Southern California Steelhead Passage Assessment, Lower Santa Margarita River, California and CUP Surface Water Availability Analysis (TM 1.1)

Appendix D

Model Descriptions:
Reservoir Operations Model
LSMR Model

EXCERPT FROM March 2001 Permit 15000 Study - Some Values have been UPDATED. To be used for description of Reservoir Operation Model (ROM) only.

E.3 RESERVOIR OPERATIONS

The scope of this analysis is to address multiple scenarios for diverting water from the Santa Margarita River for use on Camp Pendleton. The goal is to maximize the amount of water diverted from the Santa Margarita River under the permitted water rights. The surface water analysis is based on general principals of hydrology and hydraulics. This baseline data and format for simulating streamflow for each alternative is laid out at the beginning of this section. A more detailed description of each alternative and the monthly results follows.

There is an established point of diversion to Lake O'Neill and the five existing recharge ponds, below where the De Luz Creek tributary enters the Santa Margarita River. Currently, the system diverts water from the Santa Margarita River at an average flow of 60 cfs. Stetson Engineers is seeking to improve the diversion at this point by increasing the diversion capacity of the channel, enlarging the volume of the recharge ponds, and/or providing additional reservoirs for off-stream storage.

Stetson Engineers has explored four alternatives to improve Camp Pendleton's existing diversion capabilities. A MODFLOW ground-water model ran multiple simulations for each alternative to explore how different hydrologic factors would affect the ground-water system. A reservoir operations model was constructed to supply input for the ground-water model, while also providing a balanced water budget for Lake O'Neill and the recharge ponds.

The reservoir operations model was used to estimate the rate of diversion from the Santa Margarita River to both the recharge ponds and Lake O'Neill. The model used 1980 to 1999 hydrology in order to construct streamflow at a point below the confluence of De Luz Creek and the Santa Margarita River. Applying daily estimates of streamflow and historical measurements of precipitation and evaporation, the reservoir operations model was used to predict the daily diversion during the historical period.

E.3.1 LAKE O'NEILL

Lake O'Neill is a 1,200 acre-foot reservoir located on Fallbrook Creek, a minor tributary of the Santa Margarita River. Most of the water stored in the lake is diverted from the nearby Santa Margarita River. The dam creating Lake O'Neill and the diversion ditch from the Santa Margarita River were constructed in 1883 as part of the farm irrigation system. Since acquisition by the U.S. Government for Camp Pendleton, Lake O'Neill has been used for recreation, training purposes, and subsequent ground water recharge (Leedshill and Herkenhoff, 1988).

E.3.2 RECHARGE PONDS

There are five recharge ponds located off the diversion channel from the Santa Margarita River. These ponds permit water to recharge the ground-water system. The reservoir operations model calculates the daily flow of water into the recharge ponds, the net effect of precipitation and evaporation, the volume of water infiltrating into the ground, and finally the volume of water, which spills out of the last pond. These calculations provide input for MODFLOW, which then simulates the path of the recharged water once it infiltrates below the surface.

E.3.3 DIVERSION CAPACITY

The diversion capacity is defined by the amount of water that can be directed into the O'Neill ditch based on the available streamflow in the Santa Margarita River, defined bypass flow, and diversion capacity. The available streamflow is the calculated or calibrated values at the diversion structure for the period of record minus the defined bypass flow of 3 cfs. No water may be diverted from the Santa Margarita River if the flow in less than 3 cfs, and for all other flows at least 3 cfs must be bypassed around the diversion structure. There are two existing water diversion rights.

1) The Pre-1914 Water Right allows for 1,100 AFY of storage plus 100 AFY of dead storage and 400 AFY of evaporation and seepage from Lake O'Neill. The total diversion right is for 1,500 AFY at a maximum diversion rate of 20 cfs. The diversion period is between April 1st and October 31st although the Base and FPUD have an agreement that allows for diversion from November 1st through March 31st.

2) Permit 15000 License 10494 allows for 4000 AFY to be collected in the underground storage reservoir by way of the percolation ponds and the natural channel of the river. The existing system can divert a maximum of 60 cfs, but by improving the existing constrictions, this capacity could be greatly increased. The permitted diversion period is between October 1st and June 30th.

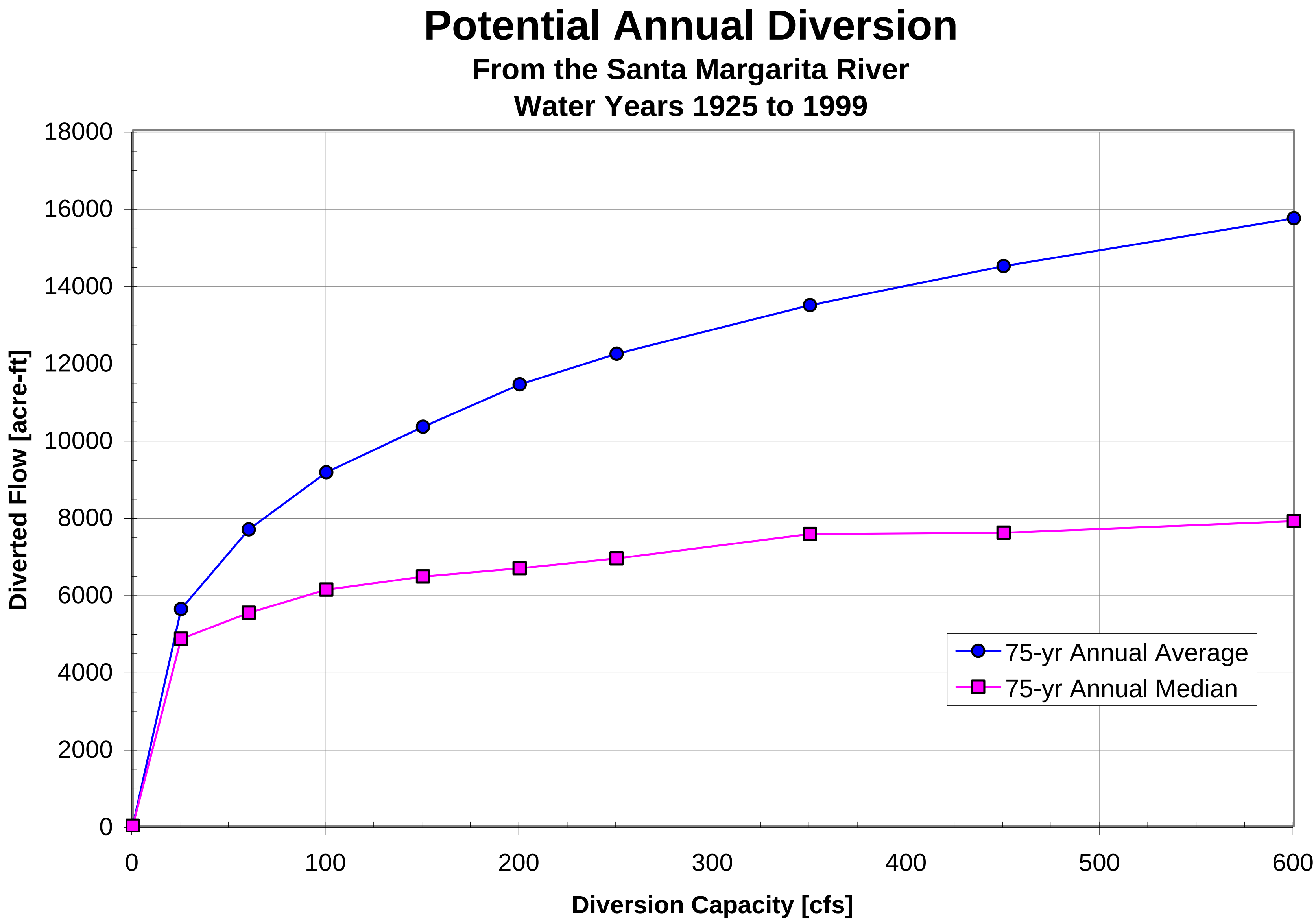
Since one of the goals of the study is to find the optimal scenario for diverting water from the Santa Margarita River year round, a range of capacities for the diversion channel were explored. At present, the bottleneck in the diversion system is the road crossing downstream of the headgate. It is feasible to redesign the road crossing to handle a higher flow capacity. Ten scenarios were investigated to simulate the quantity of water that could be diverted from the historical streamflow in the Santa Margarita River for water years 1925 to 1999 based on channel capacities equal to 25, 60, 100, 150, 200, 250, 350, 450, and 600 cfs. For each year the total annual flow was calculated, along with the total, median, and mean divertable flow for each scenario. It was also noted the number of days when the channel was running at full capacity. For the 75-year period of record, the total, minimum, maximum, mean and median flow were tabulated for each scenario. Table E-9 shows the summary for the 75-year period of record for each channel capacity.

TABLE E-9: SUMMARY OF ANNUAL DIVERSION POTENTIAL FOR VARIOUS DIVERSION CAPACITIES

Water Years 1925 - 1999			Diversion Capacity (cfs)								
Diversion Potential	Unit	Santa Margarita River Flow	25 cfs	60 cfs	100 cfs	150 cfs	200 cfs	250 cfs	350 cfs	450 cfs	600 cfs
75-yr Annual Average	(AF)	30,474	5,614	7,672	9,150	10,332	11,421	12,218	13,477	14,488	15,723
75-yr Annual Median	(AF)	12,246	4,845	5,511	6,110	6,451	6,667	6,920	7,552	7,588	7,886
# of Days Flow >= Diversion Capacity	(AF)	N/A	3,316	1,715	2,470	831	671	559	424	356	283

*** See Attachment E-3 for table of annual results**

Figure E-3 illustrates the annual diversion potential for the range of capacities studied. Based on the median of a 75-yr potential annual diversion analysis for the range of diversion



Potential Annual Diversion
From the Santa Margarita River
Water Years 1925 to 1999
Diverted Flow [acre-ft]
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
100
200
300
400
500
600
Diversion Capacity [cfs]
75-yr Annual Average
75-yr Annual Median

FIGURE E-3

capacities, it was found that 200 cfs represented the optimal diversion capacity. Furthermore, a 200 cfs canal capacity minimizes the spill from the last recharge pond, while maximizing the recharge to the ground-water basin.

A more detailed analysis was performed by dividing the 75 year period of record into wet and dry years. An annual frequency distribution diagram was created base on the USGS Gorge gage (44000) for water years 1925 to 1999. Wet years were defined as years where the total flow has <18% occurrence. Dry years were defined as years where the total flow has a >85% occurrence. The previously described procedures and statistics were replicated for wet and dry years to refine the optimization process. In essence, it would be advantageous to divert large amounts of water during wet years so that the subsequent dry years will be adequately compensated by the surplus storage.

Another pertinent question relates to the current capacity of the channel. This was explored using actual data from the Camp Pendleton gage. The actual channel flow was computed as the sum of the flow diverted to the recharge/spreading ponds plus the flow diverted to Lake O'Neill. Annual diversions to Lake O'Neill and the recharge ponds can be seen in Table E-10.

together because the time of concentration for the peak pulse to pass through each watershed to a defined point will be very different.

Looking at the 15-minute hydrograph for recent storms in March 1991, March 1995, and January 1995 the known peaks and their corresponding daily means were used to calculate a peak:mean ratio. A mean flow value that will cause the dam to collapse can be determined based on this ratio. Since this method has the potential to both under-estimate and over-estimate the number of days when the dam will collapse, three ratios were evaluated for the period of record (Table E-11).

TABLE E- 11: RELATION OF INSTANTANEOUS PEAK TO DAILY MEAN

peak:mean (-)	Peak flow to deflate dam (10-year Storm) Q_{peak} (cfs)	Mean flow to deflate dam Q_{mean} (cfs)	
5:1	18,000	3,600	Most Conservative
3.5:1	18,000	5,143	
2.5:1	18,000	7,200	Least Conservative

It was assumed that the Obermeyer dam would be deflated to let the 10-yr flow, with an instantaneous peak of 18,000 cfs, pass over the structure. A peak to mean ratio of 5:1 was used to be conservative. Thus, on any day when the flow in the Santa Margarita River was greater than 3,600 cfs, the Obermeyer dam would deflate and do water would be diverted. This condition was applied to Alternatives 2, 3, and 4 to represent the most conservative case.

E.3.5 PRECIPITATION

The daily precipitation values used in the SCS-Curve Number method for streamflow and runoff were also used in the reservoir operations analysis. Hourly data from the Oceanside rainfall gage in southern California was used as the primary source of data. Data sets were obtained from the Desert Research Institute (DRI). There was missing data for random months in 1984, 1989, 1993, 1994, and 1998. For these days, daily rainfall, also from Oceanside (DRI), was used. Monthly precipitation values at Oceanside are shown in Attachment E-1.

E.3.6 EVAPORATION

Evaporation removes water from the surface area of an open body of water. These monthly values were applied on a daily basis to the surface area of Lake O'Neill and the recharge ponds. The consumptive use rates (Table E-12), for water surface evaporation, were taken from 'Addendum to DRAFT Technical Memorandum dated April 11, 1995' 4/25/95 (Stetson Engineers).

TABLE E- 12: EVAPORATION RATES

MONTH	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
In/month	2.31	2.92	4.06	4.94	5.87	6.37	6.99	6.75	5.62	4.03	2.70	2.15	**54.71**
in/day	0.07	0.10	0.13	0.16	0.19	0.21	0.23	0.22	0.19	0.13	0.09	0.07	**1.80**

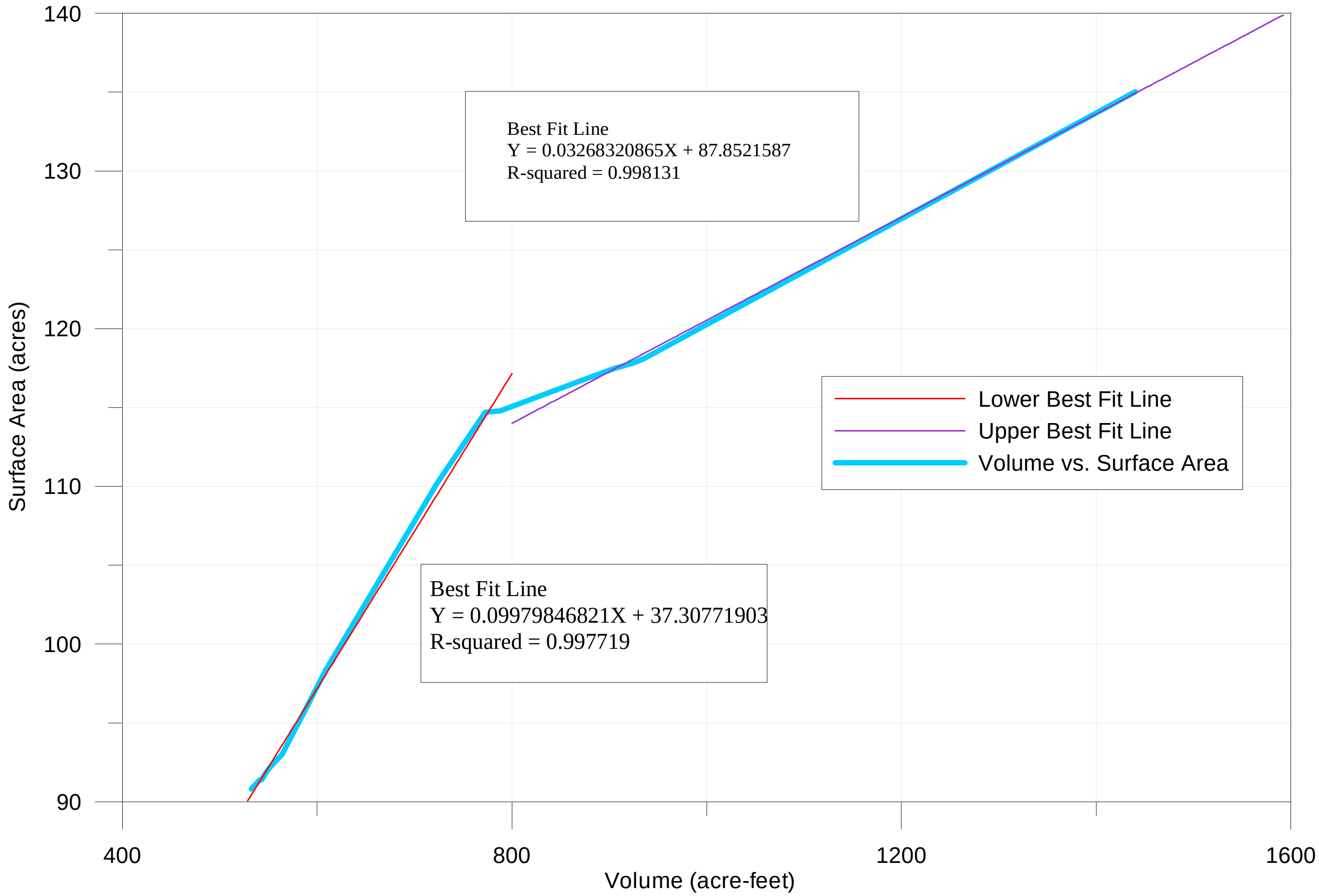
The evaporation rate for each month was applied to the surface area of each pond. The ponds are assumed to be rectangular in shape, such that at any depth the surface area is constant. The evaporative loss for the ponds was calculated on a daily basis based on the availability of water in the ponds and the precipitation falling on that day.

The surface area of Lake O'Neill changes with the daily depth of water. Actual data from the Public Works Survey Department at Camp Pendleton (Drawing # 10601), following a 1977 Dredging Survey, was used to construct a graph of Volume vs. Surface Area (Figure E-4). A trendline for this graph was used to calculate the volume of loss from evaporation each day, based on the daily changes in the volume of Lake O'Neill.

E.3.7 INFILTRATION RATES

The most important attribute of the recharge ponds is the ability of water to infiltrate below the surface to recharge ground water. The reservoir operation model used infiltration rates ranging seasonally from 0.2 to 1.8 feet/day. The infiltration rates for January and June for ponds 1 and 2 are based on the results of an infiltration study conducted by Stetson Engineers. The rates were interpolated between January and June (Table E-13) to reflect the decrease in infiltration rates on spreading systems during periods of continual wetting. After June, no water is diverted to the recharge ponds; thus, the simulated rates remain constant until maintenance in the fall rejuvenates the original infiltration rates. Ponds 3, 4, and 5 were assumed to have slightly higher infiltration rates than ponds 1 and 2, because most of the fine sediment would have already

Volume vs. Surface Area[1] of Lake O'Neill and Best Fit Lines



1. Data based upon maximum surface area and capacity, and values of surface area and capacity from December through May, 2000. Actual data froma Public Works Survey Department at Camp Pendelton (Drawing # 10601), following a 1977 Dredging Survey

FIGURE E-4

settled out in the first two ponds, reducing the risk of clogging in the later ponds. Proposed ponds 6 and 7 were assumed to be as efficient as ponds 3, 4 and 5 by the same reasoning. The ground-water model simulated the conditions below ground surface, to estimate if there would be enough room to store the percolating water. An optimal conjunctive-use-pumping rate was determined such that the storage could handle the influx of water from the recharge ponds.

TABLE E- 13: INFILTRATION RATES (FEET/DAY)

MONTH	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Pond 1	**1.4**	1.40	1.1	0.8	0.5	**0.2**	0.2	0.2	0.2	0.2	1.4	1.4	**9.00**
Pond 2	**1.5**	1.5	1.4	1.2	1.1	**0.9**	0.9	0.9	0.9	0.9	1.5	1.5	**14.10**
Pond 3	1.6	1.6	1.6	1.2	1.1	0.9	0.9	0.9	0.9	0.9	1.5	1.5	**14.55**
Pond 4	1.8	1.8	1.8	1.2	1.1	0.9	0.9	0.9	0.9	0.9	1.5	1.5	**15.15**
Pond 5	1.8	1.8	1.8	1.2	1.1	0.9	0.9	0.9	0.9	0.9	1.5	1.5	**15.15**
TOTAL	**8.1**	**8.1**	**7.7**	**5.6**	**4.7**	**3.8**	**3.8**	**3.8**	**3.8**	**3.8**	**7.4**	**7.4**	**68.0**
Pond 6	1.8	1.8	1.8	1.2	1.1	0.9	0.9	0.9	0.9	0.9	1.5	1.5	**15.15**
Pond 7	1.8	1.8	1.8	1.2	1.1	0.9	0.9	0.9	0.9	0.9	1.5	1.5	**15.15**
TOTAL	**11.7**	**11.7**	**11.3**	**8.0**	**6.8**	**5.6**	**5.6**	**5.6**	**5.6**	**5.6**	**10.4**	**10.4**	**93.8**

E.4 DEVELOPMENT OF ALTERNATIVES

A reservoir operations model was performed for each of the four project alternatives, including a no project alternative. The results are presented below.

E.4.1 ALTERNATIVE 1: NO PROJECT ALTERNATIVE

The reservoir operations model used for Alternative 1 estimated the rate of diversion from the Santa Margarita River to both the recharge ponds and Lake O'Neill. The model used 1980 to 1999 hydrology and future streamflow augmentation in order to construct streamflow at a point below the confluence of De Luz Creek and the Santa Margarita River. Applying daily estimates of streamflow and historical measurements of precipitation and evaporation, the reservoir operations model was used to predict the daily diversion during the historical period. The same model was also used to estimate daily diversion rates in Alternatives 2 through 4, based on improvements and expansion of the existing diversion facilities.

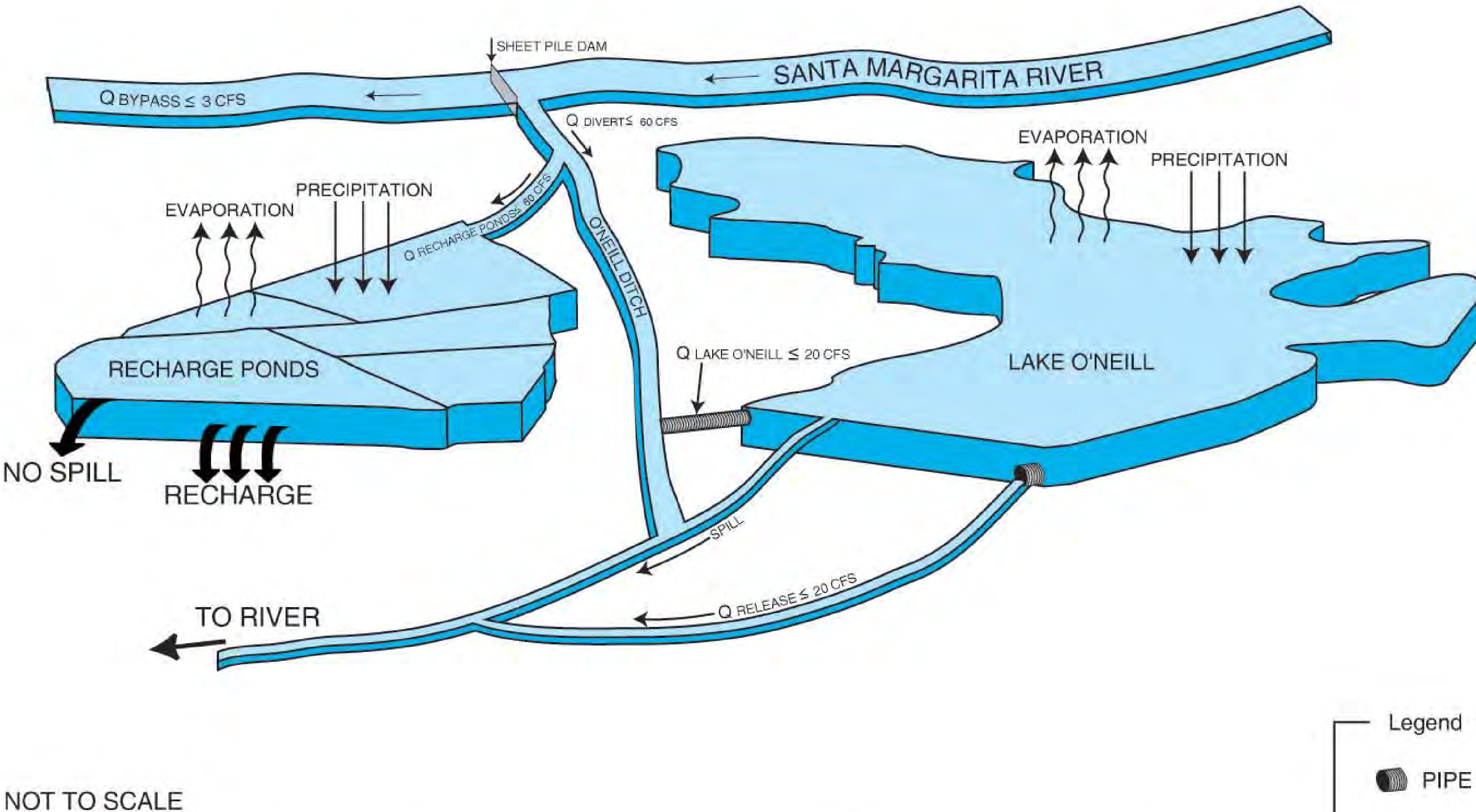
Limitations to the diversion rate from the Santa Margarita River accounted for in the reservoir operations model included not only the available water supply and physical limitations of the diversion facilities, but also such factors as available water rights, recharge pond infiltration rates, rainfall, evaporation, and spill from both the ponds and the lake. The Alternative 1 reservoir operations model also accounted for augmented surface flows and increased diversion efficiencies due to the maintenance and repair projects recommended in Chapter 6. Results from the model analysis were used by the ground-water model to estimate recharge at the ponds, streamflow past the diversion point, and releases from Lake O'Neill.

Diversions to Lake O'Neill and the recharge ponds were simulated in the reservoir operations model in order to establish baseline conditions. Simulated diversions to Lake O'Neill and the recharge ponds were estimated based on the limitations of the existing 1,500 AFY water right for diverting to Lake O'Neill and the 4,000 AFY license for diverting to the recharge ponds, complimented by the increased efficiency from the maintenance and repair of the relocated headwall and headgate. The diversion channel was assumed to divert a maximum of 60 cfs, based on the size of the culverts in the upper road crossing that impose flow restrictions.

A schematic diagram of the reservoir operations model is shown in Figure E-5. During periods of diversion, three cfs remains in the Santa Margarita River while the remaining surface flow may be diverted to either Lake O'Neill or to the recharge ponds. The simulated diversion to Lake O'Neill is limited to 20 cfs or less, while the maximum simulated diversion to the recharge ponds is 60 cfs.

The timing and quantity of diversions in the Alternative 1 reservoir operations model obeys certain constraints with respect to the filling and draining of Lake O'Neill.

- Beginning November 1st of every year, the lake is drained at a rate of 20 cfs. The drained flow leaves the lake through a pipe and into a channel flowing towards the Santa Margarita River. The water drained from the lake is recaptured by ground-water recovery wells located down-gradient of the release point. Draining terminates once the volume of Lake O'Neill approaches 100 AF.



STETSON ENGINEERS INC.

Surface Water Analysis
Resevoir Operations Model

Alternative 1
No Project

FIGURE E-5

1828-324LakeGraph1.ILL

- Water is diverted to Lake O'Neill between December 1st and March 31st. Between April and October, precipitation and evaporation act to raise and lower the water levels in the lake during this period.

- The reservoir operations model commences the use of the Pre-1914 water right from December 1st to March 31st. The Pre-1914 water right allows for 1,500 AFY to be diverted from the Santa Margarita River to Lake O'Neill, at a maximum diversion rate of 20 cfs. During this time, Lake O'Neill may approach its capacity of 1,200 AF, and on occasion will spill out of the lake via a spillway located on its western side. The effects of precipitation and evaporation are applied such that in dry years it may take slightly over 1,200 AF to fill the lake, while in wet years it may take less than 1,200 AF.

Alternative 1 operations model allows for the filling of Lake O'Neill exclusively from water diverted from the Santa Margarita River. Fallbrook Creek is allowed to bypass Lake O'Neill completely, helping to recharge the ground-water basin below the percolation ponds. The Pre-1914 water right is fully maximized every year and is only dependent upon the winter baseflow of the Santa Margarita River. Once Lake O'Neill has completed filling, water in O'Neill Ditch is then directed to the recharge ponds. The diversion schedule to the recharge ponds and Lake O'Neill, as dictated by the existing license and vested water right, is described in Table E-14.

TABLE E- 14: ALTERNATIVE 1 - DIVERSION SCHEDULE TO THE RECHARGE PONDS

Month	Activity	Rate	Limit	Water Right
Diversions to Lake O'Neill				
Nov	Drain	$Q_{release}$ <= 20 cfs	Min Volume = 100 AF	N/A
Dec to March	Fill	$Q_{Lake\ O'Neill}$ <= 20 cfs	1,500 AF	Pre-1914 Water Right
April to Oct	Precip-Evap	Q_{spill} = f(precip-evap)	N/A	N/A
Diversions to Recharge Ponds				
Nov	Fill w/ 100% Q_{divert}	$Q_{recharge\ ponds}$ <= 60 cfs	No Spill	License 21471 A
Dec to March	Fill w/ $Q_{divert} - Q_{Lake\ O'Neill}$	$Q_{recharge\ ponds}$ <= 60 cfs	No Spill	License 21471 A
May to June	Fill w/ Q_{divert}	$Q_{recharge\ ponds}$ <= 60 cfs	No Spill	License 21471 A
July to Sept	No Diversion	$Q_{recharge\ ponds}$ = 0 cfs	N/A	N/A
Oct	Fill w/ Q_{divert}	$Q_{recharge\ ponds}$ <= 60 cfs	No Spill	License 21471 A

APPENDIX D: GROUND-WATER MODEL

EXCERPT FROM Appendix D of March 2001 Permit 15000 Study - Some Values have been UPDATED. To be used for description of Groundwater Model only.

D.1 INTRODUCTION

A ground-water flow model (Model) was developed to simulate the impacts to the ground-water basin due to historical hydrology and water management practices that affects the hydrologic condition of the Upper Ysidora, Chappo, and Lower Ysidora sub-basins. The Model also provides the necessary tool to measure the changes in ground-water conditions and the potential affect to riparian vegetation and streamflow in the study area, as various stresses are applied in relationship with development of Permit 15000. Changes in ground-water pumping, streamflow, diversions, and wastewater production are simulated so that each of these stresses can be reviewed to estimate their potential impact to the condition and health of the Santa Margarita River and the sub-basins. The impacts of these stresses were measured as changes in the overall water budget, changes in ground-water levels, and changes in evapotranspiration (ET) demands.

The Model described in this appendix is used to estimate the impact of each of four different project alternatives that could be constructed to perfect Permit 15000 and expand the Base's diversion of water from the Santa Margarita River. Equally important, the Model described in this report may also be used in the future as a management tool to determine the best location for ground-water pumping, effects of adding or removing sources of water from the basin, and use in negotiations with local, state and federal regulators. A particle tracking or contaminant transport package may also be added to the Model to estimate the impacts of pumping and hydrologic conditions on the transport and movement of organic and inorganic compounds in each of the three sub-basins. The Model is the compilation of all environmental, wastewater, and water supply data on the Base and should be managed and maintained into the future in order to maximize water supply and minimize impact to the environment.

D.2 PREVIOUS STUDIES

Two previous modeling studies were considered for compilation of the Model used to address concerns for Permit 15000's impact to ground water. The original base data for the Chappo and Upper Ysidora ground-water model was constructed from LAW/Crandall's work for the Department of the Navy, Southwest Division (1995). A ground-water model was later developed by IT Corporation to simulate the movement of volatile organic compounds (VOC) in the Chappo sub-basin (IT Corporation, 1996). In September 2000, Stetson Engineers extended the boundary of the original LAW/Crandall ground-water model to include the Lower Ysidora sub-basin and all contributions made by wastewater discharge to the Lower Santa Margarita River Basin (The Environmental Company, 2000).

Both LAW/Crandall and IT Corporation conducted aquifer pumping tests to obtain hydraulic properties of the sub-basins, which were summarized in their reports and used to develop their respective models. IT Corporation's contaminant modeling work was used to verify hydrogeologic conditions within the Chappo sub-basin and placement of proposed production wells.

The ground-water model constructed for Camp Pendleton by Law/Crandall, Inc. (1995) was used to evaluate the potential effect of production wells on contaminant migration within the Chappo sub-basin. A MODFLOW™ flow model was coupled with MODPATH™, a particle tracking model, to simulate flow within the drinking water supply basins. The MODFLOW™ river package was used to simulate recharge from the river to the ground-water aquifer. The river was simulated as a loosing stream throughout the model domain. The model was based on annual time-steps and assumed a continuous, steady source of water in the river. Hydraulic properties obtained from aquifer pumping tests were used in the model and summarized in their report. Their study was based upon average monthly pumping at the Upper Ysidora and Chappo production wells, and considered the effects of four proposed production wells. LAW/Crandall's study concluded that construction of a new well in the Lower Chappo might increase the potential for contaminants to be drawn into existing wells, and proposed three new production wells to be located in the Upper Ysidora.

A ground-water flow and contaminant transport model was used to study migration of VOC (volatile organic compounds) impacted ground water in the Chappo sub-basin as part of the draft Remedial Investigation and Feasibility Study for Operable Unit 2 (IT Corporation, 1996). The model was constructed to evaluate different remedial alternatives with respect to the VOCs located in the 22/23 Area of Camp Pendleton. The options included no action, pump and treat, and pumping/injecting scenarios. Given the highly porous media of the Chappo and the effects of dilution and dispersion, it was estimated that the impacted ground water would return to background conditions by natural attenuation within 10 years, and therefore no further action was recommended.

The two models described in this section represent the numerical ground-water modeling efforts previously performed on the Lower Santa Margarita Basin. In addition to these numerical models, development of analytical and spreadsheet models that account for the interaction between surface and ground water have been conducted by The Environmental Company (September 2000), Fallbrook Public Utility District (Fallbrook PUD, 1994) and Camp Pendleton (Leedshill, 1989).

The selected numerical model, MODFLOW™ (McDonald and Harbaugh, 1988) is a three-dimensional ground-water flow model developed by the USGS. MODFLOW™ uses mathematical expressions to represent the ground-water flow system, including initial conditions, boundary conditions, hydrogeologic attributes of the aquifer, and simplifying assumptions that capture the heterogeneities of the subsurface.

D.3 GROUND-WATER MODEL CONSTRUCTION

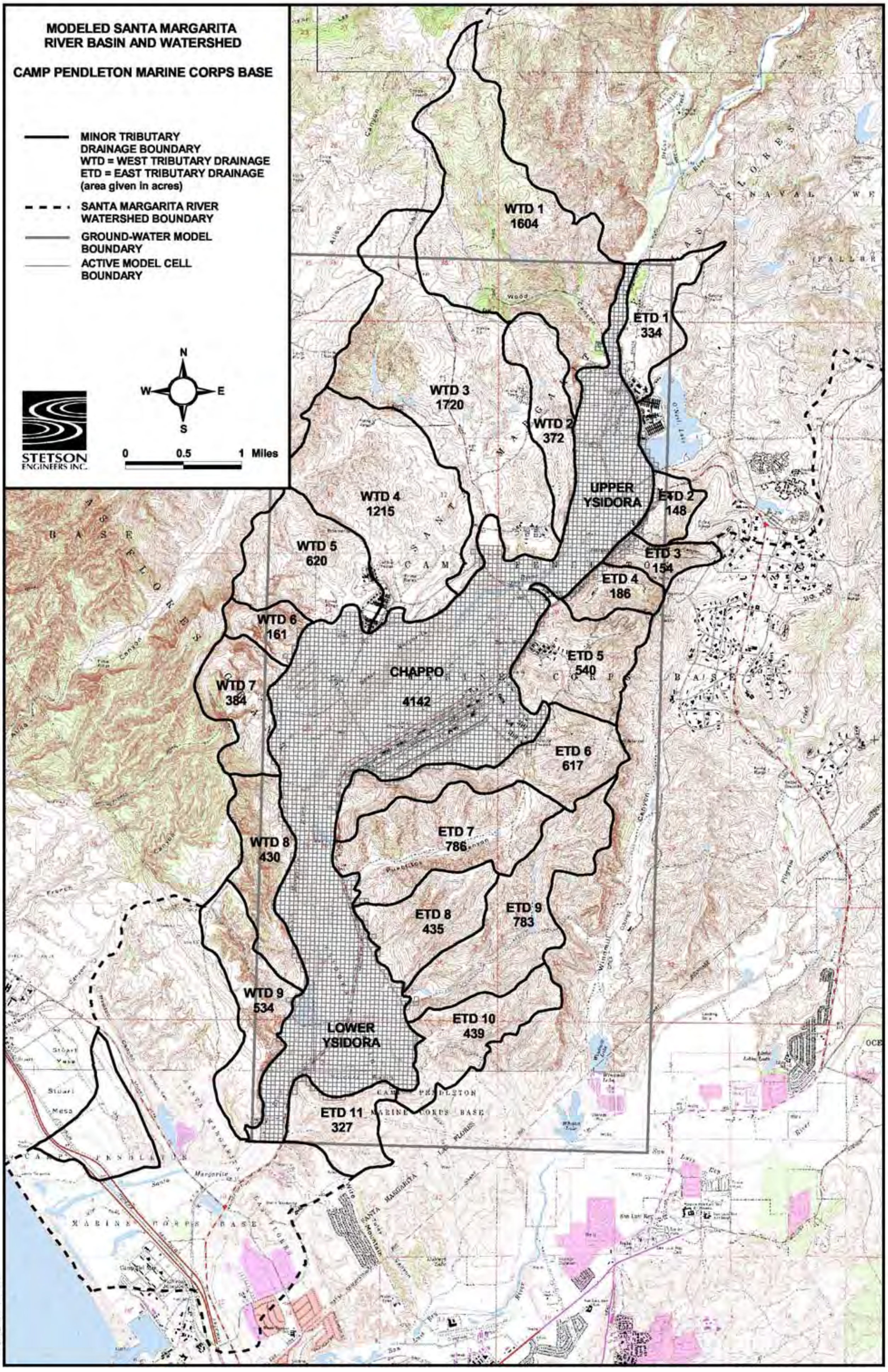
The selected numerical model, MODFLOW™ (McDonald and Harbaugh, 1988) is a three-dimensional finite-difference ground-water flow model code developed by the USGS. This computer code was chosen because of its flexibility in the type and number of hydrogeologic components that can be used to properly simulate the ground-water basin. The Santa Margarita River Basin model was developed using the streamflow, evapotranspiration, recharge, pumping, and general head boundary modules (or packages) of MODFLOW™. The data development for these different model input parameters are described in this section of the appendix.

The Model consists of 2 layers, 202 rows, 90 columns, and 7,390 active cells. A 20-year calibration period from water year (WY) 1980 through 1999 was established to simulate extended wet and dry periods. Monthly stress periods were simulated to capture the seasonal variations observed in existing water level and stream gage data. The Santa Margarita River was simulated to have the flexibility to be a gaining, loosing, or dry stream at different stream reaches or with different seasonal variations.

D.3.1 MODEL AREA AND GRID LAYOUT

The model area extends from the bedrock narrows just north of the Naval hospital to the narrows just south of the Lower Ysidora. The areal extent is comprised of the Upper Ysidora, Chappo, and Lower Ysidora alluvial sub-basins (Figure D-1). The northeast model boundary was located approximately 3,600 feet north of the existing diversion structure to minimize boundary effects at the diversion weir and channel. The southwest model boundary was established just north of the estuary and does not consider any tidal influence. The active modeled area of the three sub-basins is approximately 4,100 acres, and the surrounding watershed drainage area is approximately 11,800 acres.

The Model was constructed with two layers representing the Upper and Lower Alluvium of the Santa Margarita River Basin. The Lower Alluvium is generally more coarse-grained than the Upper Alluvium, except in the Upper Ysidora sub-basin where the entire section consists of coarse sand and gravel. These two units are the main ground-water bearing formations. The total thickness of the alluvium increases downstream from about 120 feet at the De Luz Creek confluence to about 200 feet near the coast. Each layer was discretized into 202 rows and 90 columns with 200-foot by 200-foot spacing.


MODELED SANTA MARGARITA RIVER BASIN AND WATERSHED
CAMP PENDLETON MARINE CORPS BASE
MINOR TRIBUTARY DRAINAGE BOUNDARY
WTD = WEST TRIBUTARY DRAINAGE
ETD = EAST TRIBUTARY DRAINAGE
(area given in acres)
SANTA MARGARITA RIVER WATERSHED BOUNDARY
GROUND-WATER MODEL BOUNDARY
ACTIVE MODEL CELL BOUNDARY
N
W
E
S
0
0.5
1 Miles
STETSON ENGINEERS INC.
WTD 1
1604
WTD 2
372
WTD 3
1720
WTD 4
1215
WTD 5
620
WTD 6
161
WTD 7
384
WTD 8
430
WTD 9
534
ETD 1
334
ETD 2
148
ETD 3
154
ETD 4
186
ETD 5
540
ETD 6
617
ETD 7
786
ETD 8
435
ETD 9
783
ETD 10
439
ETD 11
327
UPPER YSIDORA
CHAPPO
4142
LOWER YSIDORA
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Top elevations at active model cells were assigned from a 5-foot contour interval topographical survey provided by the Base (MCB-CP, 1999) as GIS coverage. The surrounding no-flow model cells were based on 20 foot contour intervals from USGS topographical maps (1968 Morro Hill; 1975 Oceanside, 1975 San Luis Rey, and 1968 Las Pulgas Canyon). Two layers were chosen to represent the alluvial aquifer in all three sub-basins. Well logs and cross sections of the Lower Santa Margarita River ground-water basin (Worts and Boss, 1954; Slemon, 1978) show a coarser (cobbles, gravel, and sand) lower alluvium beneath a finer (gravel, sand, silt, and clay) upper alluvium. Though the ground-water basin is considered to be one aquifer, the two layers allow for the simulation of variable materials. Well logs and geologic cross sections were used to determine the elevations of the interface of the upper and lower alluvium and the depth to bedrock (Figure D-2; Worts and Boss, 1954). There is a general downward slope of the interface between the two layers from the northeast edge (south of the De Luz confluence) of the model domain toward the southwest edge (Lower Ysidora Narrows). The finite-difference grid was constructed to account for the changes in elevations and downward slope of the surface and contacts from northeast to southwest.

D.3.2 MODELED TIME PERIODS

Water years 1980 through 1999 were chosen for the calibration period. This interval of time was selected because it contained consecutive years with below normal and above normal hydrogeologic conditions (precipitation and streamflow) and continuous field data for model input. The data reviewed included USGS streamflow gage records, precipitation databases, production well records, and historical Water Master Reports for Lake O'Neill release/spill and river diversion information.

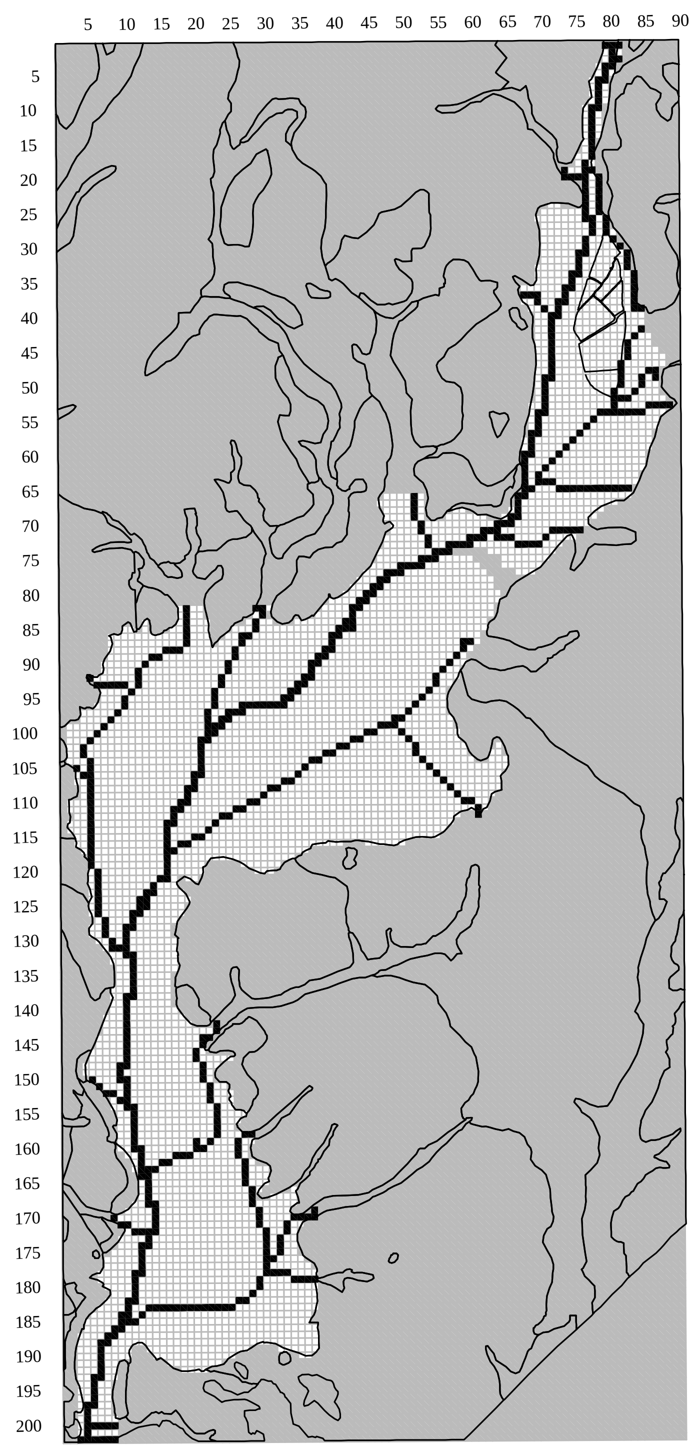
The steady-state Model was constructed with monthly stress periods. During each stress period, streamflow, recharge, evapotranspiration, pumping rates, etc. remained constant. Average values for each month were used as input into the Model for each of these parameters, such that the Model simulates average constant conditions throughout each month. The average monthly values accounted for variation in the seasonal natural system with the highest streamflows and precipitation occurring during the winter season and a dry climate occurring during the summer and autumn.

D.3.3 INITIAL AND BOUNDARY CONDITIONS

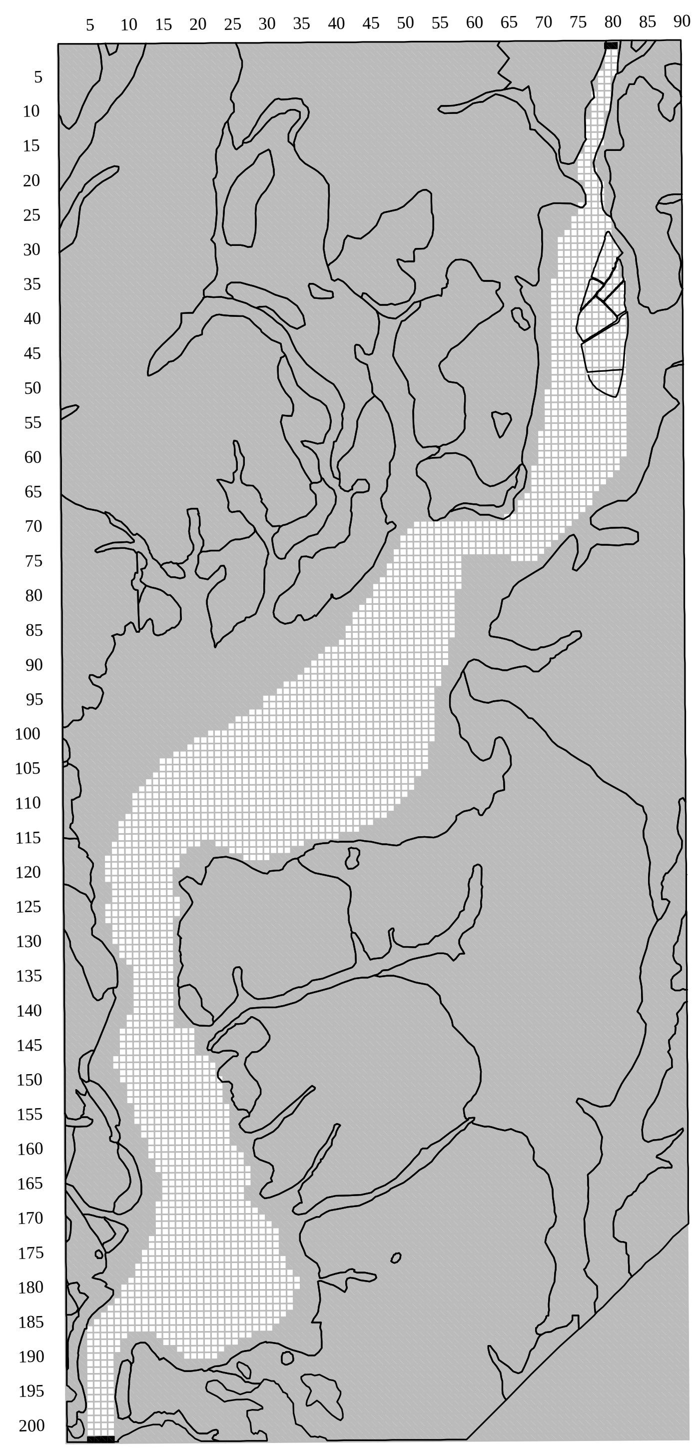
D.3.3.1 No-Flow and Active Cells

The bedrock units to the east and west of the river’s alluvial sub-basins were simulated as no-flow boundaries and considered as inactive cells without contributing to ground-water flow. Although there is some subsurface flow though the bedrock, it is generally considered to be non-water-bearing due to very low permeability. Figure D-3 displays the active and no flow cells for

FIGURE D-3



Ground-Water Model
Layer 1



Ground-Water Model
Layer 2

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- ■ STREAM CELL
- ▩ NO FLOW CELL
- □ ACTIVE CELL
- ⁓ OUTLINE OF GEOLOGIC UNITS
- ■ GENERAL HEAD BOUNDARY CELL
- ⌗ FINITE DIFFERENCE GRID (200 ft. x 200ft.)

GROUND- WATER MODEL
BOUNDARY CONDITIONS AND
ACTIVE CELLS

F:\DATA\1828\REPORT\GWMODEL\DFX\LAYER1_GRID1_D-3.DWG the two Model layers. Layers 1 and 2 contain approximately 4,600 and 2,800 active model cells, respectively. Table D-1 summarizes the active cell area for the three sub-basins.

TABLE D - 1 ACTIVE MODEL CELLS

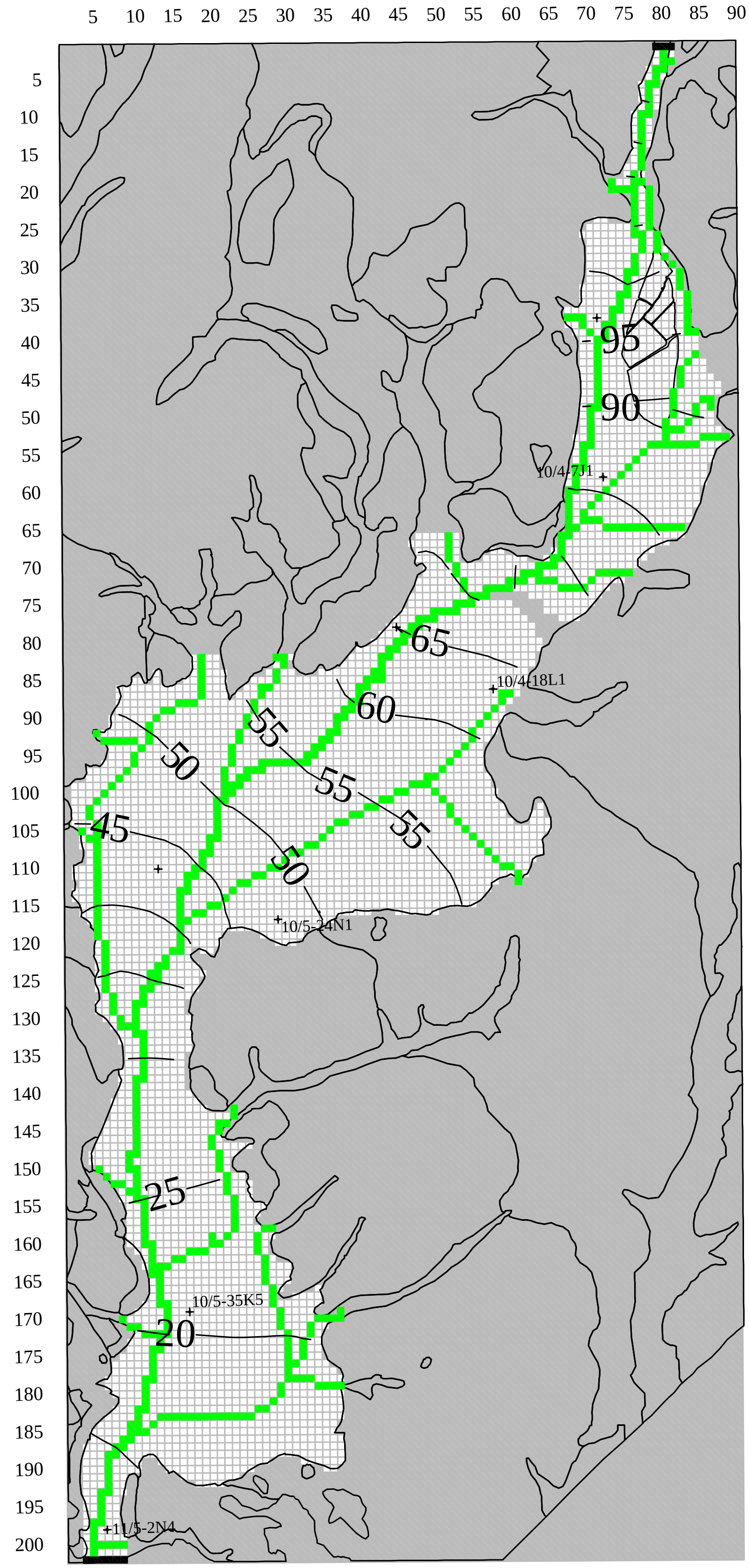
Sub-Basin	# Active Cells		Active Cell Area (ac)		Average Active Cell Thickness (ft)	
	Layer 1	Layer 2	Layer 1	Layer 2	Layer 1	Layer 2
Upper Ysidora	916	618	840	570	56	81
Chappo	2,353	1,290	2,160	1,180	60	90
Lower Ysidora	1,310	903	1,200	830	89	133
Total	4,579	2,811	4,200	2,580	n/a	n/a

D.3.3.2 Initial Water Levels (Ground-Water Head)

Through an interative process, beginning with WY 1980 average water levels and ending with simulated October 1979 water levels, initial water level conditions were established for the Model. Available measured water level data at 5 monitoring wells during this first simulated month were used to confirm these initial conditions. Table D-2 compares simulated initial ground-water levels with October 1979 measured and the WY 1980 average annual values. Figure D-4 shows the initial ground-water level contours.

TABLE D - 2 OCTOBER 1979 MEASURED AND SIMULATED WATER LEVELS (FEET, MSL)

Monitoring Well	Sub-Basin	WY 1980 Average Annual Water Level	Oct 1979 Measured Water Level	Simulated Initial Water Level
10/4-7J1	Upper Ysidora	87	85	85
10/4-18L1	Chappo	67	65	64
10/5-24N1	Chappo	50	47	48
10/5-35K5	Lower Ysidora	22	21	21
11/5-2N4	Lower Ysidora	11	10	11



-○- Target Water Level Well

Initial Ground-Water Level Countours (feet,msl)

Lower Santa Margarita River

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D.3.3.3 Modeled General Head Boundaries and Underflow

General head boundaries were established at the upgradient (northeast) and downgradient (southwest) active cells in both layers to simulate subsurface underflow. Underflow into and out of the Model domain is controlled by the general head boundary and the simulated ground-water head within the aquifer. A general head boundary has more flexibility than a constant head boundary by establishing a theoretical reservoir head at a certain distance from the Model boundary that the model can draw upon for underflow into the Model domain. This allows for some seasonal water level fluctuations at the boundaries. The following table summarizes the parameters were used in establishing the general head boundaries within the different layers at the upgradient and downgradient active cells. Conductance (C) across an active cell surface is calculated by the following equation:

$C = K_b (A/B)$ where: K_b = hydraulic conductivity of the boundary material (L/T)
A = area of the boundary (L^2); and
B = thickness or width of boundary (L).

TABLE D - 3 GENERAL HEAD BOUNDARY PARAMETERS

Parameter	Northeast Upgradient GHB		Southwest Downgradient GHB	
	Layer 1	Layer 2	Layer 1	Layer 2
Head @ Boundary	132.18 ft, msl	132.18 ft, msl	9.82 ft, msl	9.82 ft, msl
Avg Saturated Thickness of Cell	35 feet	65 ft	74 ft	84 ft
Width of Cell	200 ft	200 ft	200 ft	200 ft
Gradient from Model Domain to Boundary	.00218 ft/ft (11.5 ft / mile)*	.00218 ft/ft (11.5 ft / mile)*	.00218 ft/ft (11.5 ft / mile)*	.00218 ft/ft (11.5 ft / mile)*
Distance to Boundary	1000 ft	1000 ft	1000 ft	1000 ft
Hydraulic Conductivity	338 ft/day	451 ft/day	37 ft/day	338 ft/day
Avg Calculated Conductance	2400 ft^2/day	5700 ft^2/day	550 ft^2/day	5700 ft^2/day
Estimated Underflow	18 af/m	18 af/m	5 af/m	35 af/m

* from Troxell and Hofmann, 1954

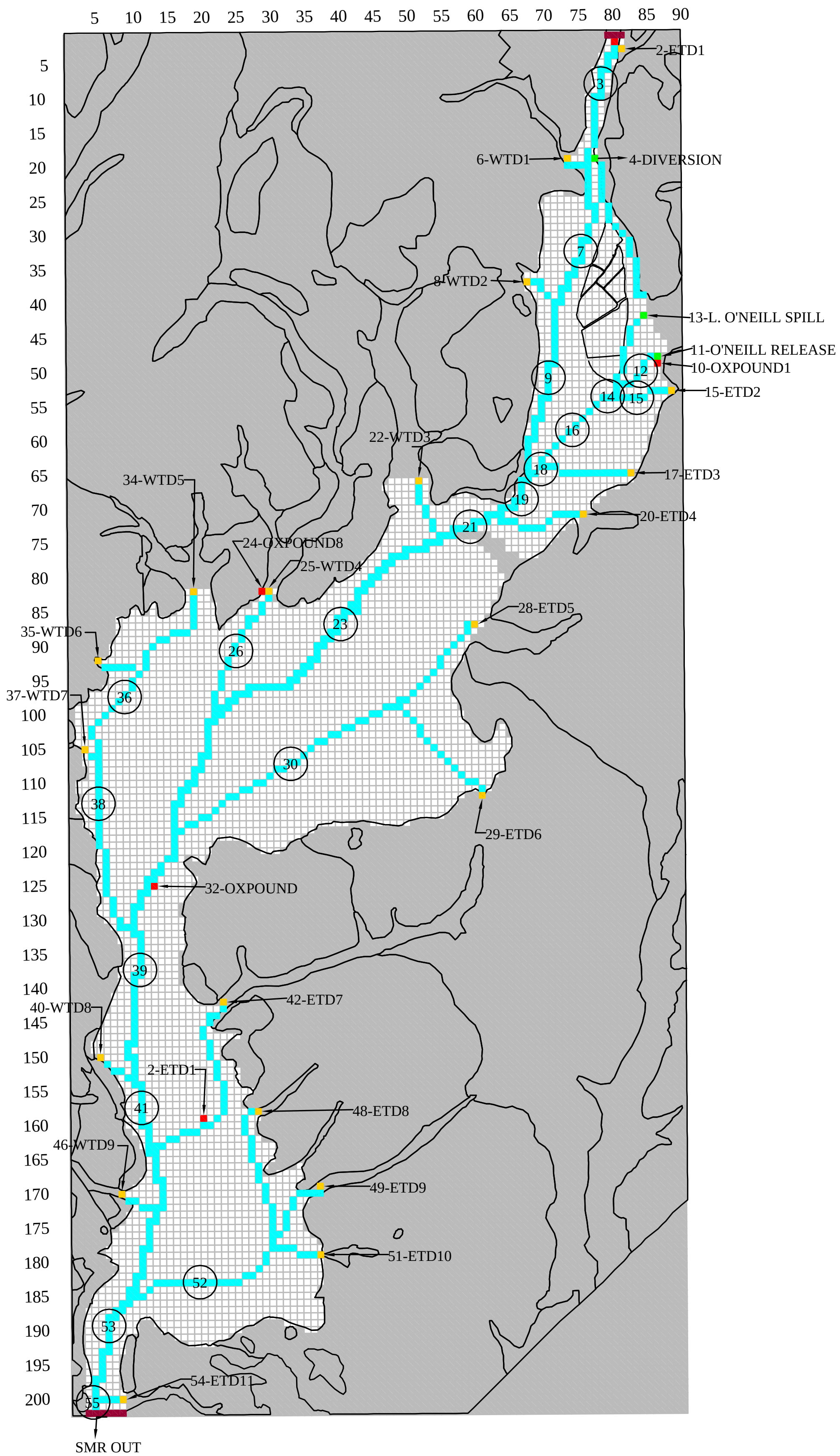
D.3.3.4 Modeled Streamflow

The MODFLOW™ streamflow package was used to simulate the flow of the Santa Margarita River, including minor tributary drainages, historical oxidation pond discharges, diversions, Lake O'Neill spills and releases, and the river system's interaction with the alluvial aquifer. The streamflow package is able to account for flow in the river and whether a river reach is gaining water from or losing water to the aquifer. The USGS developed the Streamflow Package to account for intermittent rivers typical in the southwestern United States, like the

Santa Margarita River. It permits rivers to go dry and then re-wet if ground water becomes available further downstream. The major inflows to the river that were simulated are: surface flow into the top of the Model domain, ground-water discharge into the river, wastewater discharge from Oxidation Ponds 1, 2, 3, 8, and 13 (after evaporation and infiltration to ground-water), recoverable runoff from minor side tributary drainages (Figure D-5), and spills and releases from Lake O'Neill. The major outflows from the river that were simulated include surface flow leaving the southern end of the model domain, infiltration to ground water, and diversions to the recharge ponds and Lake O'Neill. Table D-4 summarizes the Model input streamflow data on an annual basis throughout the 20 year simulated time period. Table D-5 presents the same information summarized by average annual monthly volumes. The average monthly streamflow volumes demonstrates the seasonal nature of the hydrologic conceptual site model .

TABLE D - 4 MODEL INPUT: AVERAGE ANNUAL STREAMFLOW (AF/WY)

AF/WY	SMR	Lake O'Neill Spill	Lake O'Neill Release	Ox Ponds	Minor Tribs	Active Cell Runoff	Subtotal	Div	Balance
1980	175,417	3,961	700	2,307	5,755	1,790	189,930	0	189,930
1981	21,149	0	700	2,142	732	0	24,724	0	24,724
1982	57,715	330	700	1,956	3,125	418	64,244	0	64,244
1983	82,811	1,658	700	2,195	3,153	535	91,052	7,845	83,207
1984	22,888	1,009	700	2,122	1,131	180	28,030	1,990	26,041
1985	20,450	473	700	2,360	897	314	25,194	3,261	21,932
1986	46,545	1,727	700	1,961	3,509	411	54,853	7,937	46,916
1987	12,246	1,296	700	2,695	603	0	17,540	2,371	15,169
1988	32,493	1,251	700	3,153	2,353	113	40,063	3,029	37,034
1989	16,267	1,150	700	2,486	1,131	260	21,994	3,641	18,353
1990	9,256	186	700	2,365	579	0	13,086	3,623	9,463
1991	53,443	1,840	700	1,972	1,837	286	60,078	6,136	53,942
1992	32,780	840	700	2,061	2,593	296	39,271	6,163	33,108
1993	224,666	5,680	700	2,422	3,822	1,233	238,522	697	237,825
1994	16,866	0	700	970	529	0	19,065	3,759	15,306
1995	99,762	2,742	700	933	3,157	1,080	108,374	1,602	106,772
1996	11,910	0	700	856	244	0	13,709	1,099	12,610
1997	21,060	0	700	949	2,059	486	25,254	3,633	21,621
1998	100,677	2,363	700	917	1,275	745	106,676	4,659	102,017
1999	9,365	0	700	902	453	0	11,421	2,955	8,466
Average	53,388	1,325	700	1,886	1,947	407	59,654	3,220	56,434
Median	27,690	1,079	700	2,092	1,556	291	33,651	3,145	30,505
20 Yr Total	1,067,765	26,505	14,000	37,726	38,938	8,146	1,193,080	64,400	1,128,680



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6-WTD1	Stream Segment # - Stream Segment ID (arrow direction indicates direction of flow at cell)		
	WTD	=	West Tributary Drainage
	ETD	=	East Tributary Drainage
	OXPOUND	=	Discharge at Waste Water Oxidation Pound
38	Continuation of Santa Margarita River, or of side drainage		

Ground-Water Model Stream Construction

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TABLE D - 5 MODEL INPUT: AVERAGE MONTHLY STREAMFLOW (AF/WY)

Avg AF/M	SMR	Lake O'Neill Spill	Lake O'Neill Release	Ox Ponds	Minor Tribs	Active Cell Runoff	Subtotal	Div	Balance
Oct	960	6	0	149	48	0	1,163	17	1,147
Nov	2,286	36	700	155	198	17	3,392	38	3,353
Dec	2,778	4	0	167	227	49	3,225	144	3,081
Jan	11,887	174	0	175	644	207	13,089	409	12,680
Feb	15,750	456	0	169	323	84	16,782	784	15,999
Mar	11,893	473	0	174	381	50	12,972	823	12,149
Apr	3,273	115	0	151	74	0	3,614	561	3,053
May	1,856	49	0	151	1	0	2,057	337	1,720
Jun	945	5	0	149	1	0	1,099	79	1,020
Jul	569	2	0	151	10	0	733	15	718
Aug	429	0	0	152	0	0	580	7	573
Sep	762	4	0	143	39	0	949	6	942
Avg Mo.	4,449	110	58	157	162	34	4,971	268	4,703
Med Mo.	2,071	21	0	151	61	0	2,641	111	2,529
Ttl Avg Anl	53,388	1,325	700	1,886	1,947	407	59,654	3,220	56,434

Simulated Stream Geometry and Conductance

Stream geometry encompasses the location of the river within the basin, streambed width and length within a Model cell, and the streambed thickness. The following two reports were used to establish these parameters for the Model:

- Santa Margarita River Sedimentation Study; Phase I: Preliminary Hydraulic and Sediment Transport Analyses. Northwest Hydraulic Consultants (NCH); February 1997

- Draft Report: Santa Margarita River Hydrology, Hydraulics and Sedimentation Study. WEST Consultants Inc. (WEST); September 1999.

Changes in the river's low-flow channel location have been recorded since 1879 (NHC, 1997). The most recent change occurred during the flood event of January 1993, within the timeframe of the Model. Figure D-5 shows the location established in the Model for the stream and minor tributaries, diversion, and canals. Streambed conductance (C_{str}) values for each stream cell representing the Santa Margarita River were calculated from WEST's stream geometry profiles, using the following equation:

$$C_{str} = K_z (A/b)$$

where:
K_Z = hydraulic conductivity of streambed material (L/T)
A = area of the stream cell: length x width (L^2); and
b = thickness of the streambed (L).

The length of each stream cell was 200 feet and the width varied from 80 feet to 1,060 feet (WEST, 1999). Streambed thickness ranged from 6 to 12 feet. The streambed conductance for each Model stream cell was held constant throughout all stress periods of the model run. This simplifying assumption does not account for the seasonal change in the width of the streambed as the river widens and narrows with available water. For minor tributary drainages, the conductance was set to 500 ft/d, whereas conductance of the Santa Margarita River stream cells was estimated to range from 400 to 8800 ft/day. The conductance of the diversion channel was set to 5 ft/d to avoid any double counting of recharge volume at the ponds. Attachment 1 following this appendix shows the MODFLOW™ Streamflow Package, including the stream elevation and streambed conductance for all stream segments and reaches. The stream segment order, side tributaries, diversions and canals, and oxidation pond discharges to the river are shown in Figure D-5.

Santa Margarita River Streamflow from WY 1980 through 1999

The Santa Margarita River has a dominating influence on the hydrogeologic conditions within the Model domain. The Santa Margarita River is often dry for several months of the year in parts of the Chappo and Lower Ysidora sub-basins. In extremely dry years, there has been no flow at all reaching the ocean. In extremely wet years, the average daily flow has reached as high as 19,500 cfs and the peak daily flow has exceeded 44,000 cfs (January 1993). The hydrologic variability of the Santa Margarita River makes it both a powerful and vulnerable source of water for its many users (Figure D-6). As shown in Table D-5, the average monthly streamflow during the calibration period at the top of the Model boundary is 4,450 af of water, ranging from a 20 year average of 430 af/m in August to 15,750 af/m in February.

Diversions from the Santa Margarita River from WY 1980 through 1999

River water was diverted for ground-water recharge in percolation basins and to fill Lake O'Neill. Attachment 2 contains the simulated monthly historical diversions from the Santa Margarita River from WY 1980 through 1999. The diversion structure and ponds were under maintenance an repair during the first part of the simulated time period. The river over-banked and by-passed the ground-water recharge basins during the 1993 flood event. Average annual diversions from WY 1980 through 1999 to Lake O'Neill was 490 af/wy, ranging from 0 to 1,340 af/wy.

Lake O'Neill Spill and Release from WY 1980 through 1999

Historically, Lake O'Neill receives surface diversions from the Santa Margarita River, inflow from the surrounding watershed (including Fallbrook Creek), and direct precipitation. A spreadsheet analysis was performed to proportion the available water on a monthly basis to

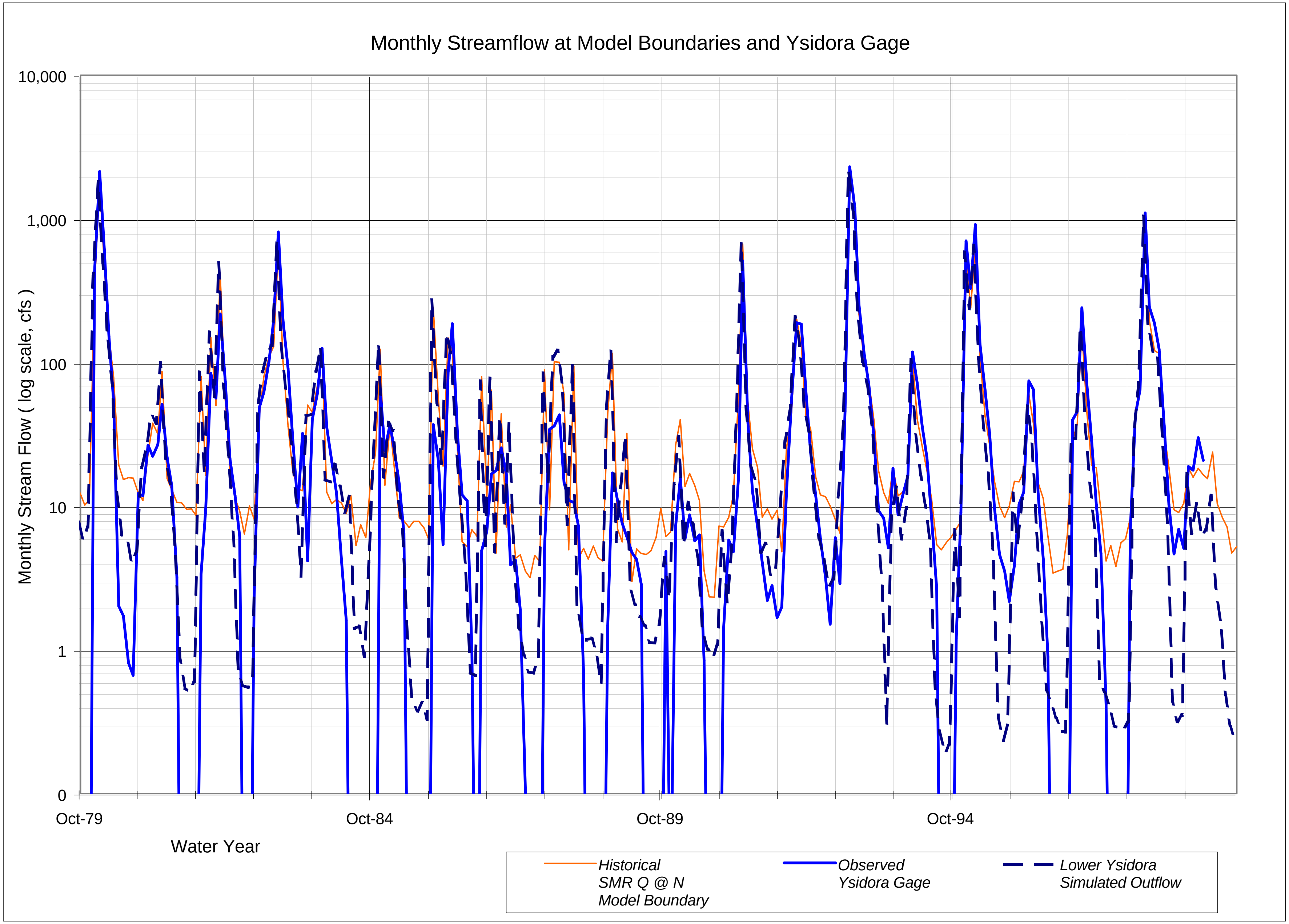

Monthly Streamflow at Model Boundaries and Ysidora Gage
Monthly Stream Flow (log scale, cfs)
10,000
1,000
100
10
1
0
Oct-79
Oct-84
Oct-89
Oct-94
Water Year
Historical SMR Q @ N Model Boundary
Observed Ysidora Gage
Lower Ysidora Simulated Outflow

Figure D - 6

evaporation off of the lake surface, spills at the spillway, and the annual November release. Spills and releases from Lake O'Neill were estimated from Annual Watermaster Reports, and Fallbrook Creek streamflow was used from the USGS stream gage on Fallbrook Creek. Table D-4 and 5 show the estimated annual summary for each of these inflows and outflows for the calibration period, WY 1980 through WY 1999. Appendix E describes the surface water analysis for full diversions to Lake O'Neill under the pre-1914 water right and proposed Permit 15000 diversions to Lake O'Neill.

Minor Tributary Drainage and Surface Runoff from WY 1980 through 1999

Precipitation runoff into the model domain is estimated to comprise approximately 3.6% of the Santa Margarita River surface flow in the three sub-basin. Local runoff generated by precipitation events is dependent on soil characteristics, land slopes, existing soil moisture, storm intensity, and storm duration. Due to these factors, the runoff varies greatly from year to year, month to month, and location to location. Within the alluvial floodplain on Camp Pendleton, runoff is generally minimal due to the flatness of topography, undeveloped characteristic of the area, and sandy soil. In the foothills and mountainous areas dominated by bedrock formations, runoff may be significant during large precipitation events. The minor tributary runoff was calculated as part of the stream analysis in Appendix E.

The watershed drainage area for the active model cells is shown in Figure D-1. Tables D-6 below shows each of the 20 minor tributary drainage areas and the alluvium surface area of the valley floor, along with the water runoff volume proportioned to each. Table D-7 shows the same information as average monthly volumes and demonstrates the seasonal distribution of runoff.

TABLE D - 6 WY 1980 - 1999 MINOR TRIBUTARY AND ALLUVIUM SIMULATED RUNOFF

Stream Segment	Minor Tributary Drainage	Area (acre)	Average (af/wy)	Median (af/wy)	Total (af/ 20 wy)
2	E Trib 1	330	60	60	1,150
6	W Trib 1	1,600	260	200	5,150
8	W Trib 2	370	60	50	1,190
15	E Trib 2	150	30	20	510
17	E Trib 3	150	190	120	3,890
20	E Trib 4	190	30	30	640
22	W Trib 3	1,720	220	150	4,430
25	W Trib 4	1,220	130	90	2,610
28	E Trib 5	540	90	90	1,860
29	E Trib 6	620	110	100	2,122
34	W Trib 5	620	50	30	990
35	W Trib 6	160	50	40	1,000
37	W Trib 7	380	70	50	1,330
40	W Trib 8	430	80	70	1,610
42	E Trib 7	790	140	130	2,700
46	W Trib 9	530	50	30	920
48	E Trib 8	440	70	70	1,500
49	E Trib 9	780	130	130	2,690
51	E Trib 10	440	80	70	1,510
54	E Trib 11	330	60	50	1,130
	Total Side Trib	11,790	1,950	1,580	38,940
	Q alluvium	4,140	410	290	8,150

TABLE D - 7 AVERAGE MONTHLY MINOR TRIBUTARY AND ALLUVIUM RUNOFF

Month	**Precipitation (Oceanside)** (12.01 in/yr avg) (avg in/m)	**11 East Side Minor Tributary Drainages** 7,510 acres (avg af/m)	**9 West Side Minor Tributary Drainages** 4,280 acres (avg af/m)	**Q al (Alluvium)** 4,140 acres (avg af/m)	**Total Runoff** 15,930 (avg af/m)
Oct	0.45	20	20	0	50
Nov	1.26	100	100	20	220
Dec	1.59	120	110	50	280
Jan	2.95	340	310	210	850
Feb	2.35	160	170	80	410
Mar	2.01	180	200	50	430
Apr	0.75	40	30	0	70
May	0.11	0	0	0	0
Jun	0.11	0	0	0	0
Jul	0.10	0	0	0	0
Aug	0.05	0	0	0	0
Sep	0.31	20	20	0	40
Total (af/y)		980	960	410	2,350

Wastewater Discharge from WY 1980 - 1999

Wastewater from Sewage Treatment Plants (STP) 1, 2, 3, 8, and 13 was discharged into oxidation ponds and then released into the Santa Margarita River during the calibration period. This inflow was proportioned to streamflow and to ground-water recharge. The streamflow portion is discussed in this section. The following wastewater flow assumptions were made:

- The oxidation pond associated with STP 1 is located outside of the model domain and does not appear to contribute to the basin's ground-water recharge, therefore only the discharge to the stream, located near the Lake O'Neill release point, was modeled.

- The flow path for wastewater releases from STP 2 include: oxidation pond 2, to golf course irrigation or oxidation pond 3, then to a river discharge point near oxidation pond 13 in the Lower Ysidora. Only STP 2 water discharged to the river is considered in the model because oxidation ponds 2 and 3 are outside of the modeled active cells.

- Wastewater from STP 3 flows to an oxidation pond in the south end of Chappo, just north of the narrows. It is assumed that approximately 10% of the water in the oxidation pond recharges the ground water beneath the pond and the remaining 90% is released to the Santa Margarita River during the calibration period. Monthly precipitation and potential evaporation are accounted for prior to calculating available ground-water recharge and release to the stream.

- Oxidation pond 8 is located in the Chappo on the west side of the river, within the active model cells. It is assumed that approximately 10% of the water in the oxidation pond recharges the ground water beneath the pond and the remaining 90% is released to the Santa Margarita River. Monthly precipitation and potential evaporation are accounted for prior to calculating available ground-water recharge and release to the stream.

- The largest oxidation ponds, located in the Lower Ysidora, were associated with STP 13. The use of these ponds was discontinued after they were damaged during the 1993 flooding. During their operation, it is assumed that approximately 10% of the water in the oxidation ponds recharged the ground water beneath the pond and the remaining 90% is released to the Santa Margarita River. Monthly precipitation and potential evaporation are accounted for prior to calculating available ground-water recharge and release to the stream.

Attachment 2, Table D-A2-2, summarizes the average annual and average monthly STP releases to the oxidation ponds and the discharges to the Santa Margarita River that were incorporated into the modeled calibration period. The waste discharge has a small seasonal variation compared to other stream inflow parameters.

D.3.3.5 Modeled Production Wells

During the model calibration period of WY 1980 through WY 1999, Camp Pendleton operated five production wells in the Upper Ysidora, nine production wells in the Chappo, and three irrigation wells in the Ysidora Narrows and Lower Ysidora. Attachment 3 summarizes the ground-water production in the three sub-basins, showing the effects of the seasonal summer demand, increased demand of ground water following dryer than normal winters, and the 1995 base expansion. Table D-8 lists the production wells, screen intervals, period of operation during the model calibration period, and average annual pumping volumes during the pumping period. Figure D-7 shows the location of modeled production wells.

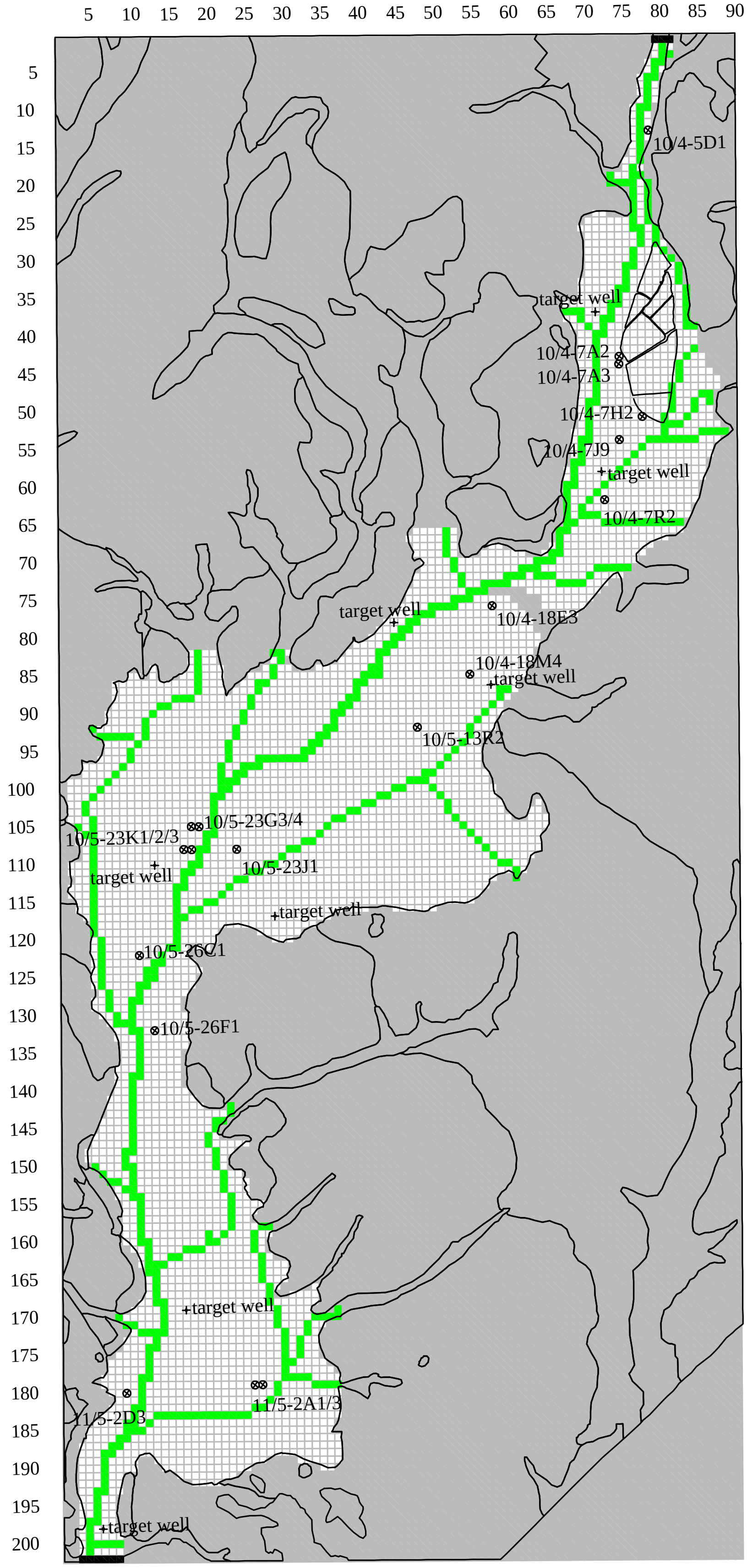
TABLE D - 8 PRODUCTION WELL INVENTORY

Well ID	Bldg No.	Year Drilled	Operation (feet, bgs)	Average AF/WY (feet, msl)	Screen Interval	Ground Surface
Upper Ysidora Sub-basin						
10/4-5D1	27911	1943	1981-1987	384	28-70	110
10/4-7R2	2603	1955	1980-1999	461	n/a	(7R1) 90
10/4-7A2	2673	1956	1980-1999	622	n/a	(7A1) 103
10/4-7A3	n/a	1999	1999	16	n/a	(7A1) 103
10/4-7H2	2671	1956	1980-1999	293	n/a	(7H1) 98
Chappo Sub-basin						
10/5-13R2	2363	1956	1980-1982	461	68-132	66
			1990-1999	506	n/a	n/a
10/4-18E3	2393	1965	1981-1999	465	89-109	78
10/4-18M4	2373	1960	1980-1999	442	84-224	76
10/5-23J1	2301	1950	1980-1999	742	107-137	52
10/5-23G3	33926	1976	7 years	44	17-118	54
10/5-23G4	n/a	n/a	1999	326	n/a	n/a
10/5-23K2	33924	n/a	11 years	238	n/a	50
10/5-23K3	n/a	n/a	1999	336	n/a	n/a
10/5-26C1	2201	1959	1980-1999	808	96-162	44
Ysidora Narrows and Lower Ysidora Sub-basin (irrigation wells)						
10/5-26F1	2200	n/a	1980-1999	941	88-170	39
11/5-2D3	n/a	n/a	1986-1999	148	n/a	n/a
11/5-2A3/1	19122	n/a	1980-1989	95	n/a	n/a

Note: n/a indicates unknown or unavailable data; bgs is 'below ground surface'; msl is 'mean sea level'

D.3.4 GROUND-WATER FLOW MODEL PROPERTIES

The ground-water flow model parameters were developed based on the conceptual site model. A numerical model inherently requires simplifying assumptions when defining a problem domain. Each volume element (a block defined by a row, a column, and a layer in the grid) is assigned a unique set of hydraulic parameters influencing the calculations depicting flow of ground water at the center of that particular block. Hydraulic properties shaped by the



⊗ Production Well
\+ Target Water Level Well

Well Locations within the Model Area

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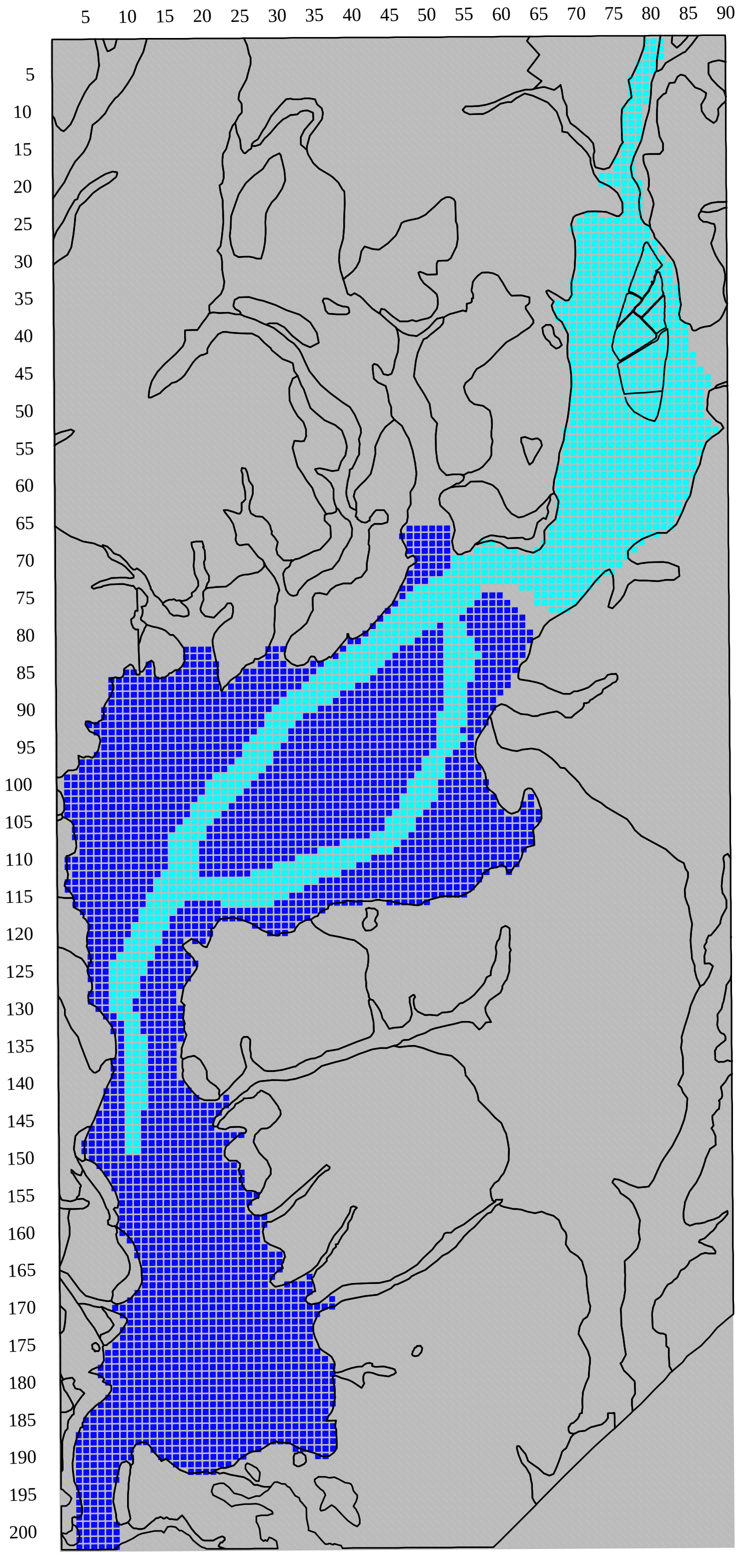
F:\DATA\1828\REPORT\GWMODEL\DFX\Well_Loc_D-5.DWG geologic substrate that the ground water flows through include hydraulic conductivity (horizontal and vertical), effective porosity, specific yield, and storativity. Aquifer transmissivity was obtained by multiplying hydraulic conductivity by the thickness of the layer at that grid block. Other cell properties influenced by climatic conditions include recharge, and evapotranspiration.

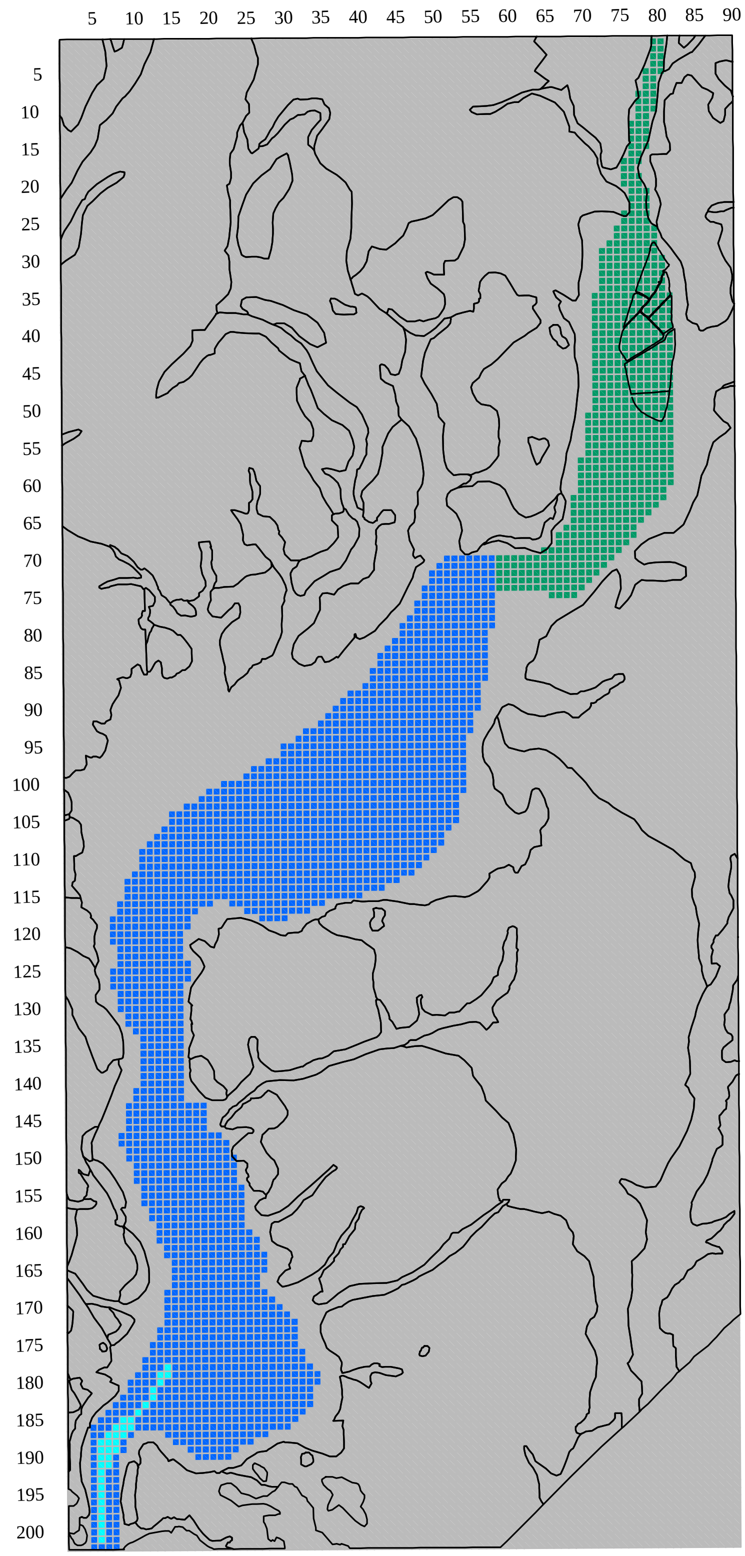
Two layers were chosen to represent the alluvial aquifer in all three sub-basins. Well logs and cross sections of the Lower Santa Margarita River ground-water basin (Worts and Boss, 1954; Slemon, 1978) show a coarser (cobbles, gravel, and sand) lower alluvium beneath a finer (gravel, sand, silt, and clay) upper alluvium. Though the ground-water basin is considered to be one aquifer, the two layers allow for the simulation of variable materials. The Model was constructed with two layers representing the two Quaternary alluvial units of the Santa Margarita River Basin. The upper layer was assigned properties of an unconfined layer to capture the water table aquifer characteristics of the upper alluvium. The bottom layer of the Model was assigned an aquifer type of an unconfined unit with variable transmissivity, allowing for variability in the saturated thickness of the lower alluvium.

D.3.4.1 Modeled Hydraulic Properties

Aquifer hydraulic characteristics were assigned based on aquifer pumping tests conducted by IT Corporation and previous model results (LAW/Crandall, 1995). Horizontal conductivities ranged from 0.8 and 37 ft/day in the silts and silty sands of the Chappo and Lower Ysidora sub-basins to approximately 300 to 450 ft/day in the gravels and sands of the lower alluvium in the Chappo and Upper Ysidora (LAW, 1995). Specific yield ranged from 0.05 in silts to 0.2 in sands and gravels (LAW, 1995). Storativity was estimated at 0.00002 to 0.00008 depending on soil type. Effective porosity was assigned values from 0.22 for sand and gravel units to 0.40 for silt/clay units. This model was constructed by combining layers 1, 2, and 3 of the Law/Crandall model as a new layer 1; and layers 4 and 5 of the LAW/Crandall model as a new layer 2. The following table summarizes the hydraulic properties used in this Model (adjusted from the LAW/Crandall model, 1995). Figure D-8 shows the extent of these property zones for layers 1 and 2.



Layer 1



Layer 2

Hydraulic Conductivity Zone	Value
1	37.00
2	192.0
3	300.0
4	388.0
5	451.0
6	494.0

Ground-Water Model Hydraulic Conductivity

Lower Santa Margarita River

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TABLE D - 9 MODELED HYDRAULIC PARAMETERS

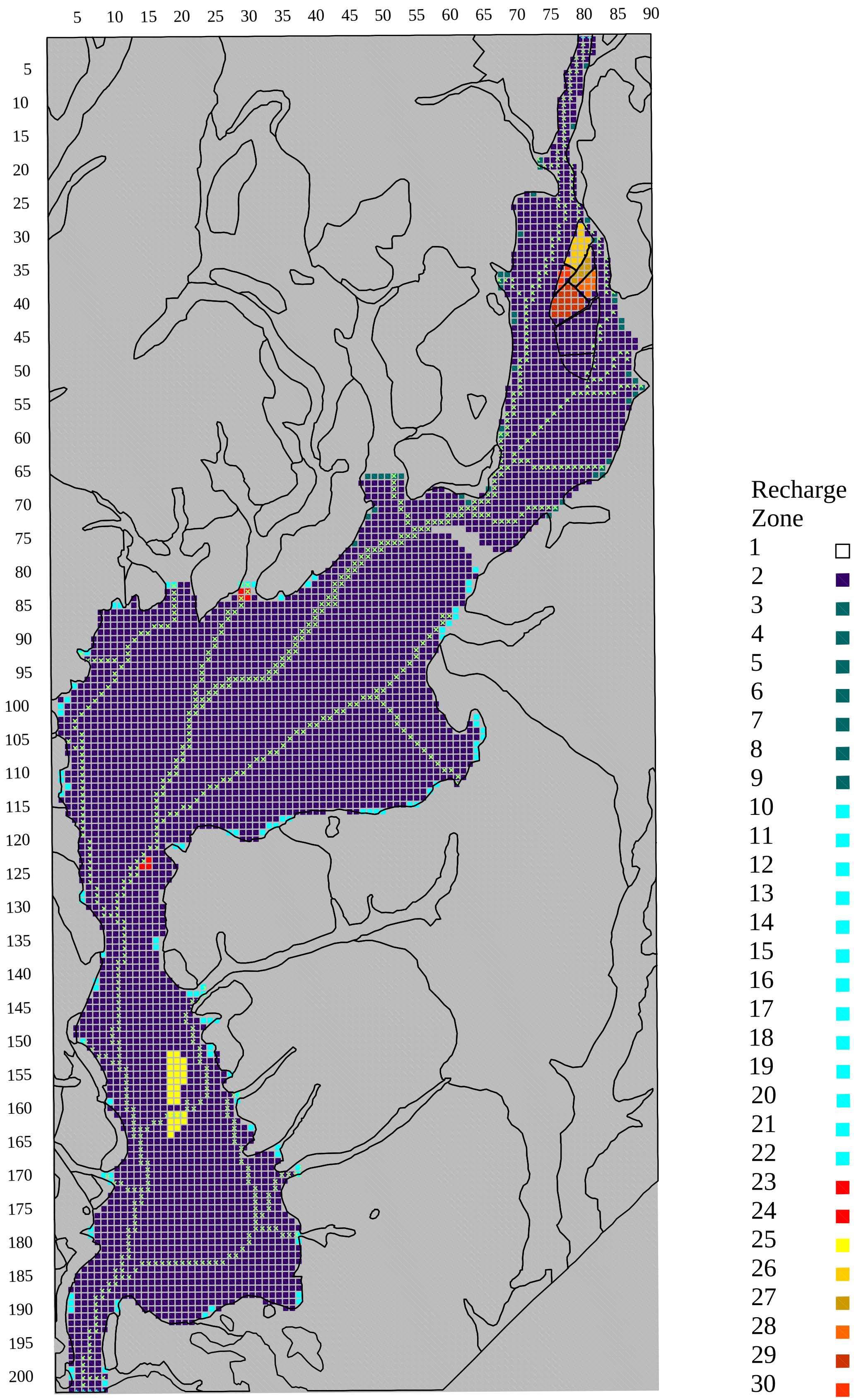
	K_{xy}/K_z (ft/day)	Storativity (1/ft)	Specific Yield (ft^3/ft^3)	Porosity (fraction)
Upper Ysidora Sub-Basin				
Layer 1 sand/gravel	338, 68	0.00002	0.2	0.22
Layer 2 sand/gravel	494, 99	0.000046	0.2	0.22
Chappo Sub-Basin				
Layer 1 near SMR	338, 68	0.00002	0.2	0.22
Layer 1 silt/sand	192, 38	0.00002	0.2	0.22
Layer 1 sand beneath Supply Depot	300, 68	0.00002	0.2	0.22
Layer 2 sand/gravel	300, 68	0.00002	0.2	0.22
Lower Ysidora Sub-Basin				
Layer 1 near SMR	338, 68	0.00002	0.2	0.22
Layer 1 silts w/ sand	192, 38	0.00002	0.2	0.22
Layer 2 sand/gravel	300, 68	0.00002	0.2	0.22

D.3.4.2 Modeled Recharge

Recharge from direct precipitation, side tributary underflow, oxidation ponds, and the recharge basins was simulated in layer 1 of the active model cells (Figure D-9). Attachment 2, Table D-A2-3 contains average annual and average monthly recharge within the model domain.

Recoverable water by runoff and infiltration from rainfall was considered to be approximately 17% of measured precipitation (Crippen, 1965), typical of a Southern California coastal climate. This recoverable water was assigned to the upper model layer as recharge and side tributary runoff. The median annual precipitation from water years 1980 through 1999 was 12.0 in/yr, ranging from 3.6 in/yr in WY 1986-87 to 25.9 in/yr in WY 1979-80. Figure D-9 shows the different recharge zones assigned within layer 1 active model cells.

Using the historical diversion data (OWR, 2000), infiltration rates at the Upper Ysidora recharge basins were calibrated with the ground-water model. The ground-water recharge pond infiltration rates were modeled with a seasonal variation ranging from 0.2 ft/day to 1.8 feet/day to account for percolation of the water diverted from the Santa Margarita River.



Ground-Water Model Recharge Zones

Lower Santa Margarita River

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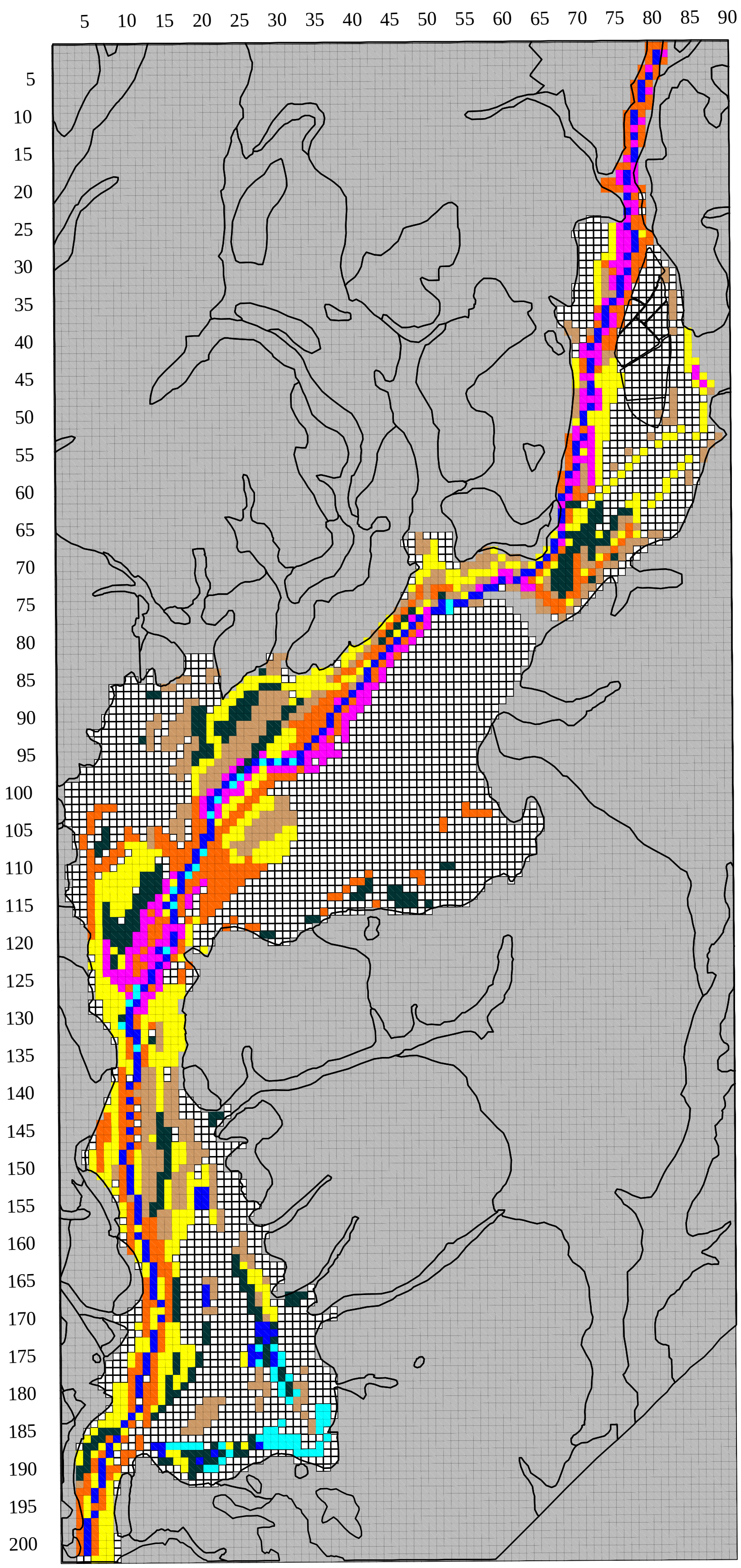
It was estimated that 10% of water stored in Oxidation Ponds 3, 8, and 13 was recharged into the ground-water aquifer (minus evaporation, plus rainfall) and included in the Model for the appropriate years of operation (Carlson, 2000, personal communication). Table D-A2-2 shows the average annual and average monthly recharge from Oxidation Ponds within the model domain

D.3.4.3 Modeled Evapotranspiration

Phreatophyte location and density of coverage was estimated from infrared and aerial photos taken in 1980, 1982, 1989, 1993 and 1997 and a riparian vegetation survey conducted in 1997 (MCB-CP, 2000) to determine ground water consumption by evapotranspiration. Dense cottonwood and willow riparian trees were assigned an ET rate of approximately 60 in/yr and an extinction depth of 20 feet. Dense wetland plants were assigned an ET rate of approximately 45 in/yr with an extinction depth of 8 feet. Different densities of phreatophytes were assigned values proportional to these values. Table D-10 shows the simulated ET zones and densities assigned to layer 1 of the model active cells, and Figure D-10 shows where these zones are located.

TABLE D - 10 MODEL INPUT: ET DENSITIES AND AERIAL COVERAGE BY SUB-BASIN

ET Zone	Vegetative Cover	ET Rate (ft/day)	Extinction Depth (ft)
1	No ET	0.00	20
2	Dense Riparian Trees	0.0118	20
3	75% Riparian Trees	0.0089	20
4	50% Riparian Trees	0.0059	20
5	25% Riparian Trees	0.0030	20
6	Dense Wetlands	0.0089	8
7	30% Wetlands	0.0030	8
8	UY open water	0.0110	3
9	CH open water	0.0104	3
10	LY open water	0.0102	3



Evapotranspiration

Zone	Value
1	0.000e+000
2	1.180e-002
3	8.900e-003
4	5.900e-003
5	3.000e-003
6	8.900e-003
7	3.000e-003
8	1.100e-002
9	1.040e-002
10	1.020e-002

Ground-Water Model ET Zones

Lower Santa Margarita River

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