LOS OSOS GROUNDWATER BASIN UPDATE
ISJ Working Group
May 4, 2010

The ISJ Working Group is working under the auspices of the Interlocutory Stipulated Judgment in the Los Osos Groundwater Basin (Basin) adjudication to draft and implement a Basin Management Plan (BMP). The BMP is in draft form and we expect will be released during 2010. This update discusses the basic elements of the BMP, updated information generated by recent groundwater investigations in the Basin, and various mitigation measures that are being evaluated to remedy water resource challenges facing the Basin.

I. LOS OSOS GROUNDWATER BASIN MANAGEMENT PLAN

The BMP is being created through collaborative participation of members of the ISJ Working Group. The BMP describes the Basin, its hydrologic and geologic settings, community water demands and groundwater quality. The BMP also acknowledges the major challenges facing the Basin, i.e., water quality in the upper aquifer and seawater intrusion in the lower aquifer.

The BMP is designed to memorialize the ongoing and future water monitoring processes, groundwater management goals for the Basin and to outline the mechanisms and processes by which those goals will be achieved. The anticipated goals include the following:

(A) Provide for a continuously updated hydrologic assessment of the Basin, its water resources and safe yield;
(B) Establish a strategy for maximizing the reasonable and beneficial use of Basin water resources;
(C) Provide sustainable water supplies for existing and planned future development within Los Osos;
(D) Stop seawater intrusion into the lower aquifer;
(E) Manage existing contamination and prevent future contamination of the upper aquifer;
(F) Protect environmentally sensitive areas within or influenced by the Basin hydrology;
(G) Quantify each party's rights to rely on the Basin water resources;
(H) Allocate costs equitably;
(I) Develop strategies to maximize the grant funding opportunities for ongoing BMP implementation; and
(J) Set water conservation goals.

The BMP describes in detail the actions that will be taken in order to implement these goals. These actions include determination of Basin water supply and demand, establishment of a groundwater monitoring program, and an operations and recharge plan for the Basin, which will provide for management of salts and nutrients in the groundwater. These actions will be coordinated with the actions to be taken by the County as part of the Los Osos Wastewater Project (LOWWP).

II. BACKGROUND

A. Groundwater Zones

The Basin contains roughly five layers of groundwater, which have been identified, from shallowest to deepest, as Zones A, B, C, D and E. Not all zones are present in all areas of the Basin. Zone A is comprised of Los Osos Creek bed alluvium. Zone B contains perched groundwater. Zones A & B are depicted in Exhibit A. Zones A & B are not generally used for groundwater production and are effectively isolated hydraulically from the underlying aquifers (Zones C, D & E) by an extensive clay layer. Zones C, D and E are the sources of groundwater production from the Basin. Zone C represents the upper aquifer, which suffers from nitrate pollution caused by septic systems. Zone D and Zone E together make up the lower aquifer, which is threatened by seawater intrusion.

B. Safe Yield

Safe yield is generally defined as the maximum draft on a basin that will not produce undesirable impacts. In the LOCSD Draft Water Management Plan produced in 2005, the Basin safe yield under then-current conditions was listed at 3,250 acre-feet per year (AFY), of which 800 AFY was for the Los Osos Creek Valley[1] and 2,450 AFY was for the urban area.

The steady-state groundwater model that has been developed primarily by Cleath + Harris, Inc. on behalf of the ISJ Working Group was updated in 2004, was converted to simulate seawater intrusion in 2005, and in 2008 was updated again to reflect current pumping conditions. The primary constraint on safe yield of the Basin is seawater intrusion. In 2009, the safe yield estimate was updated using the groundwater model. Under current conditions (assuming no Los Osos Creek Valley surplus water development), the overall basin yield estimate is 3,200 AFY. After subtracting 1,100 AFY in agricultural irrigation, private domestic use and golf course irrigation, the purveyors have available for their use an estimated 2,100 AFY of sustainable safe yield. This is comparable to the current level of community demand which has averaged approximately 2,040 AFY over the period from 2004-2008.[2]

Balancing the Basin without supplemental water requires a redistribution of pumping between the upper (Zone C) and lower (Zones D & E) aquifers. In other words, the safe yield analysis has clarified that more pumping should be done from the upper aquifer (Zone C), and less pumping from the lower aquifer (Zones D and E) in order to achieve sustainable safe yield from

[1] The Los Osos Creek Valley, also known as the Creek Compartment, extends from the Eastside (defined below), across the Los Osos Creek Valley to the east limits of the basin.

[2] It should be noted that these figures are estimates based on the existing Basin model, and the ISJ parties will develop the BMP to include a reasonable buffer to account for the uncertainty that exists in every groundwater basin model.

the Basin. In addition, it may be necessary for pumping to shift from the Westside[3] to the Eastside[4] and the Los Osos Creek Valley.

In terms of safe yield by aquifer layer, for a balanced Basin under current conditions the upper aquifer (Zone C) yield is 1,700 AFY (assuming existing nitrate contamination is either removed or adequately treated) and the lower aquifer (Zones D and E) yield is 1,500 AFY. The distribution of upper aquifer versus lower aquifer yield varies across the Basin, however, with most of the lower aquifer yield in the Eastside and Los Osos Creek Valley. After subtracting water production allocated to agricultural irrigation, private domestic use and golf course irrigation, the safe yield distribution for water purveyors is 1,460 AFY from Zone C and 640 AFY from Zones D and E.

C. Seawater Intrusion

As is commonly known, the Basin is experiencing increasing levels of seawater intrusion into the lower aquifer (Zones D and E). Between 1985 and 2005, the average annual rate of intrusion in lower aquifer Zone D was estimated at 60 feet per year for the 250 milligram per liter (mg/l) isochlor line and 45 feet per year for the 2,500 mg/l isochlor line. During this same period, the rate of intrusion for precursor trends (early-detection at lower chloride concentration based on ion ratios) at approximately 200 feet per year between GSWC wells Pecho (13L4) and Rosina (13J4), and approximately 600 feet per year between GSWC Rosina and the LOCSD Palisades well (18L2).

Seawater intrusion monitoring was conducted in December 2009 and January 2010 to update estimates of the rate and extent of seawater intrusion in lower aquifer Zones D and E and to assist in planning, implementing and evaluating sea water intrusion mitigation measures. Results of the current monitoring event, which followed three years of drought conditions, indicate that: the seawater wedge has extended into the lower aquifer through “fingers” as well as a broader front; the average horizontal rate of intrusion between 2005 and 2010, based on the 250 mg/l isochlor, has accelerated to 700 feet per year; and the 250 mg/l isochlor line has reached the LOCSD Palisades well (18L2). The results of the monitoring are reported in the Technical Memorandum from Cleath + Harris, Inc., attached as Exhibit B.

D. Peer Review

The ISJ Working Group and the County have used the groundwater model referenced above to evaluate the safe yield of the Basin and the impact of actions to be undertaken as part of the BMP and LOWWP on the health of the Basin. In order to ensure that the model results are reasonably accurate for its purposes, the ISJ Working Group hired Stetson Engineers, Inc. to perform a peer review of the model. A memorandum describing the results of that peer review is attached as Exhibit C. The key findings are that:

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[3] The Westside of the basin extends west of Palisades Avenue and includes Cuesta-by-the-Sea, Redfield Woods, the Martin Tract, Cabrillo Estates, Sunset Terrace and Monarch Grove.

[4] The Eastside of the basin extends east of Palisades Avenue and includes Baywood, downtown Los Osos, Bayview Heights, Bayridge Estates, mobile home parks on Los Osos Valley Road and all rural residential neighborhoods between South Bay Boulevard and Palomino Drive.

- While there is uncertainty in all models, the SEAWAT model developed by Cleath-Harris Geologists and recent model results appear reasonable.

- SEAWAT is an appropriate model code for the Los Osos basin for evaluation of the average groundwater basin budget (including basin and subarea yields), the extent of seawater intrusion, and for use in evaluating the relative effects of development and changes in basin management or climate.

- The current SEAWAT model and results regarding seawater intrusion and safe yield provide usable results on which to base near-term changes in pumping distribution to mitigate seawater intrusion.

The various recommendations for improvements to the model made by Stetson Engineers, Inc. in the memorandum will be addressed as part of development of the BMP.

III. GROUNDWATER MANAGEMENT ACTIONS

Based on the increasing rate of seawater intrusion described above, it is clear that quick and decisive action must be taken to address the intrusion. Specific actions that are being considered are described below.

A. LOWWP Actions

In order to mitigate the effects of increased seawater intrusion from the removal of septic tank disposal, and to use the tertiary treated wastewater effluent to assist in ensuring a safe and reliable supply of water for the Basin into the future, the County of San Luis Obispo is currently planning to take the following actions as part of the LOWWP, subject to final approval of a Coastal Development Permit by the California Coastal Commission and adoption of a final due-diligence resolution by the County.

1. ***Broderson Disposal.*** Pursuant to Condition 97 of the Coastal Development Permit for the LOWWP, the project will dispose of tertiary treated effluent at the Broderson site, up to approximately 448 AFY.

2. ***Bayridge Leach Field.*** Pursuant to Condition 101, the project will dispose of approximately 33 AFY at the site of the existing Bayridge leach field.

3. ***Indoor Water Conservation.*** Pursuant to Conditions 1, 99, 103 and 108, the project (in consultation with the water purveyors) will implement an indoor water conservation program within the prohibition zone allowing for 50 gallons per capita per day indoor water use.

4. ***Agricultural Reuse.*** Pursuant to Condition 97, the County will apply treated effluent to agricultural re-use overlying the Basin.

5. ***Urban Reuse of Treated Wastewater Effluent.*** Pursuant to Condition 97, the County will apply treated effluent to urban re-use (as identified in the Effluent Re-Use and Disposal Tech Memo, July 2008).

The ISJ Working Group recognizes the above-listed LOWWP actions are crucial to mitigating the negative impacts with which the Los Osos community is faced and that implementation of these measures should be pursued as soon as possible. The group believes these measures are complementary to the additional actions being considered by the ISJ Working Group, which are described below.

B. BMP Actions

The following actions are not being pursued as part of the LOWWP, but the ISJ Working Group is investigating these actions further and considering them as part of the BMP as means of balancing the Basin. The ISJ Working Group is committed to presenting the ISJ parties with a BMP that includes sufficient actions to balance lower aquifer water supplies and demands and stop the progress of seawater intrusion. Potential actions under investigation include the following:

1. ***Relocation of Wells.*** This action would shift the location of a certain amount of groundwater production by LOCSD, GSWC and S&T from the Westside to the Eastside or the Los Osos Creek Valley. Implementation of this action may require the drilling of new groundwater production wells and transmission mains. This action may be integrated with the agricultural reuse described as a LOWWP action above.

2. ***Water Conservation.*** In addition to the indoor water conservation measures being taken under the LOWWP, there may be opportunities to reduce urban water demands in Los Osos based on indoor water conservation outside the prohibition zone and outdoor water conservation throughout the Basin area, primarily through changing landscape types and irrigation methods. For example, commercial and residential irrigation can be automated based on specific plant needs and weather and soil conditions.

3. ***Nitrate Removal from Zone C.*** This action would require the use of well-head treatment facilities to remove nitrates to achieve 1, 400 AFY of safe yield from Zone C.

4. ***Use of Shallow Wells.*** There may be opportunities to reduce pumping from Zones C, D and E by using shallow wells from Zones A and B for irrigation.

5. ***Brackish Water Desalination.*** This action would produce groundwater from areas of Zones D and E that have been affected by seawater intrusion and treat it through a desalination process for municipal use. Strategic location of brackish groundwater production wells may assist in preventing seawater intrusion into new areas of the Basin.

6. ***Rainwater Harvesting*****.** This action would involve working with local property owners to collect rainwater for use on site.

7. ***Installation of Greywater Systems*****.** This action would involve working with local property owners to install greywater systems, by which certain types of wastewater are treated and reused on site.

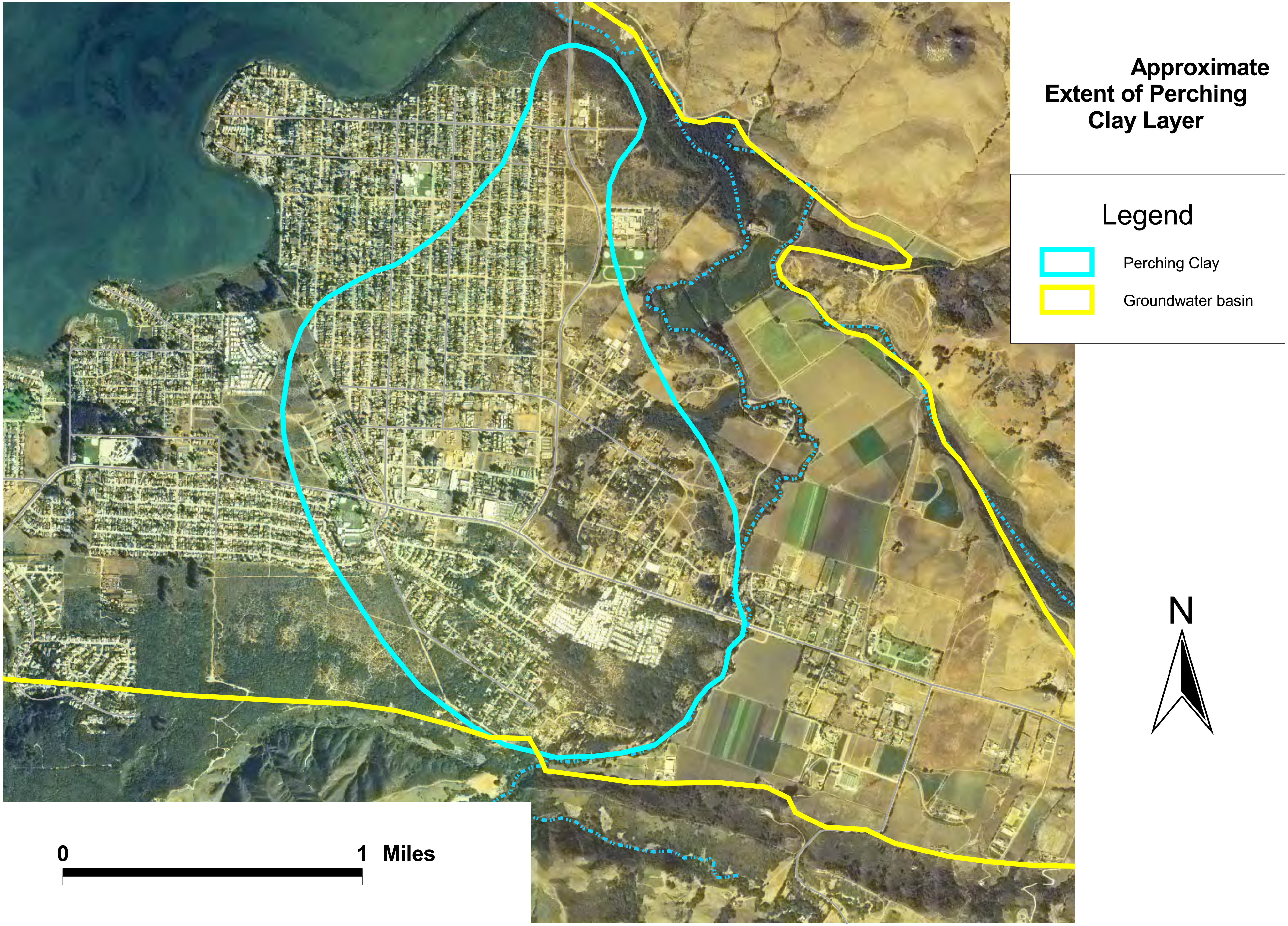
Many of these actions would involve leadership or participation by the water purveyors, as well as residents and businesses within the Los Osos community.

IV. NEXT STEPS

The ISJ Working Group is currently studying the actions above and intends to prepare a public review draft of the BMP by the end of 2010. The BMP will include a financing strategy and timeline for implementation of adopted actions.

SB 542232 v6:006774.0151

EXHIBIT "A"



Approximate
Extent of Perching
Clay Layer
Legend
Perching Clay
Groundwater basin
N
0
1
Miles

EXHIBIT "B"

Cleath-Harris Geologists, Inc.
11545 Los Osos Valley Road, Suite C-3
San Luis Obispo, California 93405
(805) 543-1413

CHG

Technical Memorandum

PROFESSIONAL GEOLOGIST
SPENCER J. HARRIS
No. HG 633
CERTIFIED HYDROGEOLOGIST
EXP. 10/31/11
STATE OF CALIFORNIA

Date: April 26, 2010
From: Spencer Harris
To: Los Osos ISJ Group

SUBJECT: Water Quality Monitoring Results Summary, November 2009 - January 2010, Los Osos Valley Groundwater Basin.

Water quality monitoring in the Los Osos Valley groundwater basin was conducted between November 2009 and January 2010. The purpose of monitoring is to update estimates concerning the rate and extent of sea water intrusion in the lower aquifer and to assist in planning, implementing, and evaluating sea water intrusion mitigation measures. The analytical results of groundwater samples collected from basin wells are presented in the attached Table 1.

Between 1985 and 2005, the average annual rate of intrusion in lower aquifer Zone D was estimated at 60 feet per year for the 250 milligram per liter (mg/l) isochlor line and 45 feet per year for the 2,500 mg/l isochlor line. These were the average annual rates estimated over the time period. Data from the 2005 study also showed the rate of intrusion for precursor trends (early-detection at lower chloride concentrations based on ion ratios) at approximately 200 feet per year between Golden State Water Company (GSWC) wells Pecho (13L4) and Rosina (13J4), and approximately 600 feet per year between GSWC Rosina and the Los Osos Community Services District (LOCSD) Palisades well (18L2).

Rates of sea water intrusion are affected primarily by water levels (pressure gradients), and aquifer permeability. The rate of intrusion is typically not uniform over time, but varies seasonally according to pumping cycles, and is accelerated during drought periods. Intrusion may also not be uniform within the aquifer zones, but may follow preferential pathways along discrete sand and gravel layers being tapped by pumping wells.

Results of the current monitoring event, which followed three years of drought conditions, indicate the average horizontal rate of intrusion between 2005 and 2010, based on the 250 mg/l isochlor, has accelerated to match the earlier precursor rates (up to approximately 700 feet per year), and has reached the LOCSD Palisades well (18L2). Evidence of accelerated seawater intrusion since 2005 has also been confirmed with geophysics at a deep monitoring well (13M1), where there has been a vertical rise in the seawater interface of 25 feet since the 2005 survey. By comparison, the sea water interface rose 30 feet at Well 13M1 between 1985 and 2005. The estimated location of the transition zone at the base of aquifer Zone D (250 mg/l isochlor) is shown in plan view in the attached Figure 1, with a cross-section of the transition zone movement in Zones D and E shown in Figure 2. An illustration showing the upward movement of sea water intrusion at monitoring well 13M1 is shown in Figure 3.

EXHIBIT "B"

Table 1
Water Quality Results - Sea Water Intrusion Monitoring
Los Osos ISJ Group

Station ID	Well Name	Sample Date	HCO3	Hardness	Cond	pH	TDS	Cl	NO3	SO4	Ca	Mg	K	Na
			mg/l	mg/l	mg/l		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
30S/10E-12J1	MBO5 DWR Obs.	11/20/2009	300	360	1150	7.5	732	83	ND	190	51	58	4.4	95
30S/10E-13J4	GSWC Rosina	1/14/2010	35	260	778	6	435	200	7.1	13	41	38	1.5	33
30S/10E-13L4	GSWC Pecho	11/20/2009	85	550	1610	7	979	460	10	48	91	78	2.1	69
30S/10E-13L7*	S&T #4	11/19/2009	60	110	410	6.9	270	49	59	14	18	15	1.4	38
30S/10E-13M2	Howard East	12/9/2009	55	1100	3740	7.1	2170	1100	2.2	220	160	160	4.8	370
30S/10E-13N	S&T #5	11/19/2009	41	89	386	6.8	267	73	27	11	15	13	1.4	38
30S/10E-24C1	GSWC Cabrillo	11/20/2009	60	150	611	7.1	347	130	18	22	23	22	1.6	52
30S/11E-7Q3	LOCSD 8th St.	11/19/2009	220	290	782	7.4	465	92	ND	46	46	42	1.9	53
30S/11E-17E7**	So. Bay Obs. Deep	11/19/2009	ND	100	1100	11.2	427	110	6.1	54	39	1	8.7	110
30S/11E-17E8	So. Bay Obs. Middle	11/20/2009	120	160	455	7.3	255	42	19	12	25	23	1.3	29
30S/11E-17N10	GSWC So. Bay #1	11/20/2009	230	220	638	7.3	357	41	2.4	30	35	33	1.7	37
30S/11E-18K8	10th St. Obs. East	11/20/2009	230	220	620	7.5	378	32	ND	40	51	24	1.8	23
30S/11E-18K9	LOCSD 10th St.	11/20/2009	180	160	539	7.2	307	36	4.6	27	27	24	1.3	32
30S/11E-18L2	LOCSD Palisades	11/19/2009	200	590	1460	7.2	890	360	1.8	39	94	86	2	44
30S/11E-18L6	Palisade Obs. 6"	12/9/2009	270	380	856	7.5	528	68	ND	85	70	50	2.2	36
	18L6 @ 400'	12/9/2009	280	400	857	7.3	535	68	ND	85	76	52	2.2	35
	18L6 @ 500'	12/9/2009	260	440	856	7.4	521	68	ND	84	81	59	2.5	42

ND = Not Detected

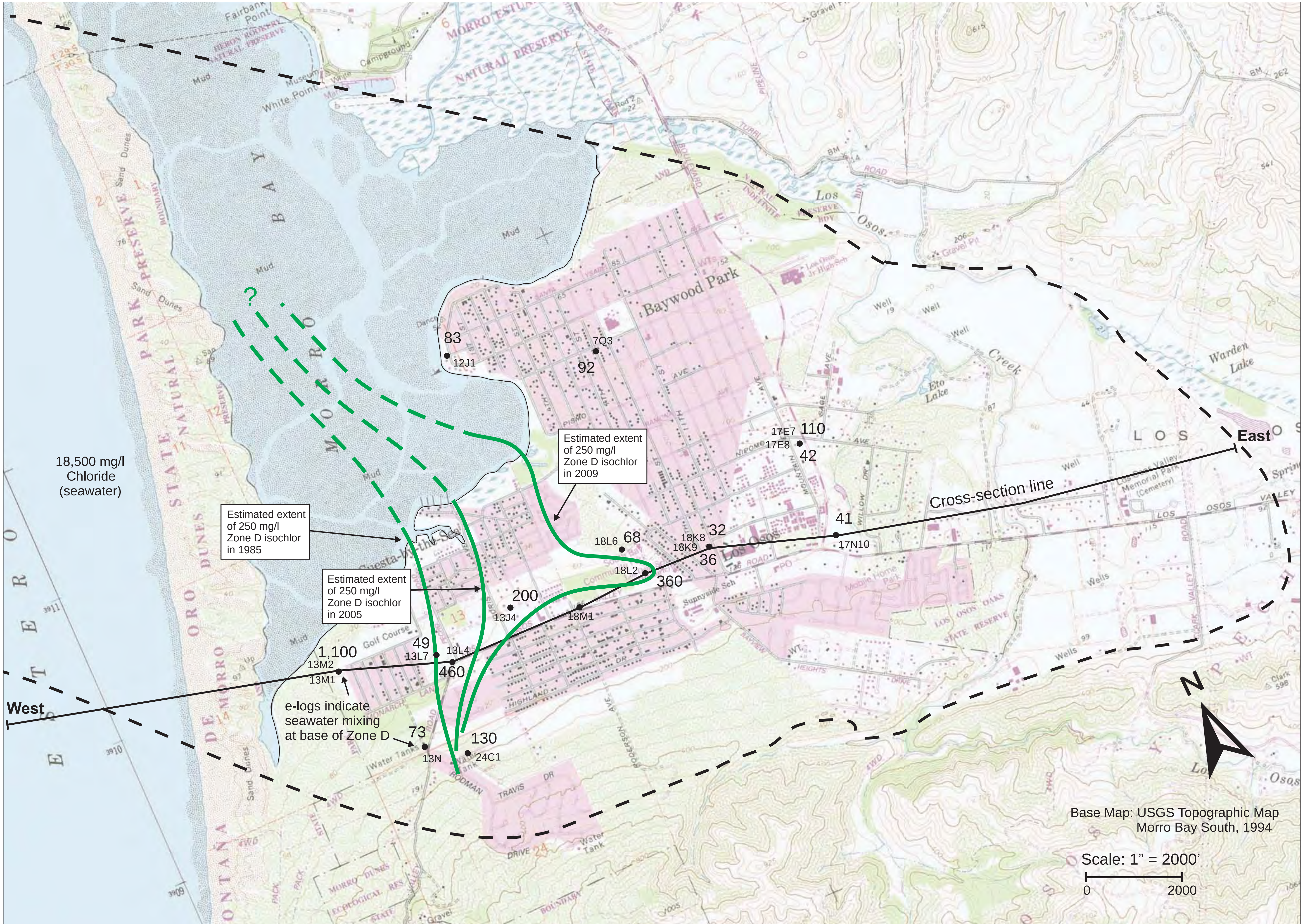
*Water sample from 13L7 affected by borehole leakage from upper aquifer

**Water sample from 17E7 affected by high pH. Alkalinity 140 mg/l as carbonate and hydroxide

Legend and Detection Limits

General Mineral	Description	Detection Limit for Reporting
HCO3	Bicarbonate Alkalinity in mg/L CaCO3	2.0
Hardness	Total Hardness in mg/L CaCO3	1.0
Cond	Electrical Conductance in μmhos/cm	1.0
pH	pH in pH units	0.1
TDS	Total Dissolved Solids in mg/L	10.0
Cl	Chloride concentration in mg/L	1.0
NO3	Nitrate concentration in mg/L	0.4
SO4	Sulfate concentration in mg/L	0.5
Ca	Calcium concentration in mg/L	0.03
Mg	Magnesium concentration in mg/L	0.03
K	Potassium concentration in mg/L	0.10
Na	Sodium concentration in mg/L	0.05

EXHIBIT "B"



Explanation

83 / 12J1 — Well location with Nov. 2009 - Jan 2010 chloride data

Estimated extent of 250 mg/l Zone D isochlor

NOTE: the isochlor lines are interpreted from water quality and geophysical data, and include consideration of well construction and use.

approx. basin limits

Figure 1

Lower Aquifer
Chloride Concentrations
Nov. 2009-Jan. 2010

Los Osos ISJ

Cleath-Harris Geologists, Inc.

EXHIBIT "B"

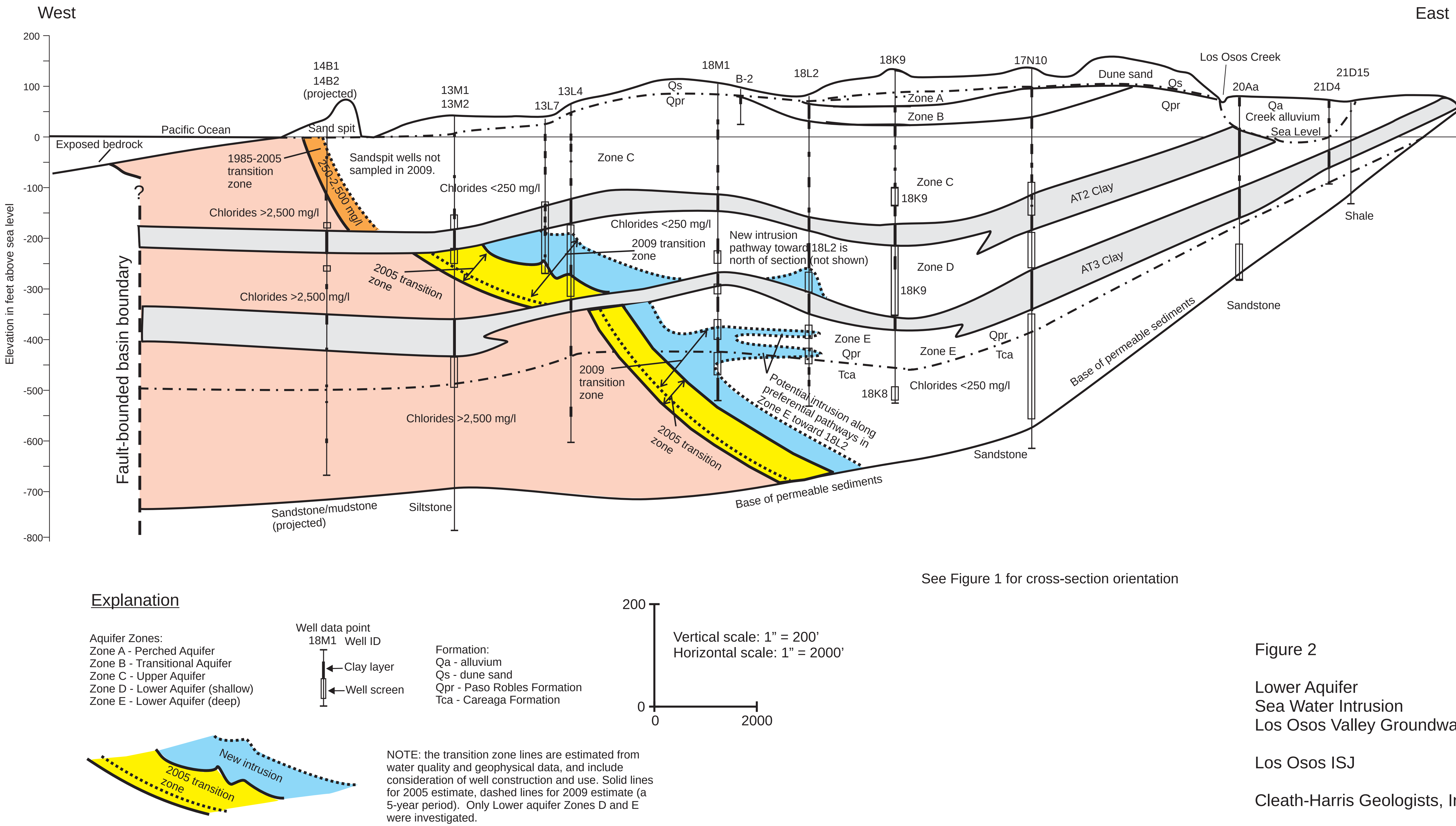


Figure 2

Lower Aquifer
Sea Water Intrusion
Los Osos Valley Groundwater Basin

Los Osos ISJ

Cleath-Harris Geologists, Inc.

EXHIBIT "B"

Well 30S/10E-13M1

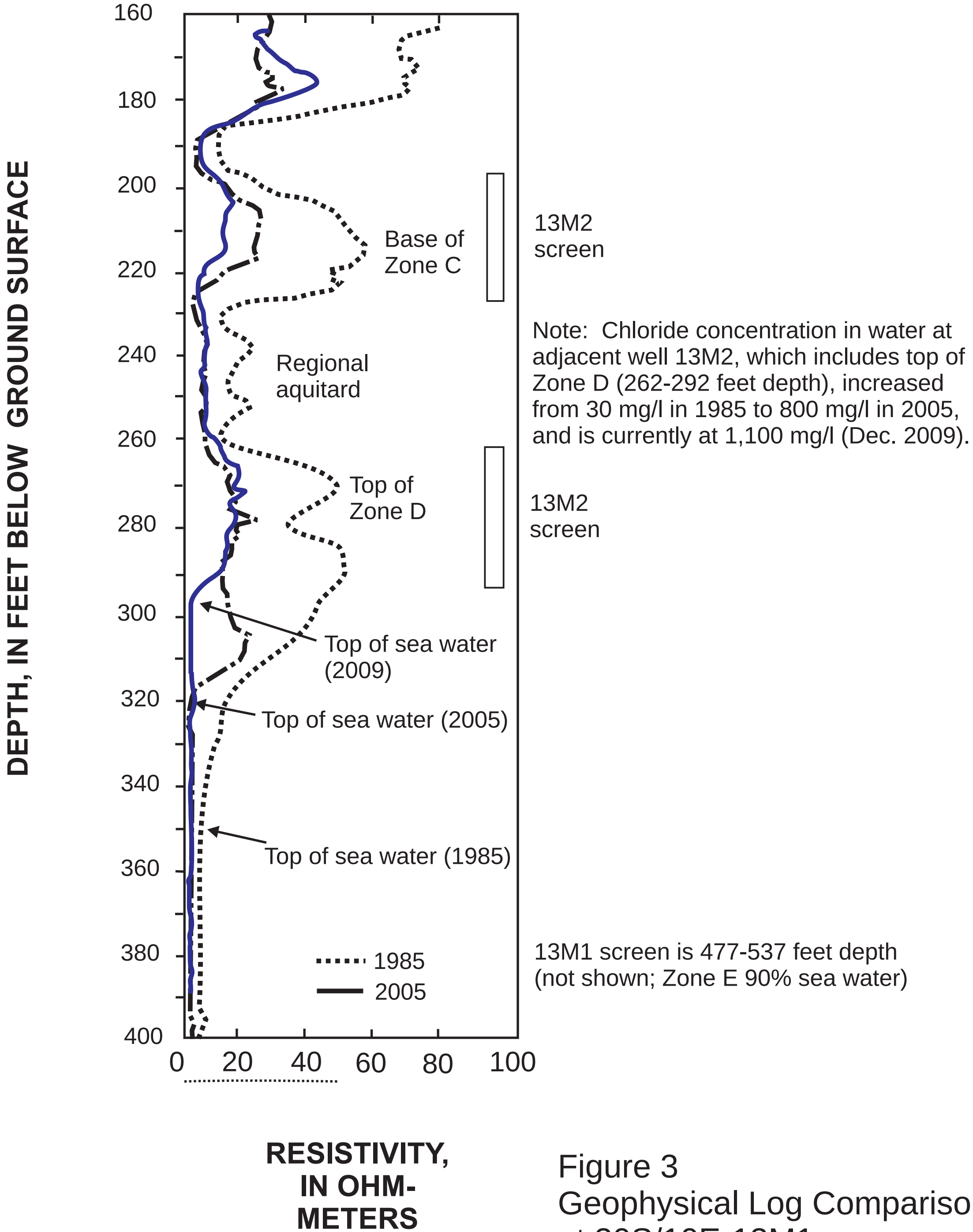


Figure 3
Geophysical Log Comparison
at 30S/10E-13M1

Los Osos ISJ

Cleath-Harris Geologists, Inc.

EXHIBIT "C"

TECHNICAL MEMORANDUM

STETSON ENGINEERS INC.

2171 E. Francisco Blvd., Suite K • San Rafael, California • 94901
TEL: (415) 457-0701 FAX: (415) 457-1638

TO: Mr. Robert Miller, Wallace Group DATE: May 3, 2010

FROM: Peter M. Pyle, P.G., CHG. JOB NO: 2323

RE: Peer Review of the Los Osos Groundwater Model

Stetson Engineers Inc. was contracted by Brownstein Hyatt Farber Schreck, LLP, on behalf of the ISJ Parties to review and evaluate the groundwater model and related technical studies to determine the validity of the model and assumptions. We were also tasked with providing an opinion on the safe yield estimates determined using the model for the urban area and Los Osos Creek Valley portions of the groundwater basin with consideration of climate fluctuations. The contact for the ISJ Parties is Robert Miller of Wallace Group in San Luis Obispo who is managing the contract. Much assistance and additional data was provided by Mr. Spencer Harris of Cleath-Harris Geologists, Inc. (CHG).

Stetson Engineers, Inc. performed the following tasks for this peer review:

1) Reviewed key documents specified in the request for proposals (RFP) as well as additional information listed below.
2) Attended a kickoff meeting with the ISJ Technical Group in December 2009.
3) Conducted a one-day model work session with Spencer Harris of Cleath-Harris Geologists, Inc. of San Luis Obispo.
4) Reviewed the model electronic data and output.

Stetson Engineers, Inc. reviewed the following key reports for this study:

1) Seawater Intrusion Assessment and Lower Aquifer Source Investigation of the Los Osos Valley Groundwater Basin, Cleath and Associates, October 2005.
2) Flow Model Conversion and Urban Area Yield Update, Cleath-Harris Geologists, Technical Memorandum, July 2009a.
3) Los Osos Creek Valley Yield Evaluation, Cleath-Harris Geologists, Technical Memorandum, July 2009b.
4) Appendix D of the Draft Environmental Impact Report, Los Osos Waste Water Project, County of San Luis Obispo, November 2008.

In addition to those studies, the following reports and data were reviewed:

1) Simulated effects of a Proposed Sewer Project on Nitrate Concentrations in the Los Osos Valley Groundwater Basin, prepared for LOCSD and Cleath and Associates, Yates and Williams, November 2003.
2) Hydrogeology and Water Resources of the Los Osos Valley Groundwater Basin, USGS WRIR 88-4081, Yates and Wiese, 1988.
3) Conducted phone discussions with Spencer Harris of CHG on model input and output and basis for key model assumptions.
4) Sent via email requests for selected data and model sensitivity analyses, and reviewed and evaluated these additional data.
5) Los Osos Wastewater Management Plan Update, Technical Memorandum #3, Ripley Pacific Team, July 2006.
6) Comments regarding the Ripley Pacific Team's Technical Memorandum #3, Los Osos Wastewater Management Plan Update, Cleath and Associates, October 2006.
7) A Practical Guide to Groundwater and Solute Transport Modeling, Spitz and Moreno, 1996.
8) Applied Contaminant Transport Modeling, Zeng and Bennett, 1995.
9) A critical review of data on field-scale dispersion in aquifers, Gelhar and others, 1992.

Summary of Findings

While there is uncertainty in all models, the SEAWAT model developed by Cleath-Harris Geologists and recent model results (CHG, 2009a, b) appear reasonable. However, we have several recommendations; 1) The need for additional model documentation including definition of model limitations and uncertainty in the results and technical basis for input data, 2) Model refinement and additional scenarios including evaluation of climatic variability other than sea level rise and development of a monthly transient flow model using the model structure from the existing model with the addition of the STR package of Modflow. The recommendations are discussed in more detail in the various subsections and under Recommendations, below.

The scenario described in CHG (2009b) regarding redistribution of pumping in the basin with an increase in pumping the Los Osos Creek subbasin is reasonable and could be initiated without further modeling or analysis, provided the change is gradual, with continued water level and water quality monitoring and analysis. The model could be updated as the effects of that plan/strategy become more fully understood. The recommended approach is phased redistribution of pumping with contingency plans in place to make adjustments as needed and as ongoing monitoring data indicate.

Model Data and Assumptions

This section of the peer review focuses on important model structure and input data that can significantly affect model results.

Model Structure

Cleath and Associates (2005) report contains the information used as a basis for the current SEAWAT model of the Los Osos groundwater basin including the hydrogeology and structure of the basin, aquifer hydraulic parameters, sources of recharge, water quality (including isotope analysis) and the extent of seawater intrusion. Those data provide a strong foundation on which to build the groundwater flow and seawater intrusion model. The current (CHG, 2009a,b) SEAWAT model consists of four layers representing the three primary water bearing units in the basin and a thick aquitard that extends throughout much of the basin.

Based on the data and reports reviewed, the structure of the model is sound and can effectively simulate hydrologic processes in the groundwater basin, particularly as regards the different characteristics and extent of seawater intrusion in each of the main water bearing units (Zones C, D and E). The Los Osos creek subarea on the eastern side of the Los Osos basin has a slightly different structure which the current model (CHG, 2009 a,b) also suitably represents. The model grid is uniform at 250 x 250 feet which is reasonable for the Los Osos basin given its scale, density of data, and resolution required of model results.

Hydraulic Parameters

A key hydraulic parameter that controls groundwater and seawater flow in the model is horizontal hydraulic conductivity (Kh). Its distribution by layer were requested from CHG and reviewed. The distribution is shown for each model layer in the attached Figures 1 through 4. This distribution was discussed with Mr. Harris and compared to that of pumping test results presented in Cleath and Associates (2005), and supplemental data provided by Mr. Harris.

The K distribution by layer seems appropriate and honors the field test data, which need not be precisely replicated in the model due to field data limitations and scale. I had questions regarding the K distribution representing the Los Osos Creek alluvium which appeared different from that of typical stream alluvium. However, discussions with Mr. Harris confirmed that the K values used in that area honor the unique geology of this region.

This type of information (maps and discussion of aquifer hydraulic properties) should be included in a future report on the SEAWAT model used in the CHG (2009a,b) studies.

Recharge Preprocessor

The 2009 SEAWAT model does not include the upper two geologic units which occur in the western two thirds of the basin including the perched aquifer (Zone A) and the transitional aquifer (Zone B). The upper zones are not generally used for production and are effectively isolated hydraulically from the underlying aquifers (Zones C, D and E) by an extensive clay layer. An unsaturated zone exists between the clay layer and the underlying aquifers although there is some leakage that occurs through it. SEAWAT cannot simulate unsaturated flow while the more recently developed GSFLOW code developed by the USGS has that capability. This limitation of SEAWAT requires that recharge to the saturated flow portion of the model from precipitation, minor tributaries, return flow from irrigation and septic tank seepage be determined by other methods.

For the Los Osos basin this method has been a spreadsheet preprocessor developed by Yates and Williams (2003). That report briefly describes this recharge and nitrogen loading preprocessor program which calculates deep percolation. This model preprocessor was not evaluated in detail for this review. There are many parameters and sources of data which are used in that preprocessor, some of which were changed to develop input for the CHG 2009 SEAWAT model. An Excel worksheet containing the model and input data was provided by Mr. Harris for this review, but the input data could not be evaluated in detail in the time available.

It is suggested that the preprocessor documentation be updated such that the input data sources and methods of calculating deep percolation and evapotranspiration is transparent. Changes to the model for use in successive models should be sufficiently described, accessible and readily available for review. Flow diagrams showing how the spreadsheet preprocessor works and its most sensitive variables should be included. We do not have a suggestion at this time as to whether the preprocessor could be improved or replaced by a more conventional unsaturated flow model due to our limited knowledge of it. However, model code refinements may be available in the near future that will allow simulation of unsaturated flow and seawater intrusion using the same basic data sets as currently used in the current Los Osos model. It is suggested that the model be updated to include unsaturated flow when possible.

Representation of Los Osos Creek

The recharge pre-processor does not include calculation of the recharge from Los Osos Creek to the aquifer in the Los Osos Creek subarea. This is an important component of the model because it allows an increase in recharge as water levels decline in that area due to proposed increased pumping (CHG, 2009b). Recharge is controlled by the model using the RIV module which allows river/creek seepage based on the water level in the creek, the head in the aquifer beneath the creek, and a coefficient based on the width of the creek, creek bed thickness and vertical permeability. While use of the RIV module can produce usable results for this type of creek, the

STR module could have provided a better calibration. The STR module allows the stream flow to reduce or cease during dry periods or seasons, thus providing a limit to how much seepage/recharge can occur from the creek to the aquifer. A recent version of SEAWAT (late 2009 available in GW Vistas updates) is available and should be used in updated versions of the Los Osos model.

In order to evaluate whether the RIV module was properly used to represent Los Osos Creek seepage, two analyses were performed. For the first, Creek flow data and a precipitation graph with a cumulative departure curve was requested from CHG. The Creek flow data is shown in Figure 5. It shows that data is missing for 1983, a wet year, and 1985-93 most of which were dry years. The wet or dry year condition was determined using long term precipitation data with a cumulative departure curve requested from CHG (Figure 6). A comparison of Figures 5 and 6 indicate the creek flow data is skewed to wet years.

The average creek flow for all of the years shown is 3,940 afy with a median of 2,230 afy. If a balance period is selected (Figure 6) which is limited to 1979-81 creek flow data (Figure 5), the average is 2,326 afy with a median of 1,630 afy. This suggests that no more than about 1,600 afy should be allowed by the model to seep from the stream to the underlying aquifer. The results of the increased pumping in the Los Osos creek subarea by CHG (2009b) is well within this limit at 1,013 afy. In addition, the gage from which the flow data in Figure 5 was obtained is located somewhat downstream from the basin and model boundary such that some seepage to the aquifer can occur in the groundwater basin upstream of the gage. The STR package will allow more accurate representation of stream leakage in future revisions of the model.

The second analysis requested of CHG was a sensitivity analysis of the conductance coefficient used in the model RIV module representing Los Osos Creek. CHG went farther than that and performed a sensitivity analysis on all other RIV variables including head in the River. The results of that sensitivity analysis indicate that for a change in creek bed permeability of 100% the change in seepage is less than 1%. For a change in stream bed permeability of 100% and stream width increase of 100% the change in seepage is also less than 1%. The amount of seepage is more sensitive to stream stage with an increase in stream stage of 0.5 feet resulting in an increase in seepage of about 1.4% which is still not large. Mr. Harris has indicated he is aware of this sensitivity and has calibrated stream stage so as not to allow seepage in excess of available stream flow. Again, use of the more recent version of SEAWAT with the STR package and run in transient mode with monthly data, will improve model reliability with respect to the effects of increased pumping in the Los Osos Creek subarea.

<u>Seawater Intrusion Coefficients</u>

Seawater intrusion into the Los Osos groundwater basin is primarily effected by the relative elevations of the ocean and head in each aquifer, difference in fresh and seawater density and the aquifer coefficient of dispersion, particularly the longitudinal component (dL). This coefficient is an unknown that is dependent upon aquifer permeability and the scale of the intrusion problem. Three technical references were reviewed to evaluate the potential range of this variable for the Los Osos basin, as noted above. CHG was requested to perform a sensitivity analysis of the coefficient of longitudinal dispersivity. The results are shown below in Tables 1 and 2 for the 50 year calibration.

Table 1. Chloride 250 mg/l isochem - Distance from coastline 2005 (in feet)

Model Zone/Layer	Measured/Estimated	Calibration (dL/dT/dV)	Low range (dL/dT/dV)	High Range dL/dT/dV
		(100/20/2)	(10/2/0.2)	(200/40/4)
C/1	1,500	2,000	2,000	2,000
D/3	2,500 – 5,500	2,500 – 5,400	2,400 – 5,100	2,600 – 5,700
E/4	3,000 – 7,500	3,000 – 4,800	2,900 – 4,500	3,000 – 5,000

Note: dL = Longitudinal Dispersivity, dT =Transverse Dispersivity, dV = Vertical Dispersivity

Table 2. Change in distance of Chloride 250 mg/l isochem relative to calibration (in feet)

Model Zone/Layer	Calibration (dL/dT/dV)	Low range (dL/dT/dV)	High Range (dL/dT/dV)
	(100/20/2)	(10/2/0.2)	(200/40/4)
C/1	0 ft	0	0
D/3	0	-300	+300
E/4	0	-250	+250

The longitudinal, transverse and vertical dispersivities are related and are generally express as a ratio. Table 1 indicates the model simulated accuracy relative to the dL of 100 used in the model and to a wide range of values. Table 2 indicates the relative sensitivity of the model to the same range. The results indicate the model is surprisingly insensitive to longitudinal dispersivity and that the differences in simulated intrusion under the wide range of coefficients simulated is only 300 feet or about one model cell width after 50 years.

In addition to the analyses discussed above, Stetson Engineers requested that CHG provide a composite map of the simulated and measured extent of seawater intrusion as of 2005, the end of the 50 year calibration period to determine visually how well the model matches the data base on the 250 mg/l Chloride isochem. Figure 7 shows the results provided by CHG where the green area represents the 250 mg/l Chloride isochem as a wedge in Zone D due to density differences and the blue line (0.03 isochem) represent the model simulated extent of the 250 mg/l Chloride isochem in the middle of the aquifer. The model appears to match the data relatively well. A comparison of columns 2 and 3 in Table 1 provides a more precise measure of this difference.

SEAWAT Model Limitations

The current transient calibration for the SEAWAT model only represents three multi-year period and the predictions are run with steady-state (average hydrologic) inputs. This increases the uncertainty in the model for calibration and prediction of monthly water levels, recharge, stream seepage and storage change during critical dry periods. While the model structure is in place for developing a monthly transient calibration, it may take significant time and effort to calibrate the SEAWAT model. This is primarily due to known problems with numerical instability in SEAWAT when running in transient mode. This effort may be warranted in the long term but, in the short term the suggested redistribution of pumping to the Los Osos Creek area need not be delayed. In future model updates it is suggested that the model be calibrated with monthly stress and the STR package to better represent Los Osos Creek seepage to the underlying aquifer.

While careful use of the RIV module can result in reasonable results as discussed above, this is still a model limitation that, when combined with the absence of a transient SEAWAT calibration is of concern with respect to more precise evaluation of management alternatives. Note that what is suggested is more accurate predictions, and not that the current SEAWAT model does not provide useful results.

Model Results and Uncertainty

Although it was not a part of the scope of work for this review, it was hoped that an estimate of the uncertainty of the extent of predicted sweater intrusion and subbasin safe yield under future management scenarios could be provide in this review. However, as with most models, this is best defined by the developer of the model who is most familiar with the model, its input data and limitations. As suggested below, some estimate should be placed on these model results (current and future) for the purpose of assisting decision makers in allowing consideration of alternate plans should the model not prove100% accurate.

All models have an inherent degree of uncertainty. That does not invalidate their results, but knowing the uncertainty in key results is important for the planning process. In this case, such planning could include a gradual shift in municipal pumping to the Los Osos Creek subarea with appropriate monitoring to evaluate the effects of such a change, which will likely be slow to occur. Planning could therefore include various steps that could be taken should underpredicted, but not surprising results occur. For example large storage declines during dry periods in the Los Osos Creek subarea when pumping there is increased, or seawater intrusion does not slow at the rate expected, or the reduction in septic tank seepage does not slow at the rate expected, etc.

Seawater Intrusion

The model calibration provides reasonable results as noted above. However, there is likely some uncertainty regarding the exact extent of the landward movement of seawater intrusion under predictive scenarios. It is important to note that when making a comparison between predictive model simulations that the relative difference between the extent of seawater intrusion that is important for evaluating basin management alternatives rather than the absolute value of the extent of seawater intrusion or specific Chloride concentrations at any one location due to model limitations discussed above.

Given the limitations of SEAWAT, the Recommendations discussed below include suggestions for evaluating dry period, seasonal and intermittent stream conditions by updating the current model using monthly transient stress periods.

Safe Yield Estimates

The safe yield estimate for the Urban Area of 3,200 afy (CHG, 2009a) is a reasonable long term average estimate, but with limitations discussed above regarding the uncertain response of the aquifers during extended dry periods. It is suggested that a +/- value be added to that estimate based on model uncertainty.

The SEAWAT limitations regarding the RIV module to simulate leakage to the aquifer have been address above, and the additional recharge under the scenario of expanded pumping in this area is reasonable due to consideration of this limitation by CHG. An uncertainty range could also be added to the Los Osos Creek subarea safe yield estimate of 3,150 afy (CHG, 2009b) for the same reasons. Additional recharge from Los Osos Creek is an important component of this estimate. Improvements in model accuracy could be made through a monthly transient calibration of the existing SEAWAT model using the updated code with STR package capability. Reporting on an improved version of the model should still include a section on uncertainty.

Conclusions

The current SEAWAT model and results regarding seawater intrusion and safe yield provides usable results on which to base near-term changes in pumping distribution to mitigate seawater intrusion (CHG, 2009a, b). However, it is suggested that uncertainty values should be assigned by CHG to the model results given the model limitations to assist decision makers in their choice of action and any additional measures that should also be considered. Our involvement with the USGS in other basins indicates they include, and recommends others include, a limitations and uncertainty section in model documentation (W. Danskin, USGS Research Hydrologist, 2009). SEAWAT is an appropriate model code for the Los Osos basin for evaluation of the average groundwater basin budget (including basin and subarea yields), the extent of seawater intrusion, and for use in evaluating the relative effects of development and changes in basin management or climate variability.

Recommendations

Although recommendations were not requested as part of this review, they are included in the text above and summarized below.

1) Add uncertainty values to seawater inflow extent and rate, and safe yield estimates in CHG (2009 a,b) and future model documentation, memos, etc.
2) Calibrate SEAWAT in monthly transient mode and use the STR package to represent Los Osos Creek. Use a long period of record that includes the critical dry period for the region. Repeat the same hydrologic period for predictive simulations.
3) Continue to review climate change literature and determine if a comprehensive scenario regarding climate change should be run using an updated version of the model.
4) Write up the Yates preprocessor used to estimate deep percolation to the saturated flow model (SEAWAT, MODFLOW, etc) including diagrams, screen capture or other method to show how model the works, include the source of model input data, what variables are usually changed for predictive runs and which variables are most sensitive. This preprocessor provides significant input to the flow models and more complete information is needed.
5) Additional model documentation is needed on the SEAWAT model for the Los Osos Creek Basin including assumptions, maps of hydraulic property distributions by layer, stream input data, reference to the unsaturated flow preprocessor and changes to input for model simulation, and other details sufficient for a complete understanding of the model.
6) For the benefit of users of model results, future reviewers or model users it is suggested that a summary of Los Osos models and related documents be prepared. This documentation should include, at a minimum, a table with; a) the model code used, b) whether transient or steady state, c) period simulated (calibration and prediction) and stress period length, d) if Yates preprocessor or other method used to estimated deep

percolation, f) if transport, which species were simulated, and g) date and title of key documentation. This would have saved the reviewer a lot of time in trying to determine relevance and differences between these models listed below.

- Yates and Weise,1988
- Yates and Williams, 2003
- URS, 2000
- CHG 2005
- CHG 2009a, b

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EXHIBIT "C"

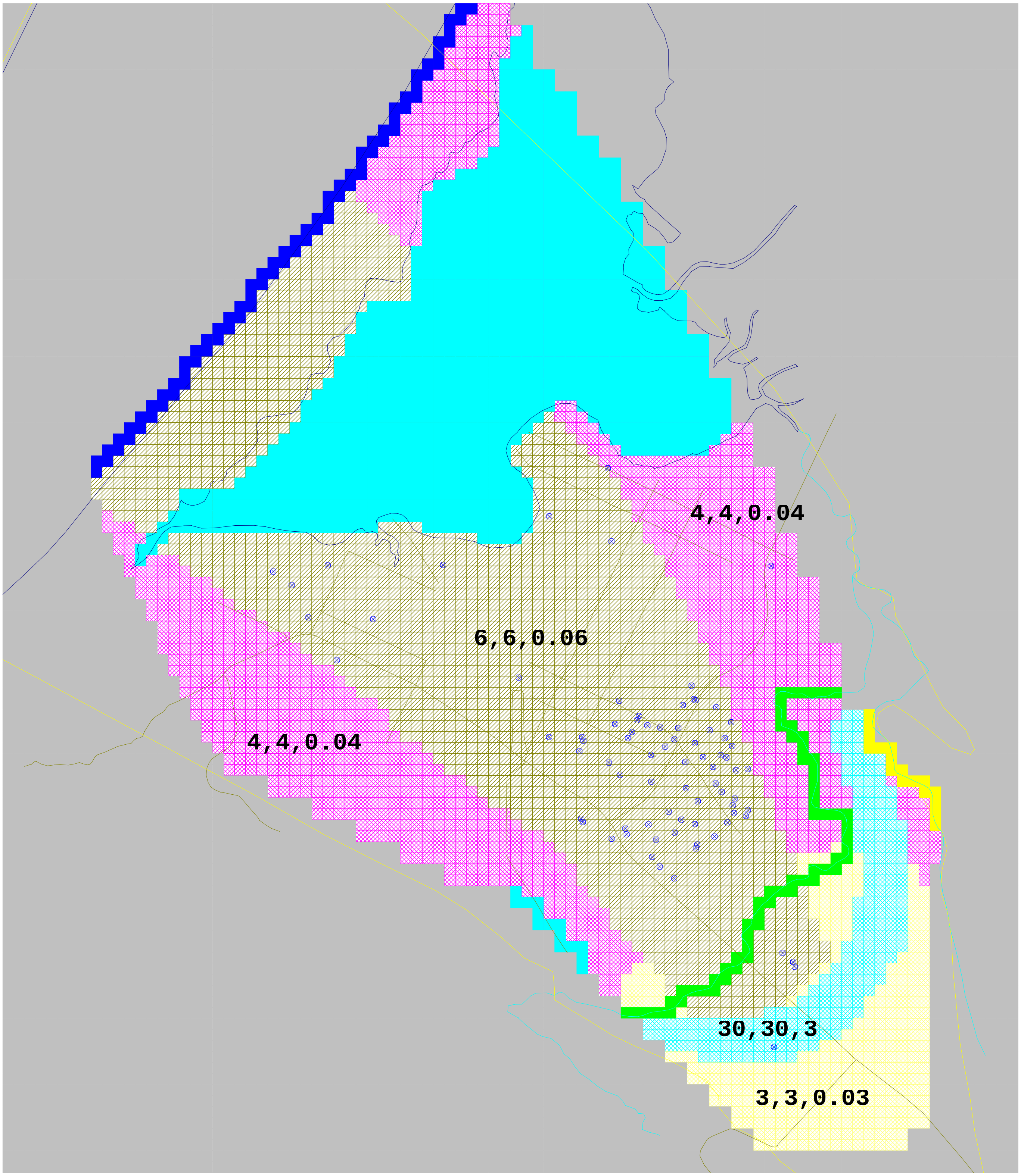

Figure 1. Horizontal Hydraulic Conductivity - Layer 1

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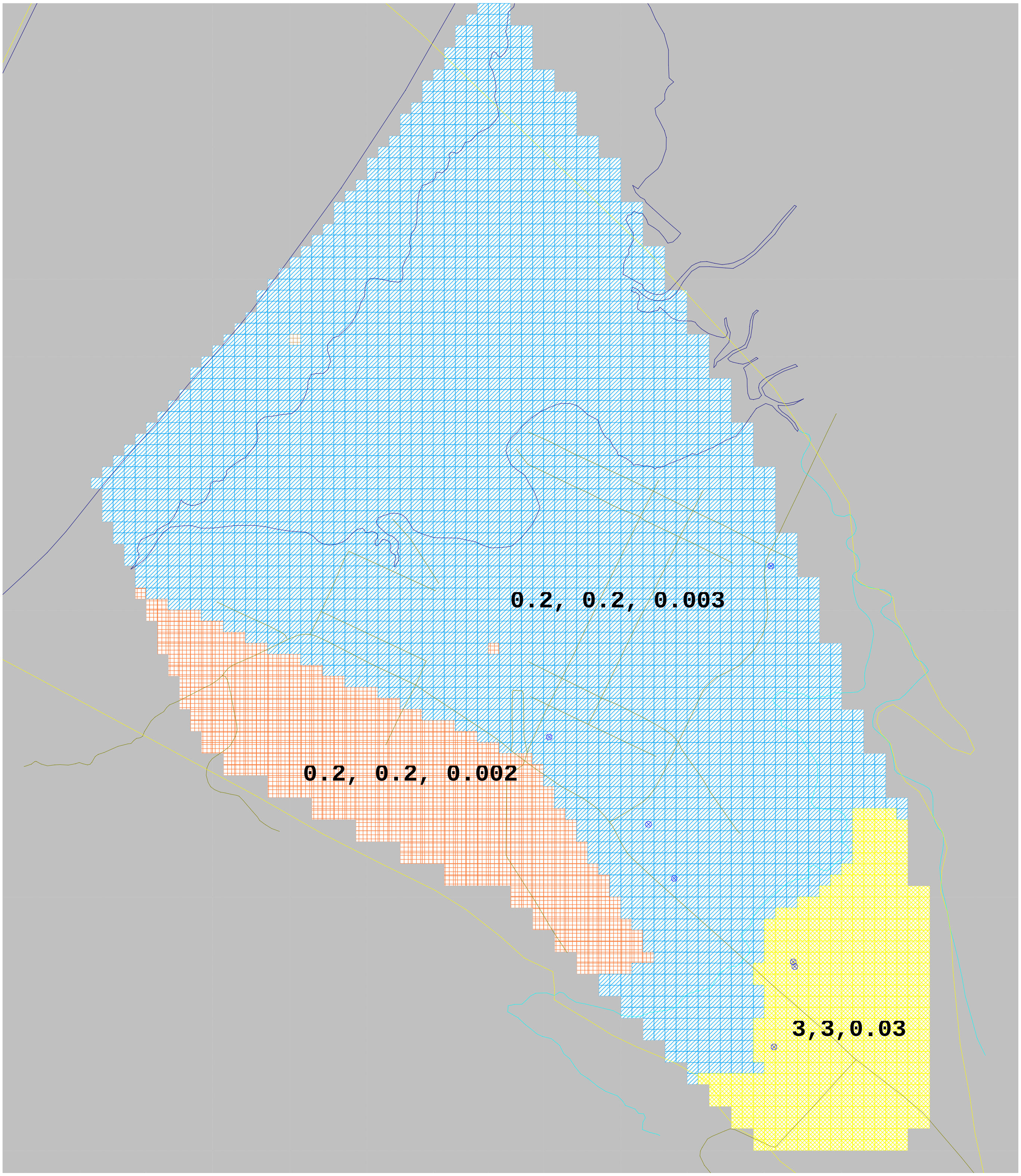

Figure 2. Horizontal Hydraulic Conductivity - Layer 2

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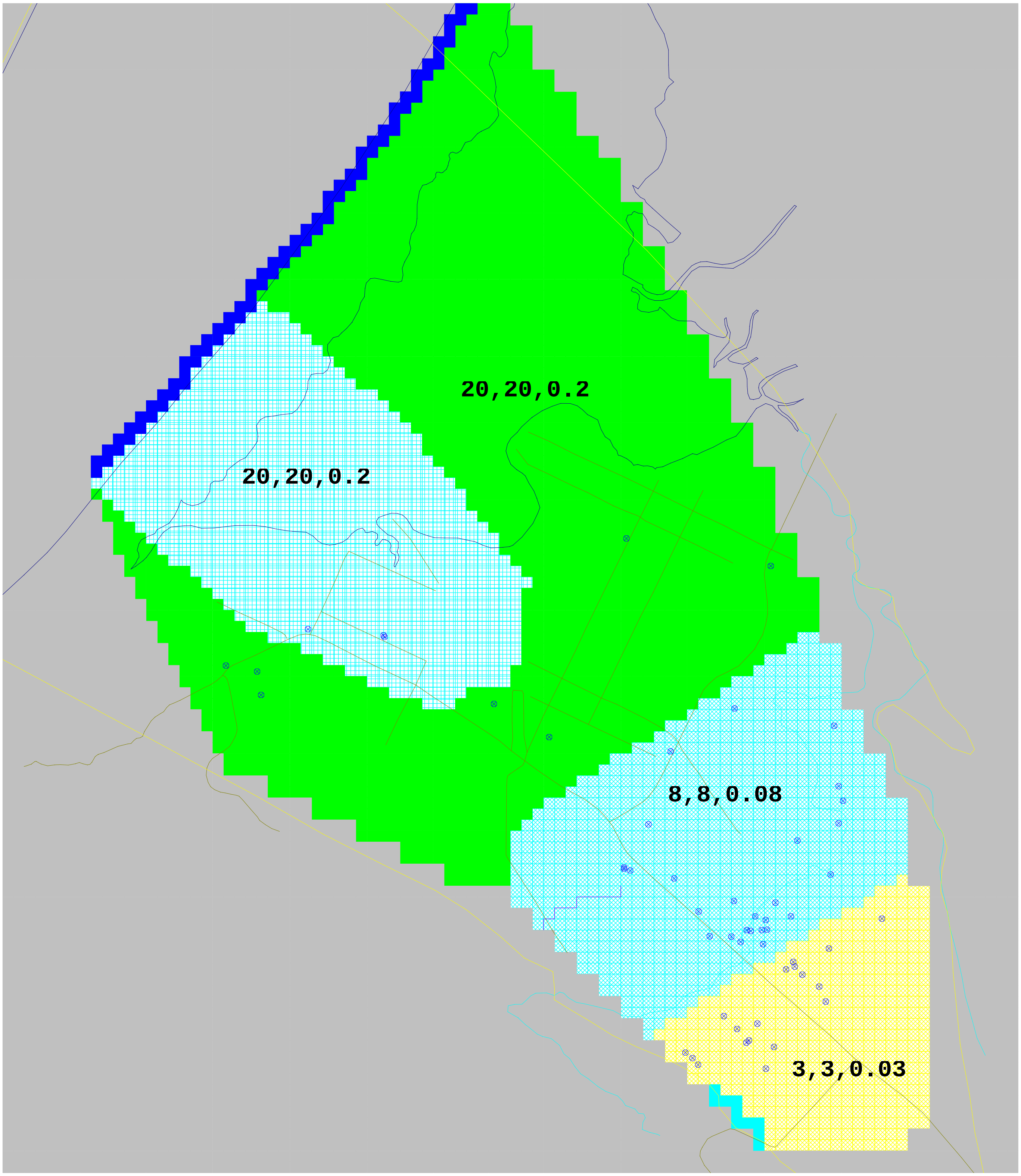

Figure 3. Horizontal Hydraulic Conductivity - Layer 3

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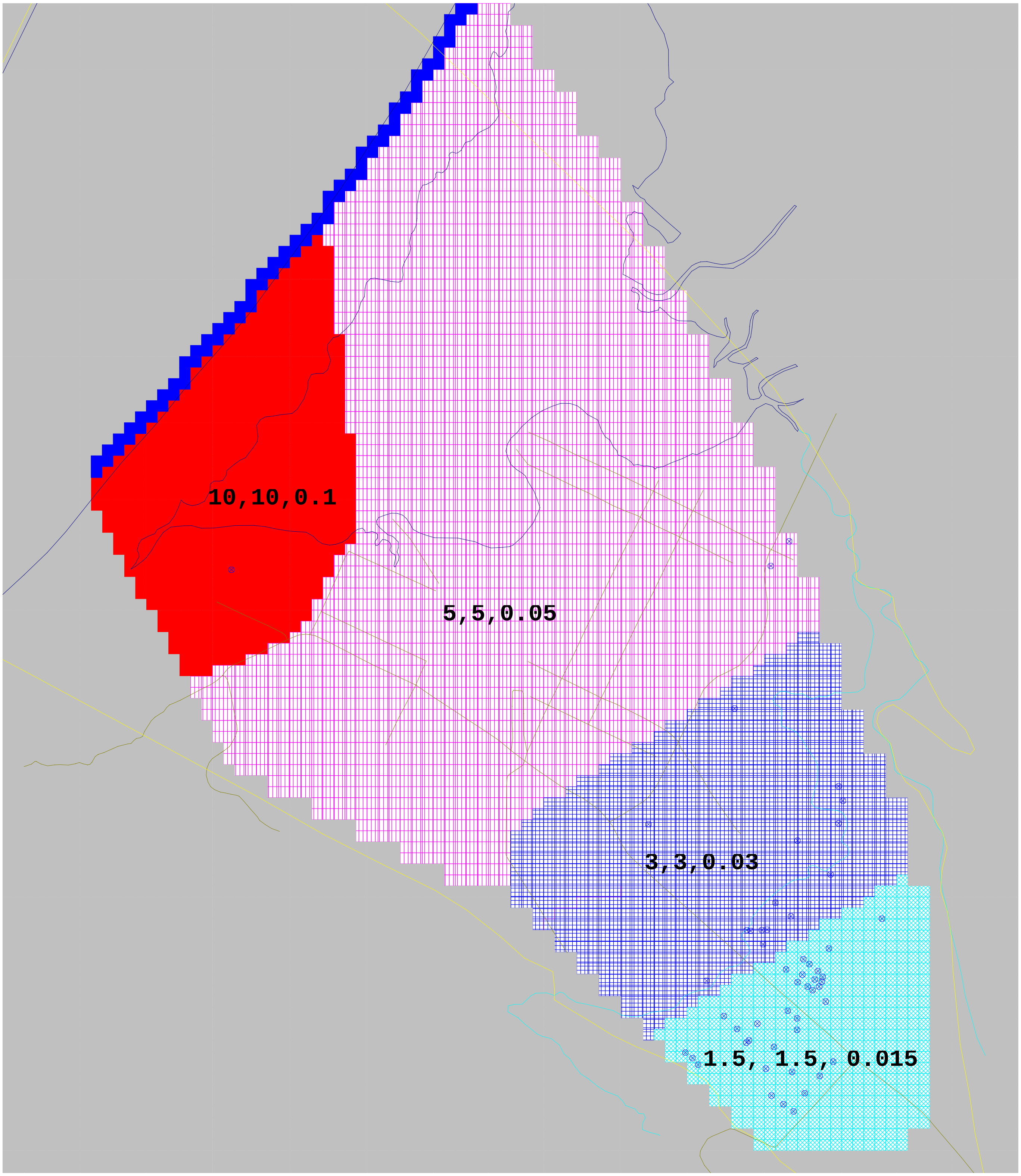

Figure 4. Horizontal Hydraulic Conductivity - Layer 4

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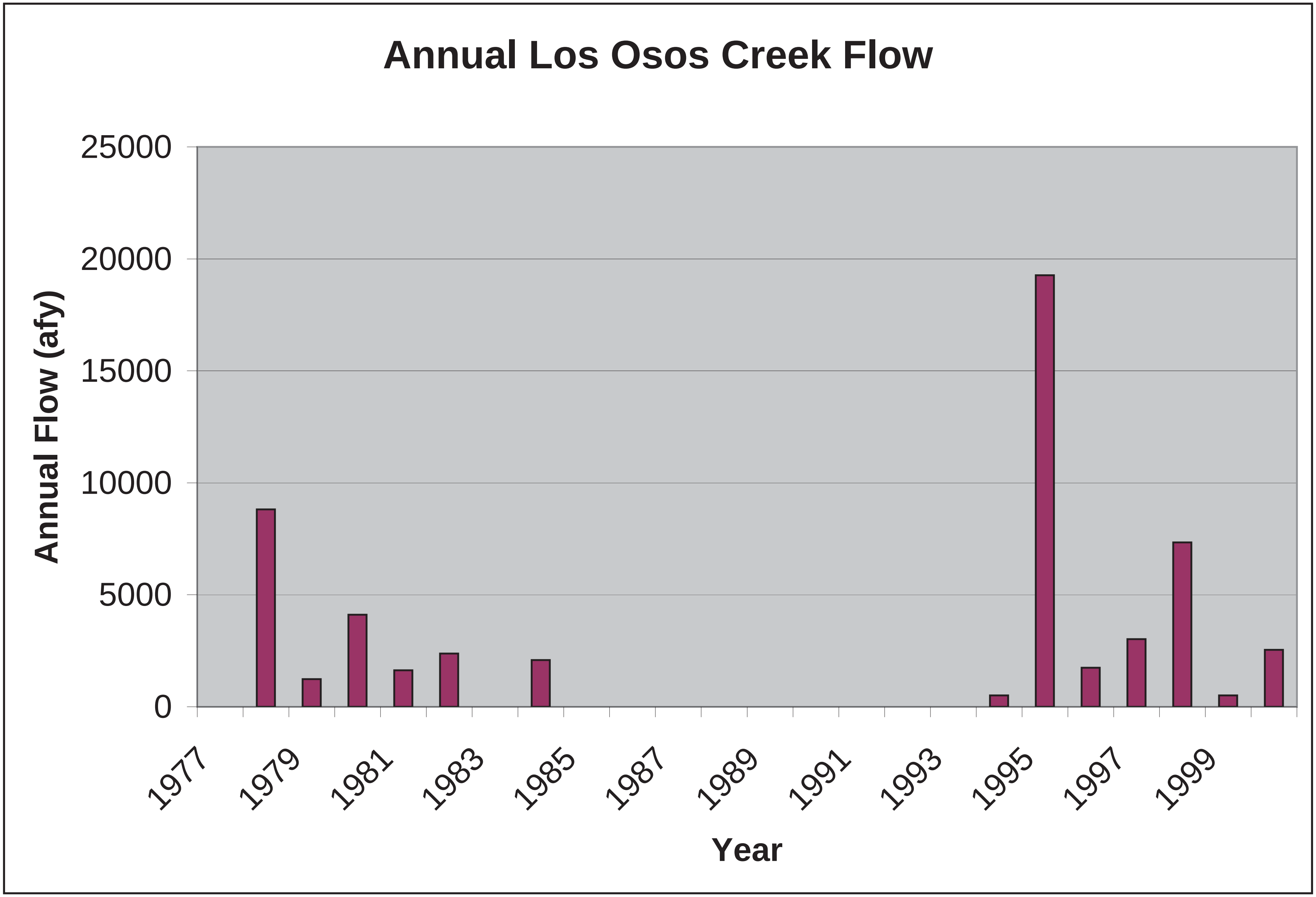

Figure 5. Annual Los Osos Creek Flow (1978-2002)

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Figure 6
Cumulative Departure Curve
Los Osos Station 197 (South Bay Fire Dept.)

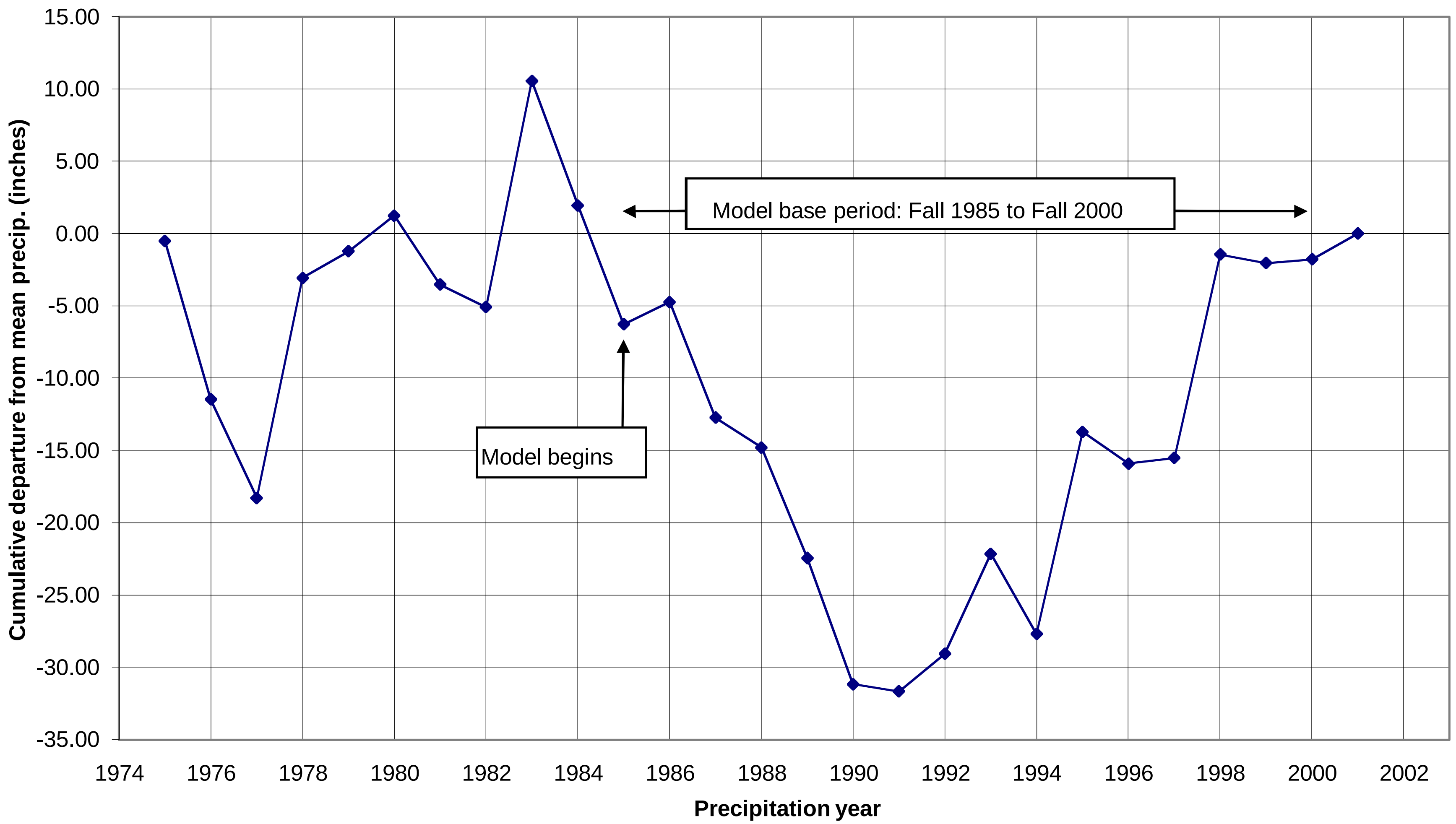
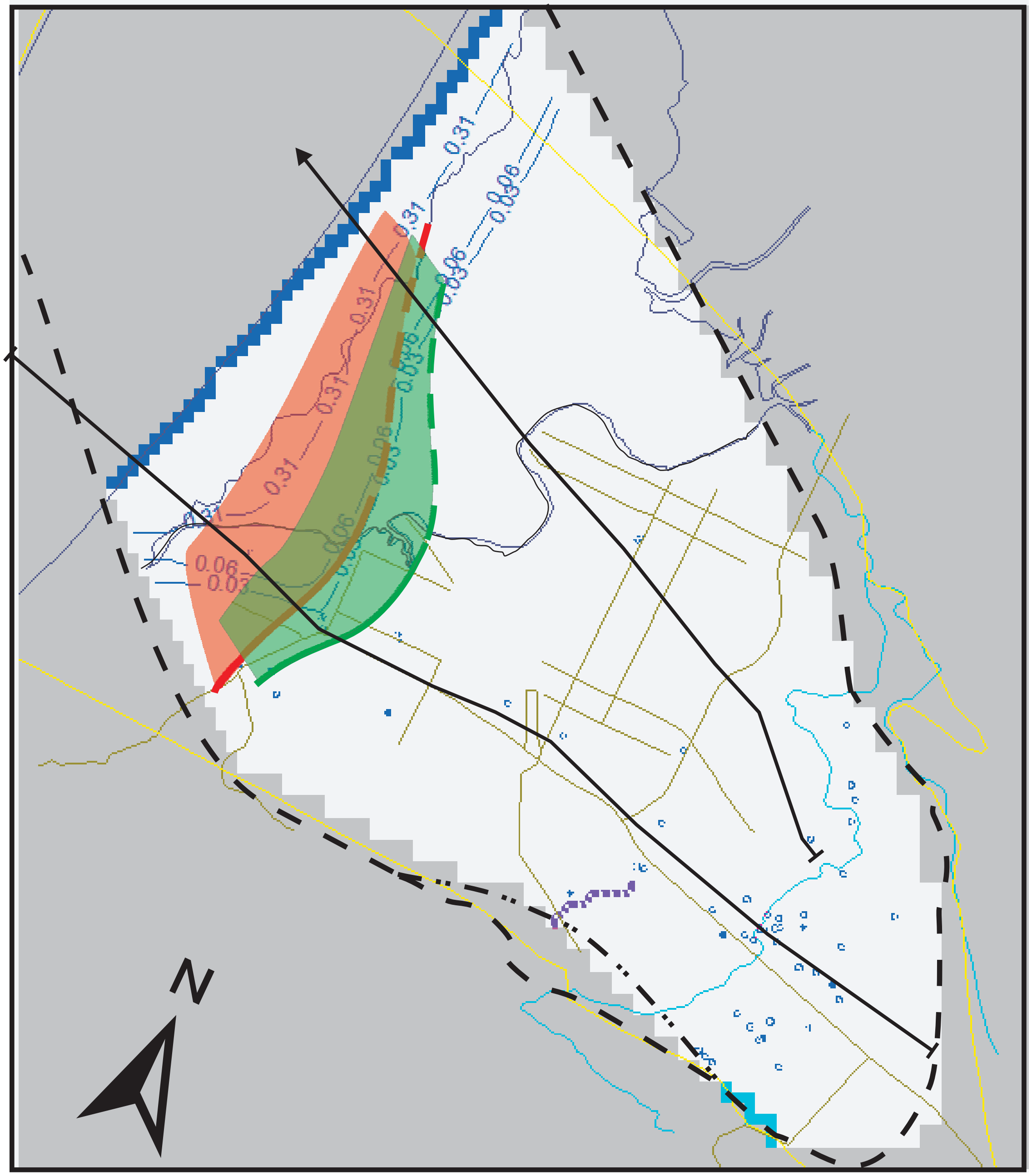


EXHIBIT "C"

Figure 7. Zone D, measured and simulated extent of seawater intrusion, 2005.
(modified from Figure A3, CHG, 2009b)



Scale 1" = 4000 feet

Simulated TDS isoconcentrations in lb/ft3

0.03 lb/ft3 = 500 mg/l TDS ≈ 250 mg/l Chloride
0.06 lb/ft3 = 1,000 mg/l TDS≈ 500 mg/l Chloride
0.31 lb/ft3 = 5,000 mg/l TDS≈ 2,500 mg/l Chloride

2005 Transition Zone:

Estimated extent of 2500 mg/l
Zone D isochlor (shading shows change with depth)

Estimated extent of 250 mg/l
Zone D isochlor (shading shows change with depth)

~~Figure A3~~

TDS Isoconcentrations
Calibration Run-2005 Zone D
May 2009 SEAWAT Model
Los Osos ISJ Group

Cleath-Harris Geologists, Inc.