwater levels in the range of 50 to 100 feet higher than would otherwise be observed without the recharge project. As expected, the increased groundwater levels are centered about the recharge cells corresponding to the southern recharge site and decrease radially away from the recharge areas. The decrease in the groundwater levels between stress period 18 and stress period 24 reflects the dissipation of the recharged water into the aquifer system towards the Baseline Condition groundwater levels during this 3-year period in which recharge was not active. The subsequent increase in groundwater levels in Alternative 1a relative to the Baseline Condition from stress period 24 to stress period 34 reflects the active recharge operations from stress periods 25-26 and stress periods 29-34.

The Change in Groundwater Storage graph presented in Figure 7 shows the effect of Alternative 1a on the Baseline Condition, and the response of groundwater storage to the seasonal and annual fluctuations of the 17-year simulation period (34 stress periods).

The Cumulative Change in Groundwater Storage Graph for Alternative 1a has a similar shape and magnitude to the recharge-only schedule curve that is also displayed in Figure 7, demonstrating that much of the recharged water remains in the basin as groundwater storage. Of the total recharge amount of 162,000 acre-feet implemented over the 34 stress periods, approximately 131,400 acre-feet (about 81 percent) of this amount is reflected in increased groundwater storage (Table 2).

The remaining 30,600 acre-feet (about 19 percent) of the recharged water discharges from the aquifer system to the stream network and leaves the area as stream outflow (Figure 7 and Table 2). Increases in evapotranspiration losses and subsurface outflows through the boundary conditions relative to the Baseline Condition were not significant for Alternative 1a.

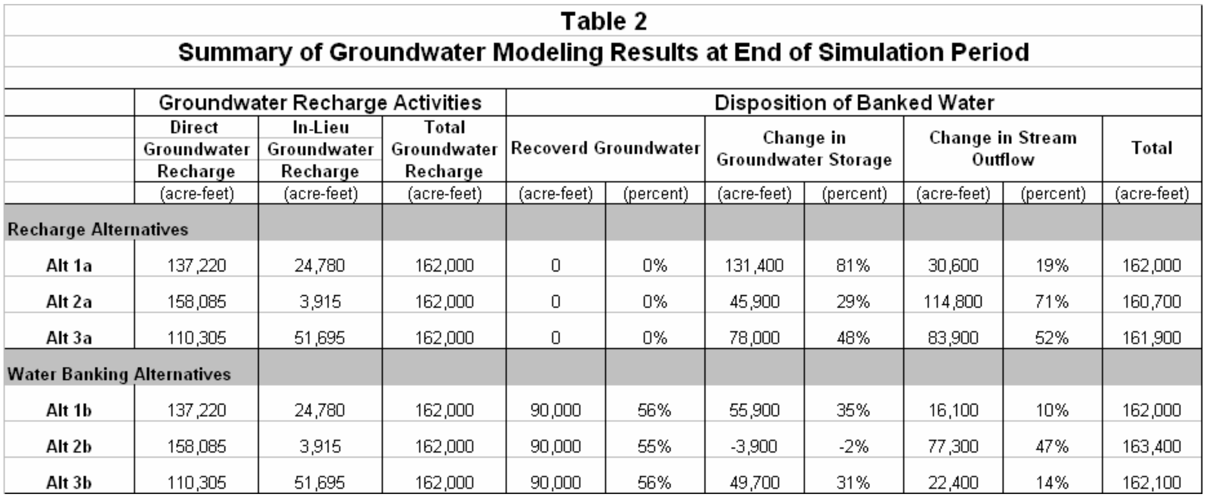


Table 2

Summary of Groundwater Modeling Results at End of Simulation Period

	Groundwater Recharge Activities			Disposition of Banked Water						
	Direct Groundwater Recharge	In-Lieu Groundwater Recharge	Total Groundwater Recharge	Recoverd Groundwater		Change in Groundwater Storage		Change in Stream Outflow		Total
	(acre-feet)	(acre-feet)	(acre-feet)	(acre-feet)	(percent)	(acre-feet)	(percent)	(acre-feet)	(percent)	(acre-feet)
Recharge Alternatives										
Alt 1a	137,220	24,780	162,000	0	0%	131,400	81%	30,600	19%	162,000
Alt 2a	158,085	3,915	162,000	0	0%	45,900	29%	114,800	71%	160,700
Alt 3a	110,305	51,695	162,000	0	0%	78,000	48%	83,900	52%	161,900
Water Banking Alternatives										
Alt 1b	137,220	24,780	162,000	90,000	56%	55,900	35%	16,100	10%	162,000
Alt 2b	158,085	3,915	162,000	90,000	55%	-3,900	-2%	77,300	47%	163,400
Alt 3b	110,305	51,695	162,000	90,000	56%	49,700	31%	22,400	14%	162,100

4.5.1.2 Alternative 1b: Water Banking Scenario

Alternative 1b involves the implementation of the water banking schedule (Figure 2) in and around the southern recharge site in the Shell Creek/Camatta Creek area (Figure 4). The water banking schedule includes both direct and in-lieu recharge operations according to the recharge schedule used for Alternative 1a as well as recovery operations during stress periods when recharge operations are not active (see Table 1 and Figure 2). The recharge operations for Alternative 1b are identical to those implemented in Alternative 1a.

For Alternative 1b, a total of 8 recovery wells were implemented in the model with a combined extraction rate of 9,000 acre-feet per stress period (i.e., 1,500 acre-feet per month for 6 months) for stress periods when recharge operations are active.

Maps displaying the differences in simulated groundwater levels in model layer 4 between Alternative 1b and the Baseline Condition following stress periods 18, 24, and 34 are presented in Figure 8. At the end of stress period 18 after a three-year recharge operation, regional groundwater levels in Alternative 1b were as high as 50 to 100 feet more than would otherwise be observed if there were no recharge project.

At the end of stress period 24 after a three-year recovery-only operation, the differences in groundwater levels between Alternative 1b and the Baseline Condition ranged from 100 feet lower to 25 feet higher than would otherwise be observed without the recharge and recovery project (Figure 8). After stress period 24, groundwater levels in Alternative 1b were generally less than those of the Baseline Condition in the vicinity of the recovery well field; however, groundwater levels for Alternative 1b remained higher in other areas near the recharge site where recovery wells were not present. At the end of stress period 34 after another three-year recharge operation, the differences in groundwater levels between Alternative 1b and the Baseline Condition ranged from about equal to the Baseline Condition (that is no overall groundwater level increase or decline) to as much as 100 feet higher than would otherwise be observed without the project (Figure 8).

Generally, groundwater level differences after stress period 34 were similar to those differences following stress period 24. Overall, the highest positive differences in groundwater levels for Alternative 1b over the Baseline Condition occurred after the three-year recharge operations (i.e., stress periods 13-18 and stress periods 29-34); while the highest negative differences occurred after the three-year recovery operation (i.e., stress periods 19-24).

A plot of the increase in groundwater storage for Alternative 1b above the Baseline Condition over the 34 stress periods is also presented in Figure 8. The cumulative storage change curve over the 34 stress periods is similar in shape to the water banking schedule curve that is also displayed in Figure 8. At the end of stress period 34, the water banking operation had extracted 90,000 acre-feet of groundwater; groundwater storage had increased by about 55,900 acre-feet above the Baseline Condition; and 16,100 acre-feet of groundwater above the Baseline Condition discharged to the stream network and left the basin as stream outflow as shown on Table 2 (i.e., 90,000 + 55,900 + 16,100 = 162,000 acre-feet of total recharge over the 34 stress periods according to the recharge schedule).

Increases in evapotranspiration losses and subsurface outflows through the boundary conditions relative to the Baseline Condition were not significant for Alternative 1b.

4.5.2 Alternative 2 - Creston Recharge Area

4.5.2.1 Alternative 2a: Recharge-only Scenario

Alternative 2a involves the implementation of the recharge-only schedule in the Creston recharge area (Figure 5). The allotments of direct recharge and in-lieu recharge for each stress period are presented in Table 1. The total in-lieu recharge potential for the Fall-Winter and Spring-Summer stress periods in Alternative 2 are 65 and 370 acre-feet, respectively, or 0.7 percent and 4 percent of the 9,000 acre-feet of water available for recharge during active recharge stress periods. The remaining water available for direct recharge during the Fall-Winter and Spring-Summer stress periods in Alternative 2 was 8,935 and 8,630 acre-feet, respectively.

Direct recharge in the Creston area was implemented in 9 grid cells in model layer 4, for a total recharge area of 90 acres (i.e., 10 acres per grid cell). Maps displaying the differences in simulated groundwater levels in model layer 4 between Alternative 2a and the Baseline Condition following stress periods 18, 24, and 34 are presented in Figure 9. Direct recharge in the Creston Area resulted in significant increases in groundwater levels that would likely result in either water ponding at the ground surface or artesian conditions in some wells. As expected, the increased groundwater levels centered about the recharge cells corresponding to the Creston recharge area and decreased in the northern direction from these recharge cells (Figure 9).

As with Alternative 1a, the decrease in the groundwater level rise between stress period 18 and stress period 24 reflects the recovery of the aquifer system towards the Baseline Condition groundwater levels during this three-year period in which recharge was not active. The subsequent increase in groundwater levels in Alternative 2a relative to the Baseline Condition from stress period 24 to stress period 34 reflects again the active recharge operations from stress periods 25-26 and stress periods 29-34.

The Change in Groundwater Storage graph presented in Figure 9 shows the effect of Alternative 2a on the Baseline Condition, and the response of groundwater storage to the seasonal and annual fluctuations of the 17-year simulation period (34 stress periods).

The Cumulative Change in Groundwater Storage Graph for Alternative 1a has a similar shape and magnitude to the recharge-only schedule curve that is also displayed in Figure 9, demonstrating that much of the water recharged remains in the basin as groundwater storage. Of the total recharge amount of 162,000 acre-feet implemented over the 34 stress periods, approximately 45,900 acre-feet (about 28 percent) of this amount is reflected in increased groundwater storage (Table 2).

The remaining 114,800 acre-feet (about 71 percent) of the recharged water discharges from the aquifer system to the stream network and leaves the area as stream outflow (Figure 9 and Table 2). Increases in evapotranspiration losses and subsurface outflows through the boundary conditions relative to the Baseline Condition were not significant for Alternative 2a.

4.5.2.2 Alternative 2b: Water Banking Scenario

Alternative 2b involves the implementation of the water banking schedule (Figure 2) in and around the Creston recharge area (Figure 5). The water banking schedule includes both direct and in-lieu recharge operations according to the recharge schedule used for Alternative 2a as well as recovery operations during stress periods when recharge operations are not active. The recharge operations for Alternative 2b are identical to those implemented in Alternative 2a. In the water banking scenario, recharge operations and recovery operations do not occur during the same stress periods but instead alternate according to the water banking schedule.

For Alternative 2b, a total of 33 recovery wells were implemented in the model with a combined extraction rate of 9,000 acre-feet per stress period (i.e., 1,500 acre-feet per month for six months). The locations of the recovery wells are displayed in Figure 10. In the model, four recovery wells were placed just east of the grid cells representing the Creston recharge area, one was placed to the west of the recharge cells, and the remaining 29 recovery wells were placed north of these recharge grid cells in the down-gradient direction.

The recovery wells were placed in and around the area in which significant groundwater level rises were observed in Alternative 2a following stress periods 18 and 34 (Figure 9).

Plan view maps displaying the differences in simulated groundwater levels in model layer 4 between Alternative 2b and the Baseline Condition following stress periods 18, 24, and 34 are presented in Figure 10. At the end of stress period 18, groundwater levels were significantly higher than the Baseline Condition, which would likely result in either ponding at the ground surface or artesian conditions in some wells.

At the end of stress period 24, the recovery effects would likely result in groundwater levels several tens of feet lower than would otherwise be observed without the recharge and recovery project.

At the end of stress period 34, the groundwater levels would likely recover in the southern portion of the area where direct recharge occurs, but water levels would still be significantly lowered in the northern and eastern part of the area as a result of the earlier groundwater recovery operations.

Generally, groundwater level differences after stress period 34 were similar to that following stress period 24 in and around the immediate recharge area. However, groundwater levels further north from the recharge area after stress period 34 have not recovered to the levels experienced after the three-year recharge period following stress period 18. Overall, the highest positive differences in groundwater levels for Alternative 2b over the Baseline Condition occurred after the three-year recharge operations (i.e., stress periods 13-18 and stress periods 29-34) in the immediate Creston recharge area, while moderate negative differences persisted elsewhere at the end of the 34 stress periods due to delayed recovery of groundwater levels.

A plot of the increase in groundwater storage for Alternative 2b above the Baseline Condition over the 34 stress periods is also presented in Figure 10. The cumulative storage change curve over the 34 stress periods bears a similar shape to the water banking schedule curve although the two curves diverge significantly by the end of the 34 stress periods because of the continued loss of recharge water in the streams and the inability of the aquifer to absorb the volume of the recharge project. At the end of stress period 34, the water banking operation had extracted 90,000 acre-feet of groundwater; groundwater storage had decreased by 3,900 acre-feet below the Baseline Condition; and 77,300 acre-feet of groundwater above the Baseline Condition discharged to the stream network and left the area as stream outflow. Increases in evapotranspiration losses and subsurface outflows through the boundary conditions relative to the Baseline Condition were not significant for Alternative 2b.

4.5.3 Alternative 3 - Salinas River/Highway 46 Recharge Area

4.5.3.1 Alternative 3a: Recharge-Only Scenario

Alternative 3a involves the implementation of the recharge-only schedule in the Salinas River/Highway 46 recharge area (Figure 6). The allotments of direct recharge and in-lieu recharge for each stress period are presented in Table 1. The total in-lieu recharge potential for the Fall-Winter and Spring-Summer stress periods in Alternative 3 are 926 and 4,818 acre-feet, respectively, or 10 percent and 54 percent of the 9,000 acre-feet of water available for recharge during active recharge stress periods. The remaining water available for direct recharge during the Fall-Winter and Spring-Summer stress periods in Alternative 3 was 8,074 and 4,182 acre-feet, respectively. Direct recharge in the Salinas River/Highway 46 area was implemented in 9 grid cells in model layer 1, for a total recharge area of 90 acres (i.e., 10 acres per grid cell).

The model results comparing the changes in groundwater levels and storage between the Alternative 3a and the Baseline Condition is shown in Figure 11 for layer 4 and Figure 12 for layer 1.

In general, the highest groundwater levels increases in model layer 4 centered about the Salinas River recharge cells and the in-lieu recharge areas to the northwest and decreased radially away from the middle regions of these areas (Figure 12). As with Alternatives 1a and 2a, the decrease in the groundwater level rise between stress period 18 and stress period 24 reflects the recovery of the aquifer system towards the Baseline Condition groundwater levels during this three-year period in which recharge was not active. The subsequent increase in groundwater levels in Alternative 3a relative to the Baseline Condition from stress period 24 to stress period 34 reflects again the active recharge operations from stress periods 25-26 and stress periods 29-34.

A plot of the increase in groundwater storage for Alternative 3a above the Baseline Condition over the 34 stress periods is also presented in Figure 11.

The cumulative storage change curve retains a similar shape to the recharge-only schedule curve over the 34 stress periods.

The impacts of Alternative 3a on stream outflow, evapotranspiration losses, boundary condition outflows, and overall groundwater storage relative to Baseline Condition are presented in Table 2.

Of the total recharge amount of 162,000 acre-feet implemented over the 34 stress periods, approximately 78,000 acre-feet (about 48 percent) of this amount is reflected in increased groundwater storage (Figure 11).

The remaining 83,900 acre-feet of the recharge discharges from the aquifer system to the stream network and leaves the area as stream outflow.

As with Alternatives 1a and 2a, increases in evapotranspiration losses and subsurface outflows through the boundary conditions relative to the Baseline Condition were not significant for Alternative 3a.

4.5.3.2 Alternative 3b: Water Banking Scenario

Alternative 3b involves the implementation of the water banking schedule (Figure 2) in and around the Salinas River/Highway 46 recharge area (Figure 6). The water banking schedule includes both direct and in-lieu recharge operations according to the recharge schedule used for Alternative 3a as well as recovery operations during stress periods when recharge operations are not active (see Table 1 and Figure 2). The recharge operations for Alternative 3b are identical to those implemented in Alternative 3a. In the water banking scenario, recharge operations and recovery operations do not occur during the same stress periods but instead alternate according to the water banking schedule shown in Figure 2 and in Table 1.

For Alternative 3b, a total of 17 recovery wells were implemented in the model with a combined extraction rate of 9,000 acre-feet per stress period (i.e., 1,500 acre-feet per month for 6 months) for stress periods when recharge operations are active. The locations of the recovery wells are displayed in Figure 13. The 13 recovery wells in the Salinas River recharge area accounted for 87 percent of the total extraction rate of 9,000 acre-feet per stress period and the 4 recovery wells placed in the in-lieu recharge area accounted for the remaining 13 percent of the total extraction.

Maps displaying the differences in simulated groundwater levels in model layer 4 between Alternative 3b and the Baseline Condition following stress periods 18, 24, and 34 are presented in Figure 13. At the end of stress period 24, water levels in the in-lieu area would approach the levels expected in the Baseline Condition. However, as noted previously, only 13 percent of the total recovery extraction occurs in the four recovery wells associated with the in-lieu recharges area, subsequently mitigating the drawdown of groundwater levels there during recovery periods. Groundwater levels in the Salinas River Area, however, would likely be depressed and might reflect a condition were not all the water could be recovered due to declining water levels.

At the end of stress period 34 the difference in groundwater levels would again increase significantly because of the direct and in-lieu recharge programs. Generally, groundwater level differences in and around both the Salinas River recharge area and the in-lieu recharge area after stress period 34 were similar to those following stress period 24. Groundwater levels further north from the Salinas River recharge area after stress period 34 have not completely recovered to the levels experienced after the three-year recharge period following stress period 18 (Figure 13). Overall, the highest positive differences in groundwater levels for Alternative 3b over the Baseline Condition occurred after the three-year recharge operations (i.e., stress periods 13-18 and stress periods 29-34) in the in-lieu recharge area, with moderate positive differences occurring around the Salinas River recharge area.

A plot of the increase in groundwater storage for Alternative 3b above the Baseline Condition over the 34 stress periods is also presented in Figure 13. Overall, the cumulative storage change curve for Alternative 3b retains a similar shape to the water banking schedule curve over the 34 stress periods (Figure 13). At the end of stress period 34, the water banking operation had extracted 90,000 acre-feet of groundwater; groundwater storage had increased by 49,700 acre-feet above the Baseline Condition; and 22,400 acre-feet of groundwater above the Baseline Condition discharged to the stream network and left the basin as stream outflow. Increases in evapotranspiration losses and subsurface outflows through the boundary conditions relative to the Baseline Condition were not significant for Alternative 3b.

4.6 Summary of Hydrogeologic Feasibility Analysis

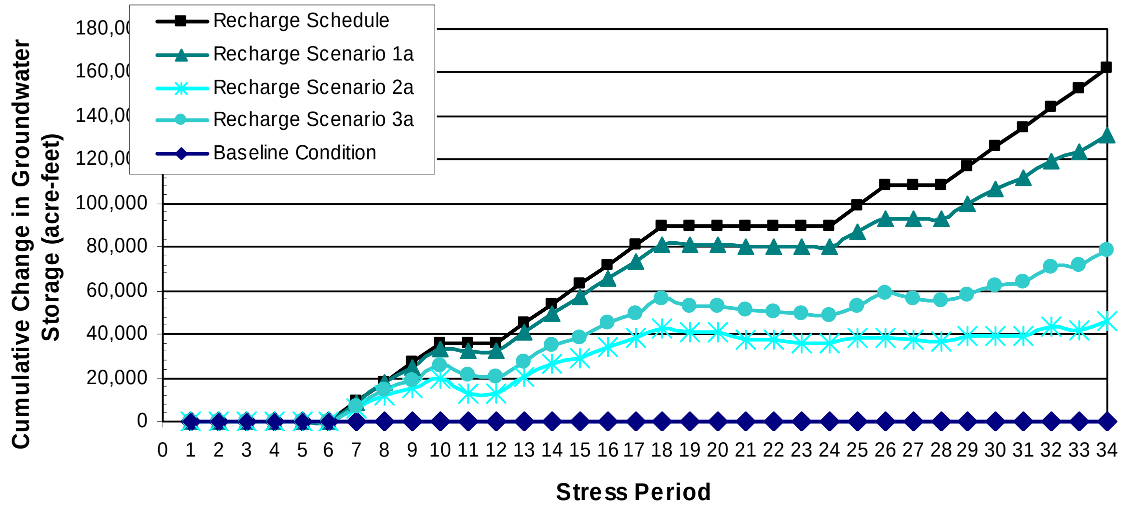
In Section 4, recharge and water banking scenarios were simulated in the three alternative areas using the numerical groundwater model by implementation of the recharge and recovery schedules presented in Figure 2. The impacts of these scenarios were evaluated by comparing their results against those of the Baseline Condition (i.e., the “no action” scenario of no recharge and no recovery operations in the same 34 stress periods). For the recharge-only scenarios (i.e., Alternatives 1a, 2a, and 3a), a total of 162,000 acre-feet of SWP water was applied over the 34 stress periods. For each stress period in which recharge operations were active, a total of 9,000 acre-feet of SWP water was applied as either direct recharge in the simulated pond areas or as in-lieu recharge in agricultural areas identified as having in-lieu recharge potential. For the water banking scenarios (i.e., Alternatives 1b, 2b, and 3b), 162,000 acre-feet of SWP water was also applied over the 34 stress periods according to the recharge-only schedule and a total of 90,000 acre-feet of groundwater was recovered (via extraction wells) according to the water banking schedule (Figure 2). The impacts on basin groundwater levels and storage from the recharge and water banking operations in the three alternative areas relative to the Baseline Condition were presented in Figures 7 through 13 and Tables 1 and 2. The overall results of the recharge and water banking scenarios summarized in Table 2 are discussed below.

4.6.1 Summary of Recharge Alternatives

Over the 34 stress periods of the model simulation period, a total of 162,000 acre-feet of SWP water was recharged in each of Alternatives 1a, 2a, and 3a. Relative to the Baseline Condition, the 162,000 acre-feet of recharge in each alternative resulted in changes in groundwater storage, stream outflows, evapotranspiration losses, subsurface flows across constant head boundaries, and subsurface flows across general-head boundaries. Recharge impacts on these groundwater mass balance components differed between alternatives as a function of their differing local aquifer characteristics (e.g., layer thicknesses, hydraulic conductivities); proximity of direct recharge areas to local streams; existing groundwater pumping operations in each area; locations of in-lieu recharge areas relative to direct recharge areas; distribution of recharge between direct recharge and in-lieu recharge; and proximity of recharge areas to constant-head and general-head boundaries.

Of the 162,000 acre-feet of SWP water recharged in Alternative 1a, groundwater storage increased by 131,400 acre-feet (about 81 percent), stream outflows increased by 30,600 acre-feet (about 29 percent), and increased losses through evapotranspiration and other boundary conditions were negligible (less than 1 percent). For Alternative 2a, groundwater storage increased by 45,900 acre-feet (about 28 percent), stream outflows increased by 114,800 acre-feet (about 71 percent), and increased losses through evapotranspiration, constant-head boundaries, and general-head boundaries were about 1,400 acre-feet (about 1 percent). For Alternative 3a, groundwater storage increased by 78,000 acre-feet (about 48 percent), stream outflows increased by 83,900 acre-feet (about 52 percent), and increased losses through evapotranspiration, constant-head boundaries, and general-head boundaries were negligible (less 1 percent). Overall, Alternative 1a retained the greatest volume of the recharge in groundwater storage at the end of the 34 stress periods, followed by Alternative 3a and then by Alternative 2a (Figure 14). For each of Alternatives 1a, 2a, and 3a, the most significant losses of groundwater in the system resulting from recharge-only operations was due to stream outflows in the basin. As shown in Figure 15, Alternatives 2a and 3a had the greatest losses to stream outflows. Losses of groundwater resulting from the recharge-only operations through evapotranspiration, constant-head boundary conditions, and general-head boundary conditions were relatively minor.

Figure 14 - Cumulative Change in Groundwater Storage



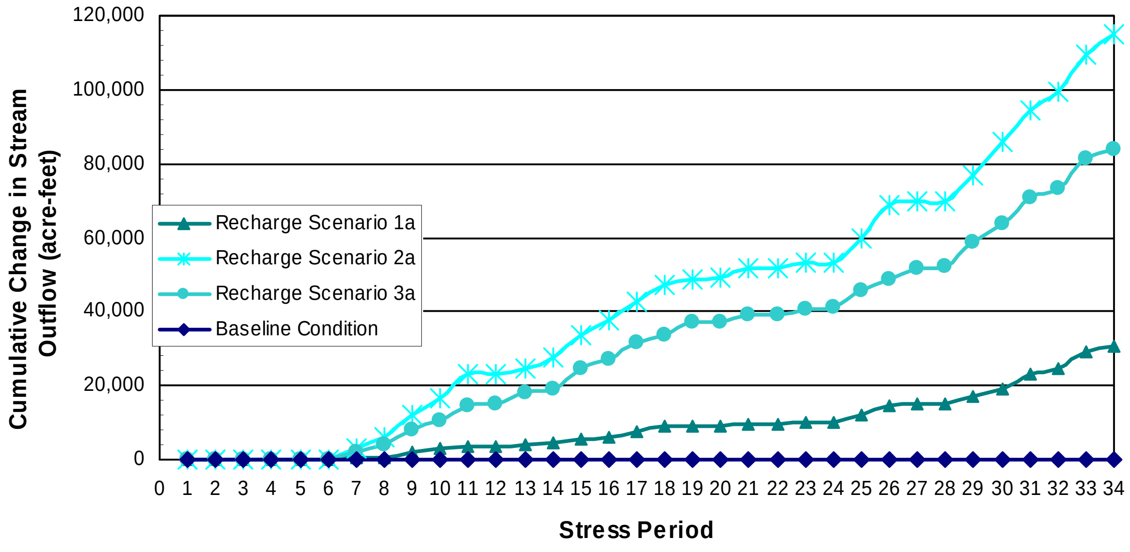


Figure 15- Cumulative Change in Stream Outflow

In each alternative, direct recharge in ponds close to local streams no doubt resulted in greater stream flow losses than if the ponds were located in areas away from streams. Losses through stream outflows for Alternative 3a were likely mitigated during the Spring-Summer stress periods when recharge operations were active due to the high allocation of SWP water (54 percent) to in-lieu recharge in the area northeast of the Salinas River/Highway 46 direct recharge site. Relatively high in-lieu recharge allocations of SWP water (26 percent) for Alternative 1a during the Spring-Summer stress periods may have also mitigated against greater stream outflow losses in that area as well. However, for Alternative 2a, where stream outflows were highest amongst the three alternatives, in-lieu recharge only accounted for 4 percent of the total recharge during the Spring-Summer stress periods when recharge operations were active.

These results suggest that both the location of direct recharge sites and the amount of in-lieu recharge significantly impact the amount of recharge that is retained within groundwater storage.

4.6.2 Summary of Water Banking Alternatives

Over the 34 stress periods of the model simulation period, a total of 162,000 acre-feet of SWP water was recharged in each of Alternatives 1b, 2b, and 3b and a total of 90,000 acre-feet of groundwater was also recovered in each. Consequently, a net recharge amount of 72,000 acre-feet (i.e., 162,000 acre-feet of recharge minus 90,000 acre-feet of recovery) was added to the basin over the 34 stress periods. As with the recharge-only scenario, recharge and recovery impacts on the groundwater mass balance components differed between alternatives as a function of a variety of physical and operational differences.

Of the 72,000 acre-feet of net recharge in Alternative 1b, groundwater storage increased by 55,900 acre-feet, stream outflows increased by 16,100 acre-feet, and changes in evapotranspiration losses and other boundary condition flows were negligible. For Alternative 2b, groundwater storage decreased by 3,900 acre-feet, stream outflows increased by 77,300 acre-feet, constant-head boundary inflows increased by about 1,400 acre-feet, and evapotranspiration losses and flows across general-head boundaries were negligible. For Alternative 3b, groundwater storage increased by 49,000 acre-feet, stream outflows increased by 22,400 acre-feet, constant-head boundary inflows increased by about 100 acre-feet, and evapotranspiration losses and flows across general-head boundaries were negligible.

The implementation of recovery operations in Alternatives 1b and 3b resulted in more similar groundwater storage increases at the end of the 34 stress periods between them than under the recharge-only operations. In other words, implementation of recovery operations significantly reduced the amount of losses through stream outflows in comparison to stream flow losses experienced under the recharge-only operations of Alternatives 1a and 3a. For the water banking scenario, stream flow losses in Alternative 1 decreased from 30,700 acre-feet to 16,100 acre-feet while stream flow losses in Alternative 3 decreased from 83,900 acre-feet to 22,393 acre-feet. Overall, groundwater storage increases in Alternative 1b were 55,900 acre-feet (78 percent of total net recharge) while storage increases in Alternative 3b were 49,700 acre-feet (69 percent of total net recharge). Under the recharge-only scenario, groundwater storage increases for Alternative 3a were only 48 percent of the 162,000 acre-feet of recharge versus 81 percent for Alternative 1a. Recharge and recovery operations for Alternative 2b actually resulted in a decrease in groundwater storage relative to the Baseline Condition after the 34 stress periods. For Alternative 2b, due to timing and the locations of the recharge operations, most of the recharge was lost from the area as stream outflow and the extraction wells subsequently mined the “native” groundwater (i.e., groundwater storage prior to implementation of recharge) thereby reducing groundwater storage below the Baseline Condition levels.

Overall, Alternatives 1b and 3b yielded potentially favorable recharge and recovery results while Alternative 2b performed relatively poorly based on changes in groundwater storage (Figure 16) and changes in stream outflow (Figure 17). The success of a recharge and recovery program is dependent on the timing, location, and magnitude of application of the recharge. As with the recharge-only scenario, the use of in-lieu recharge can significantly mitigate against the losses of recharge from the system through streams and other boundary conditions located in proximity to the direct recharge sites.

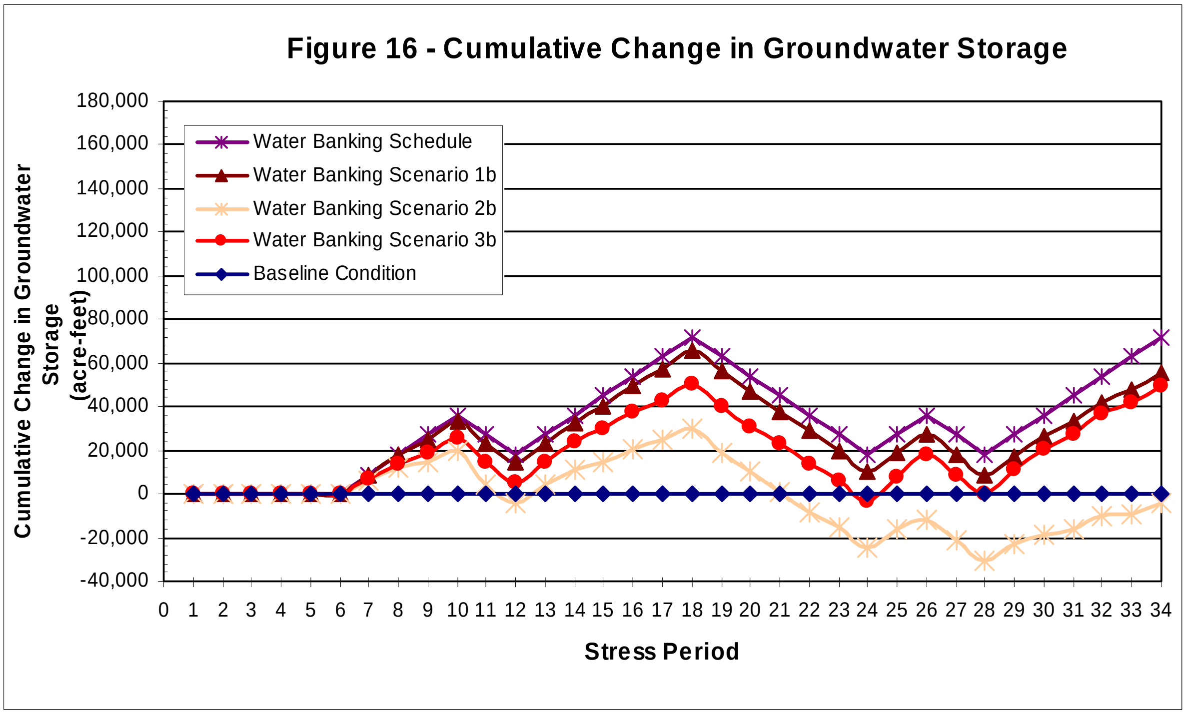


Figure 16 - Cumulative Change in Groundwater Storage

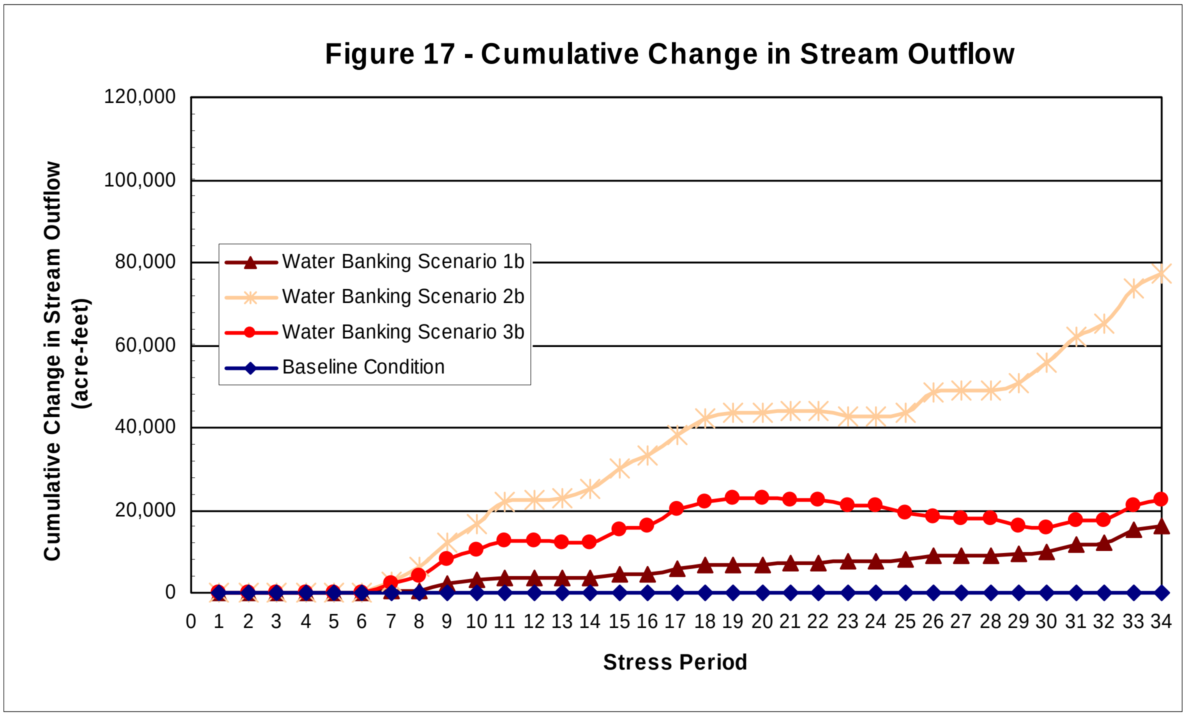


Figure 17 - Cumulative Change in Stream Outflow

4.6.3 Initial Findings and Recommendations

Based upon the hydrogeologic feasibility analysis completed as part of this analysis:

- Alternative 1 appears to have adequate groundwater storage capacity, and recharge and recovery capacity to support a water banking project. Additional analysis may be needed to refine project size and operations to reduce losses to the stream system and reduce the groundwater recovery impacts.
- Alternative 2 does not appear to have adequate groundwater storage capacity, and recharge and recovery capacity to support a water banking project.
- Alternative 3 appears to have adequate groundwater storage capacity, and recharge and recovery capacity to support a water banking project. The in-lieu recharge component along Highway 46 west of Whitley Gardens appears to provide a considerable recharge opportunity. The direct recharge and recovery operations along the Salinas River may prove problematic because the interconnectivity of the alluvial deposits with the river may reduce ability to recover the recharged water, resulting in the decline of groundwater levels in the main aquifer system as a result of increased pumping associated with the project. This area is also relied upon by existing municipal groundwater users. Additional analysis may be needed to refine project operations in this portion of the basin to further investigate the benefit of in-lieu recharge opportunities in recharge or water banking operations.

These finding and recommendations will be updated as additional information becomes available during this project and presented in the final report.

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