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Technical Memorandum

Date: March 3, 2017

From: Spencer Harris, HG 633

To: Los Osos Groundwater Basin Management Committee
Morro Bay National Estuary Program

SUBJECT: Basin Yield Metric response to reduced long-term precipitation in the Los Osos Groundwater Basin.

Dear Mr. Miller:

Cleath-Harris Geologists (CHG) has evaluated the response of the Basin Yield Metric (BYM) to reduced precipitation in the Los Osos groundwater basin. The purpose of this effort is to understand how reduced precipitation would affect basin sustainable yield, and what the corresponding level of groundwater production would be at 80 percent of the BYM (BYM 80), which is the target for safe operation of the basin, as recommended in the Los Osos Basin Plan (LOBP; ISJ Group, 2015).

Background

The Los Osos Basin Management Committee (BMC) and Morro Bay National Estuary Program (Morro Bay NEP) have requested an analysis to evaluate the BYM under 2016 conditions and LOBP program combination U+AC if average annual precipitation were reduced from the current long-term average. The LOBP evaluated a variety of programs related to basin management, and program combination U+AC was recommended for immediate implementation.

The BYM compares the actual amount of groundwater pumped in a given year with the sustainable yield of the basin under then-current conditions. For example, the BYM for 2016 is a ratio expressed as follows:

$$\frac{\text{Calendar Year 2016 Groundwater Production}}{\text{Calendar Year 2016 Sustainable Yield}} * 100$$

Groundwater production in the numerator is based on measured and estimated values, while sustainable yield in the denominator is based on a value simulated using the basin model. The LOBP established the BYM target at 80 percent or less, so that at least 20 percent of the yield of the basin can be used as a buffer against uncertainty. Climate variability is one of the sources of uncertainty.

Sustainable yield in the equation above is not simply a volume of water, but is also the distribution of groundwater pumping across the basin that maintains a stationary seawater front, with no active well producing water with chloride concentrations above 250 milligrams per liter (mg/l). Evaluation of sustainable yield for various LOBP water supply program combinations was conducted using the basin model, and model results are listed in LOBP Table 46: Most Likely Program Combinations (attached).

CHG performed a climate change analysis of the Los Osos groundwater basin sustainable yield under 2012 basin conditions and population buildout conditions (Model Results for Los Osos Climate Ready Water Utilities Project, Appendix B *in* USEPA, 2013). The analysis included a sustainable yield evaluation in response to global warming, which simulated air temperature rise, sea level rise, and reduced precipitation. Baseline, mid-century, and late-century scenarios were analyzed under two levels of global greenhouse gas emissions.

Most global climate models reviewed during the USEPA study indicated a reduction in the long-term precipitation rate. The average annual precipitation value used in the basin model is equivalent to the long-term precipitation rate through cycles of dry, normal, and wet years. The basin model simulates the average annual precipitation rate across multiple years until a steady-state condition is achieved. The historical long-term precipitation rate used in the basin model is equivalent to an average annual precipitation of 17.5 inches (USEPA, 2013).

2016 Basin Yield Metric

Water supply infrastructure at year-end 2016, for the purposes of estimating sustainable yield, include the following LOBP programs:

- Los Osos Wastewater Project
- Urban Water Reinvestment Program (Program U)
- Infrastructure Program A
- Partial completion of infrastructure Program C

The sustainable yield of program combination U+A is 2,650 acre-feet per year (AFY). Program C was also partially completed in 2016 with the construction of the first expansion well (Golden State Water Company's Los Olivos Well No. 5). The contribution of Program C to basin sustainable yield is the difference between the yield of program combination U+A (2,650 AFY) and program combination U+AC (3,000 AFY), which is 350 AFY. Close to one-third, or 110 AFY of the sustainable yield contribution from Program C was developed in 2016, bringing the simulated total estimated sustainable yield for year-end 2016 conditions to 2,760 AFY (confirmed using basin model with long-term average precipitation).

The estimated basin groundwater production in 2016 is 2,160 acre-feet, which includes 1,005 acre-feet of measured community purveyor production and 1,155 acre-feet of other estimated production (golf course, community park, memorial park, non-purveyor domestic, and agriculture). Using the equation above, the corresponding BYM for 2016 is 78 percent, which does not exceed the LOBP target of 80 percent, although not all of the infrastructure programs used for the 2016 sustainable yield estimate and related BYM calculation were operational during 2016. For comparison, the 2015 BYM was 89 percent (CHG, 2016).

The actual distribution of pumping in 2016 was not sustainable due to drought and excess Lower Aquifer pumping in the Western Area (confirmed using basin model). As previously mentioned, sustainable yield values incorporate both pumping volume and location.

Program Combination U+AC Basin Yield Metric

LOBP program combination U+AC refers to the following elements:

- Los Osos Wastewater Project
- LOBP Urban Water Reinvestment Program (U)
- Basin Infrastructure Program A
- Basin Infrastructure Program C

The difference between year-end 2016 infrastructure and U+AC infrastructure is that the U+AC programs include two additional expansion wells. These expansion wells are located in the eastern Central Area, toward Los Osos Creek (LOBP Figure 55: Basin Infrastructure Program Map, attached).

With the above programs in place, the estimated sustainable yield of the basin is 3,000 AFY. Basin demand under no further development is estimated at 2,230 AFY (LOBP Table 46: Most Likely Program Combinations, attached), which would result in a BYM of 74 percent. The basin groundwater production value which meets the BYM 80 target, and is linked to the 3,000 AFY sustainable yield, is 2,400 AFY.

Basin Model Input

Precipitation and groundwater production were the two primary model inputs adjusted in simulations performed for the BYM response analysis. A third related component, groundwater recharge from Los Osos Creek, was maintained below a maximum value. Each of these items are discussed below.

Precipitation Adjustments

Most global circulation models reviewed for the Los Osos Climate Ready Water Utilities Project predict reduced average annual precipitation in the Morro Bay area (USEPA, 2013). Projections of changes in precipitation were derived from the results of global circulation models for Intergovernmental Panel on Climate Change (IPCC) Scenario A2 (medium high emissions) and Scenario B1 (lower emissions).

IPCC emission scenario results from four global circulation models are available from Cal-Adapt (http://www.cal-adapt.org). These results have been used to characterize climate change projections in California. The four models are a subset of 16 global circulation models contained in the EPA Climate Resilience Evaluation and Awareness Tool (CREAT) used for the Los Osos Climate Ready Water Utilities Project (CREAT Version 1.0). A comparison of model results provided by CREAT and Cal-Adapt indicates that the four models used by Cal-Adapt include some of the lowest long-term precipitation rate projections.

Among the four Cal-Adapt models, the Centre National de Recherches Meteorologiques (CNRM) global circulation model provided the lowest overall long-term precipitation rate projections, which would be considered worst-case for analysis of impacts due to low precipitation. The lowest average annual precipitation is estimated at 67 percent of the long-term average of 17.5 inches per calendar year (Table 1). For correlation purposes, the BYM response analysis was performed using 100 percent, 90 percent, 80 percent, and 67 percent of the long-term average precipitation. Table 1 presents the average monthly precipitation for each precipitation reduction scenario. Precipitation reductions were calculated by multiplying long-term precipitation values by the percent of long-term average for each scenario.

Table 1
Precipitation Reduction Scenarios

Month	Precipitation Reduction Scenarios (percent of long-term average precipitation)			
	100% of average	90% of average	80% of average	67% of average
	Inches of precipitation			
January	3.57	3.21	2.86	2.39
February	3.77	3.39	3.02	2.53
March	3.29	2.96	2.63	2.20
April	1.10	0.99	0.88	0.74
May	0.43	0.39	0.34	0.29
June	0.08	0.07	0.06	0.05
July	0.01	0.01	0.01	0.01
August	0.05	0.05	0.04	0.03
September	0.24	0.22	0.19	0.16
October	0.82	0.74	0.66	0.55
November	1.40	1.26	1.12	0.94
December	2.72	2.45	2.18	1.82
Annual	17.5	15.7	14.0	11.7

Groundwater Production Adjustments

The volume and physical distribution of purveyor groundwater production was adjusted for each model scenario to provide the sustainable yield value. Annual production from domestic and agricultural wells was assumed to remain constant at current (2016) production levels and distribution. No significant increase in future private well production is anticipated by the LOBP.

Declines in purveyor groundwater production, and the associated declines in customer water use, also reduce the amount of recycled water available for recharge in the basin. Reductions in available recycled water from San Luis Obispo County's LOWRF have been simulated by a corresponding reduction in recycled water disposal volumes applied to the Broderson leach field, which is located south of Highland Drive and west of Broderson Avenue in Los Osos.

Recharge from Los Osos Creek

Recharge to the groundwater basin comes directly or indirectly from precipitation. Stream flow in Los Osos Creek, which originates as precipitation in the watershed, directly recharges the creek valley alluvial deposits, which, in turn, recharge the Upper and Lower Aquifers in the Eastern Area. The amount of potential recharge available from Los Osos Creek under reduced precipitation scenarios is a key assumption for the BYM response analyses.

County stream gage #751 is located on Los Osos Creek at the Los Osos Valley Road bridge. The gage measures runoff from the portion of the watershed upstream of Los Osos Valley Road, which covers an area of 7.27 square miles. Stream flow records are available for 19 years between 1976 and 2002 (attached, San Luis Obispo County, 2005). Table 2 presents the available annual flow records for Los Osos Creek.

Table 2
Los Osos Creek Stream Flow Records

Runoff Year with flow record	Stream Flow[1] (acre-feet)	Precipitation[2] (inches)
1976	110	7.57
1977	0	13.24
1978	8,810	30.08
1979	1,240	19.01
1980	3,890	22.33
1981	1,630	12.9
1982	2,390	21.01
1984	2,110	10.57
1985	1,920	10.56
1986	11,850	17.83
1994	497	11.63
1995	19,270	41.8
1996	1,740	16.24
1997	3,020	19.51
1998	7,340	36.53
1999	505	13.73
2000	2,540	20.97
2001	2,470	15.95
2002	0	10.25
Average	3,750	18.5

The historical recharge to groundwater from Los Osos Creek stream seepage, during years with flow records listed in Table 2, is estimated to average 600 AFY, based on a review of groundwater production records and comparison with the stream seepage estimate for 2012 (610 AFY, LOBP Figure 73: 2012 Water Balance, attached).

[1] Stream flow gage #751. Some years have partial records (see attachment). Stage data is available for recent years, but no rating curve is available, and no associated flow records have been published (CHG, 2015).
[2] Rain gage #152 (Morro Bay Fire Department), adjusted for the Los Osos area through correlation with local rain gages.

Groundwater production in the creek valley, where stream seepage occurs, averaged 790 AFY for the years listed in Table 2, similar to 2012 production (800 AFY).

The stream gage is located one mile downstream of where Los Osos Creek enters the groundwater basin (attached Figure 1). The seepage capacity of the creek bed between the basin boundary and the stream gage has been documented at up to 10 cubic feet per second, and an estimated two thirds of groundwater recharge from Los Osos Creek occurs along this reach (CHG, 2014). Therefore, the estimated average surface flow entering the groundwater basin for the years listed in Table 2 would be 4,150 AFY (3,750 AFY measured at stream gage plus 400 AFY of seepage upstream of the gage).

A maximum 800 acre-feet of groundwater recharge from Los Osos Creek is assumed to be available for sustainable yield scenarios. This value is based on maintaining the 600 AFY of historical recharge, and adding up to 200 AFY of recharge that would be partially offset by in-lieu groundwater recharge from recycled water use in the Los Osos Creek valley (196 AFY, LOBP Table 32: Urban Water Reinvestment program Recycled Water Uses, attached). In-lieu recharge in the creek valley would occur when recycled water is used for memorial park and agricultural irrigation to reduce groundwater pumping.

Stream flow entering the groundwater basin on Los Osos Creek will decline as long-term precipitation is reduced. The lowest projected average annual precipitation is 11.7 inches (Table 1), or 63 percent of the average precipitation for years with stream flow records in Table 2. By comparison, less than 20 percent of the 4,150 AFY average stream flow entering the groundwater basin during those years would be needed to provide 800 AFY of recharge to the basin. Sufficient available stream flow is expected under reduced precipitation scenarios to support 800 AFY of groundwater recharge from Los Osos Creek.

BYM Response Analysis Results

The basin model was used to evaluate BYM response to reduced precipitation. The model utilizes the U.S. Geological Survey's SEAWAT program, which was developed to simulate three-dimensional, variable-density, transient groundwater flow in porous media. SEAWAT combines MODFLOW (modular flow) and MT3D (mass transport) code, and adds variable fluid density capability specifically for seawater intrusion simulations.

Several scenarios were analyzed for the two infrastructure programs considered: year-end 2016 infrastructure and for LOBP infrastructure program combination AC. These two programs were selected for analysis by the BMC to represent current infrastructure (year-end 2016), and the most effective program combination (AC) identified in the LOBP for use with the current population. Prior to analyzing year-end 2016 infrastructure scenarios, a pre-LOWRF scenario was also prepared to evaluate the sustainability of groundwater production during drought, immediately prior to LOWRF operation.

2016 Infrastructure Scenarios

A pre-LOWRF operation scenario was prepared with septic systems in place and with the actual 2016 production distribution. The purpose of this evaluation was to determine whether the basin model predicted continued increases in the chloride metric through fall 2016.

The chloride metric is one of the measures of effectiveness for basin management, and tracks changes in Lower Aquifer water quality related to seawater intrusion mitigation. In 2016, despite a calculated BYM of below 80 percent, the chloride metric continue to rise, indicating continued advance of seawater intrusion. The pre-LOWRF scenario was a performed to test whether the basin model would simulate a chloride metric rise under 2016 conditions. The results indicated that the pre-LOWRF scenario was not sustainable, therefore the continuation of historical increases in the chloride metric during 2016 would be expected, even with the BYM below 80 percent.

The estimated sustainable yield for year-end 2016 infrastructure was analyzed using the current long-term precipitation rate and reduced precipitation scenarios. A long-term precipitation rate is appropriate for simulating sustainable yield because multiple years of basin pumping and recharge are involved. Table 3 below presents the results of the BYM analyses, with groundwater production shown for each basin area/aquifer. Basin areas and aquifers are shown in the attached Figure 1 and Figure 2 from the Los Osos Groundwater Monitoring Program 2015 Annual Report (CHG, 2016).

Table 3
Sustainable Yield for 2016 Scenarios

BASIN AREA	SUSTAINABLE YIELD SCENARIO Infrastructure and % of long-term average precipitation			
	2016 (100%)	2016 (90%)	2016 (80%)	2016 (67%)
	Simulated Sustainable Yield (acre-feet per year)			
Upper Western	100	NC[1]	NC	NC
Lower Western	190	50	30	0
Upper Central	690	NC	650	560
Lower Central	860	730	520	290
Eastern Alluvium	130	NC	NC	NC
Eastern Lower	790	NC	NC	NC
BASIN TOTAL (SUSTAINBLE YIELD)	2,760	2,490	2,220	1,870
PURVEYOR TOTAL[2]	1,640	1,370	1,000	750
2016 BYM[3]	78	87	97	116
BYM 80 PRODUCTION	2,210	1,990	1,780	1,500

[1]NC = No Change in value from 100 percent long-tem average precipitation scenario.
[2]Purveyor total (simulated) = Basin total - 1,120 AFY for golf, private domestic, and agricultural uses.
[3] BYM based on 2016 basin groundwater production of 2,160 AFY

U+AC Infrastructure Scenarios

The estimated sustainable yield for LOBP program combination U+AC was analyzed for the current long-term precipitation rate and reduced precipitation scenarios. Table 4 below presents the results of the analyses, with production shown for each basin area/aquifer.

Table 4
Sustainable Yield for U+AC Scenarios

BASIN AREA	SUSTAINABLE YIELD SCENARIO Infrastructure and % of long-term average precipitation			
	AC (100%)	AC (90%)	AC (80%)	AC (67%)
	Simulated Sustainable Yield (acre-feet per year)			
Upper Western	100	NC[1]	NC	NC
Lower Western	110	70	20	0
Upper Central	790	720	670	560
Lower Central	1,080	830	580	290
Eastern Alluvium	130	NC	NC	NC
Eastern Lower	790	NC	NC	NC
BASIN TOTAL (SUSTAINBLE YIELD)	3,000	2,640	2,290	1,870
PURVEYOR TOTAL[2]	1,880	1,520	1,170	750
BYM[3]	74	84	97	119
BYM 80 Production	2,400	2,110	1,830	1,500

[1]NC = No Change in value from 100 percent long-tem average precipitation scenario.
[2]Purveyor total (simulated) = Basin total - 1,120 AFY for golf, private domestic, and agricultural uses.
[3] BYM based on projected demand (i.e. groundwater production) of 2,230 AFY (LOBP Table 46).

Discussion

Interpretation of the results of basin model scenarios is discussed below with respect to the BYM response analysis and pumping distribution.

BYM Response to Reduced Precipitation

For year-end 2016 infrastructure scenarios, the decline in sustainable yield and the BYM 80 value is essentially proportional to the decline in precipitation. For the U+AC scenarios, there is a slightly greater decline in sustainable yield and the BYM 80 value than the actual decline in precipitation. Table 5 shows these correlations.

Table 5
BYM 80 Sensitivity to Reduced Precipitation

Infrastructure Program Combinations	Percent of Long-Term Precipitation[1]	BYM 80 (AFY)	Percent BYM 80
2016	100	2,210	100
	90	1,990	90
	80	1,780	80
	67	1,500	68
U+AC	100	2,400	100
	90	2,100	88
	80	1,830	76
	67	1,500	62

[1] 17.5 inches average annual precipitation

Pumping Distribution

As stated previously, sustainable yield is not just the amount of groundwater that can be pumped, but is also the distribution of groundwater pumping across the basin that maintains a stationary seawater front, with no active well producing water with chloride concentrations above 250 mg/l. This means the location of pumping, both vertically and horizontally in the basin, is an important aspect of any BYM.

The results of basin model scenarios show that with decreased precipitation, groundwater production in the Lower Aquifer must be reduced to avoid seawater intrusion (Tables 3 and 4). Central Area expansion well production must also be reduced, however, to avoid exceeding the available recharge (800 AFY) from Los Osos Creek.

Potential increases to the purveyor water supply from the addition of two more expansion wells under LOBP Program C will vary based on precipitation projections. Water supply increases range from 190 AFY for continued long-term precipitation, to no increase (0 AFY) for 67 percent of long-term precipitation. At 67 percent precipitation, the year-end 2016 and U+AC scenarios result in identical BYM 80 values, because neither of the two additional expansion wells included in the U+AC program combination can be used without exceeding the available recharge from Los Osos Creek.

Upper aquifer pumping is not reduced to the extent that Lower Aquifer pumping is reduced (Tables 3 and 4). This is mainly due to production declines required at mixed aquifer wells (those screened in both the Upper and Lower Aquifer) to help mitigate Lower Aquifer seawater intrusion. Most upper aquifer wells continue pumping at maximum capacity.

References

Cleath-Harris Geologists, 2014, Recycled Water Discharges to Los Osos Creek, Technical Memorandum prepared for the ISJ Group dated March 18, 2014.

Cleath-Harris Geologists, 2016, Los Osos Basin Plan Groundwater Monitoring Program 2015 Annual Report, prepared in association with Wallace Group, September 2016.
https://www.slocountywater.org/site/Water%20Resources/LosOsos/pdf/Los%20Osos%20BMC%202015%20Annual%20Report%20Final.pdf

ISJ Group, 2015, Updated Basin Plan for the Los Osos Groundwater Basin, January 2015.
https://www.slocountywater.org/site/Water%20Resources/LosOsos/pdf/Los%20Osos%20Groundwater%20Basin%20Plan%20January%202015.pdf

San Luis Obispo County Public Works Department, 2005, Hydrologic Report, Water Years 2001-2002 and 2002-2003, May 16, 2005.
https://www.slocountywater.org/site/Water%20Resources/Reports/pdf/Hydrologic%20Report%202002.pdf

San Luis Obispo County Public Works Department stream gage and rain gage sites
https://wr.slocountywater.org/list.php

USEPA, 2013, Climate Resilience Evaluation and Awareness Tool Exercise with Los Osos Water Purveyors and the Morro Bay National Estuary Program (EPA 817-B-13-003, June 2013).
https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100KKZX.TXT

ATTACHMENTS

2015 Los Osos Groundwater Basin Plan Update:

Table 32: Urban Water Reinvestment Program Recycled Water Uses
Table 46: Most Likely Program, Combinations
Figure 55: Basin Infrastructure Program Map
Figure 73: Water Balance 2012 Baseline

9.3 Urban Water Reinvestment Program

The Water Reinvestment Program set forth in this chapter is divided into two parts. The first part, known as the Urban Water Reinvestment Program, is intended to beneficially use all recycled water produced by the LOWWP under the Existing Population Scenario. The second part, known as the Agricultural Water Reinvestment Program, is intended to use all marginal recycled water produced under the Buildout Population Scenario. Although a limited quantity of agricultural reuse is planned as part of the Urban Water Reinvestment Program, the bulk of agricultural reuse will occur under the Agricultural Water Reinvestment Program.

The proposed uses of recycled water under the Urban Water Reinvestment Program are listed in Table 32. Not all potential uses will start at the commencement of LOWWP operations, or occur in their full quantities. For example, irrigation at Sea Pines Golf Course is likely to occur only if the Monarch Grove subdivision connects to the LOWWP. Any produced water that is not used for one of the potential uses listed in Table 32 will likely be reinvested in agricultural reuse. In addition, the quantity of water produced by the LOWWP may vary from 780 AFY, requiring reinvestment of either more or less recycled water for the various potential uses. Despite these uncertainties, the Urban Water Reinvestment Program is expected to deliver all recycled water produced by the LOWWP to one of the categories of reuse shown in Table 32.

Table 32. Urban Water Reinvestment Program Recycled Water Uses

Potential Use	Quantity (AFY)	Percent of Total
Broderson Leach Fields	448	57.4
Bayridge Estates Leach Fields	33	4.2
Urban Reuse	63	8.1
Sea Pines Golf Course	40	5.1
Los Osos Valley Memorial Park	50	6.4
Agricultural Reuse	146	18.7
Total	780	100

Some of the recycled water to be reinvested pursuant to the Urban Water Reinvestment Program—e.g., that delivered to the schools and community park—will offset water that would have otherwise been produced from the Basin and sold by the Purveyors to their potable water customers. The County will deliver recycled water to users within the LOCSD and GSWC service areas pursuant to agreements with the Purveyors, in order to prevent a loss of water utility revenue while still facilitating the reinvestment of recycled water in the Basin. The agreements between the County, LOCSD and GSWC will determine the respective obligations of the parties.

LOCSD and GSWC will each follow their required processes for the establishment of rates or tariffs for recycled water service. For LOCSD, that will involve commissioning a rate study and following the process of Proposition 218. For

For the Existing Population Scenario, it is apparent that certain programs must be completed in order to achieve a sustainable Basin, including the Urban Water Use Efficiency Program, Urban Water Reinvestment Program and Basin Infrastructure Program A. In addition, the Parties must implement either Basin Infrastructure Program B or C or the Supplemental Water Program at 250 AFY. It is clear that Basin Infrastructure Program D is unnecessary to achieve a sustainable Basin under the Existing Population Scenario. A summary of the most likely combinations is presented in Table 46, along with the expected Basin Yield Metric, Water Level Metric and Chloride Metric that would result from each. These combinations were selected for further consideration because they are expected to satisfy the Basin Plan goals, with relatively lower costs than other combinations.

Table 46. Most Likely Program Combinations

Combination	Water Demand†	Sustainable Yield$_X$†	Basin Yield Metric	Water Level Metric‡	Chloride Metric*
Existing Population Scenario					
E+U+AB	2,230	3,170	70	10	60
E+U+AC	2,230	3,000	74	10	65
E+U+A+S	1,980	2,650	75	10	65
Buildout Population Scenario					
E+UG+ABC	2,380	3,350	72	9	70
E+U+ABCD	2,880	3,500	82	8	85
E+UG+ABCD	2,380	3,500	68	10	60
E+U+A+S	2,130	2,650	80		

† Expressed in AFY. ‡ Expressed in feet msl. * Expressed in mg/l.

For the Buildout Population Scenario, the selection of a combination would depend heavily on whether the Supplemental Water Program were implemented under the Existing Population Scenario. If a groundwater desalination plant were previously constructed to produce 250 AFY (the assumed level for the Existing Population Scenario), then it would be reasonable for the Parties to simply install additional desalination capacity (500 AFY, for a total of 750 AFY of produced water) to achieve a sustainable Basin under Combination E+U+A+S.

If, on the other hand, the Supplemental Water Program were not to have been initiated under the Existing Population Scenario, the Parties would be unlikely to construct and operate a new desalination facility for the Buildout Population Scenario, because the costs associated with such a facility would exceed those of implementing further portions of the Basin Infrastructure Program. In order to achieve a sustainable Basin in that circumstance, the Parties would need to implement the Urban Water Use Efficiency Program, Urban Water Reinvestment Program and Basin Infrastructure Programs A, B and C. The Parties would also need to implement either Basin Infrastructure Program D or the Agricultural Water

SOURCE: 2015 LOS OSOS BASIN PLAN UPDATE

comments added in red

Figure 55. Basin Infrastructure Program Map

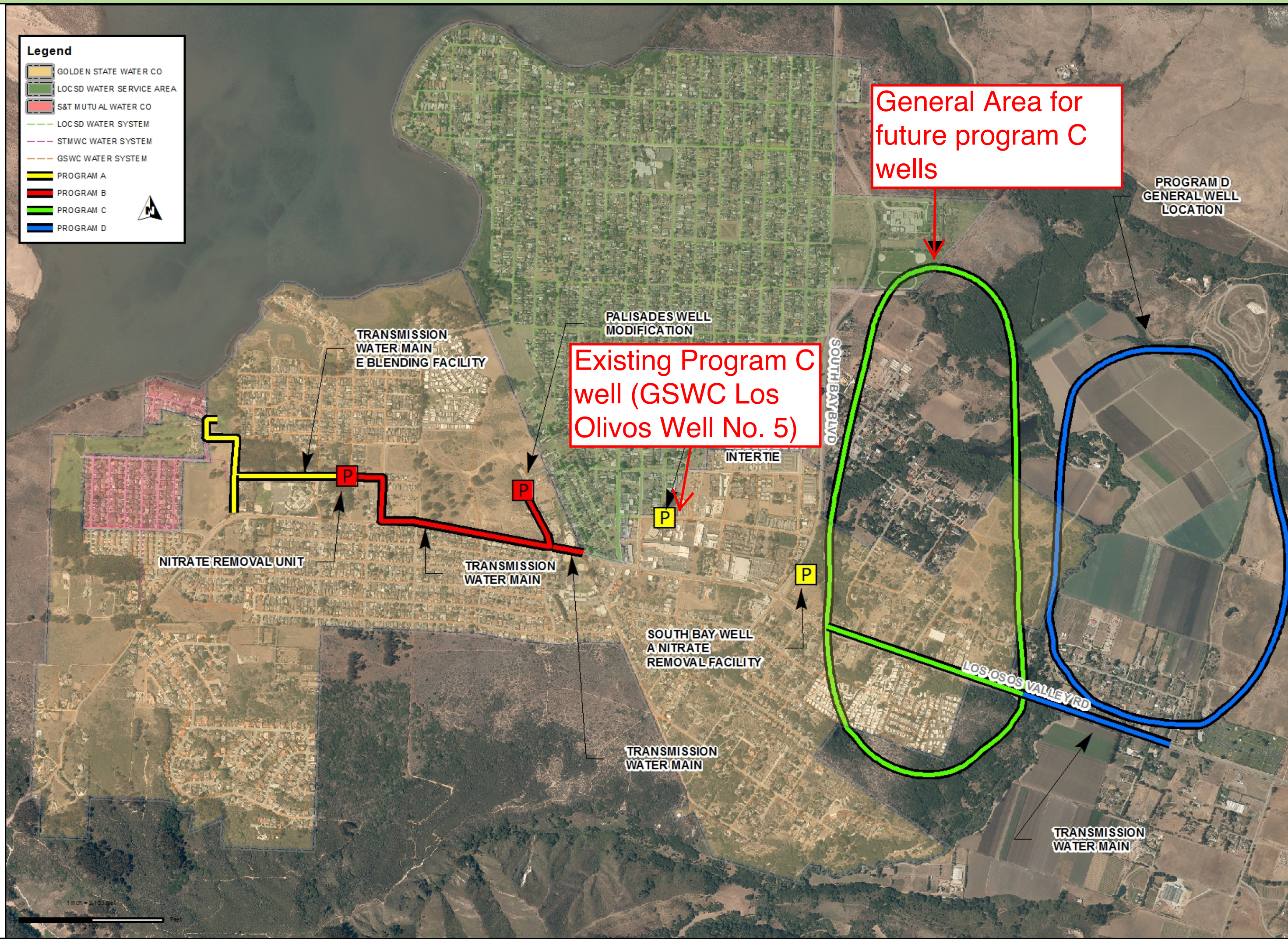
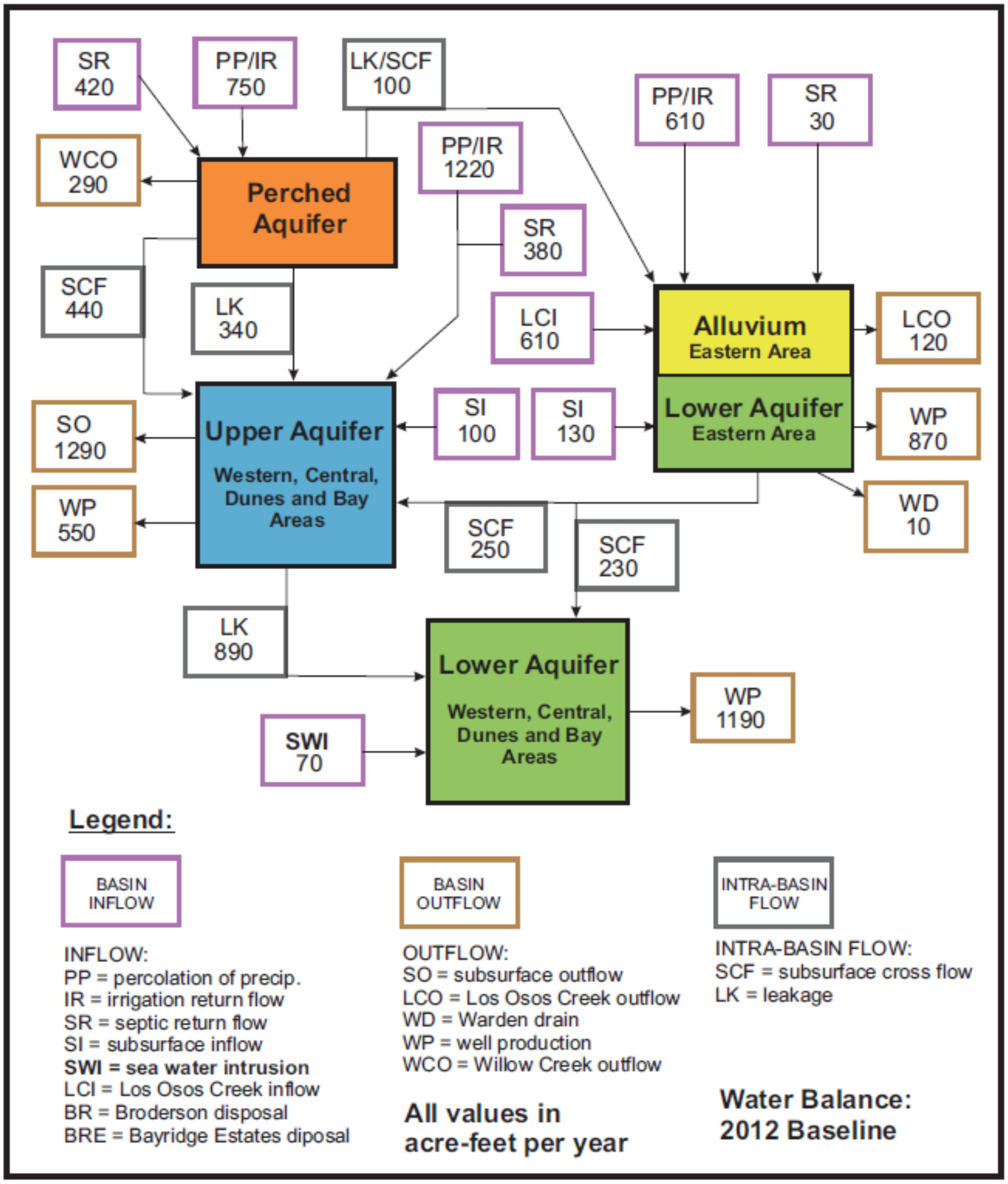


Figure 73. Water Balance: 2012 Baseline



San Luis Obispo County Public Works
Hydrologic Report, Water Years 2001-2002 and 2002-2003:

Los Osos Creek Stream Flow

Stream Flow

Stream Gage Name: **Los Osos Creek (#6)**
Water Planning Area: **3**

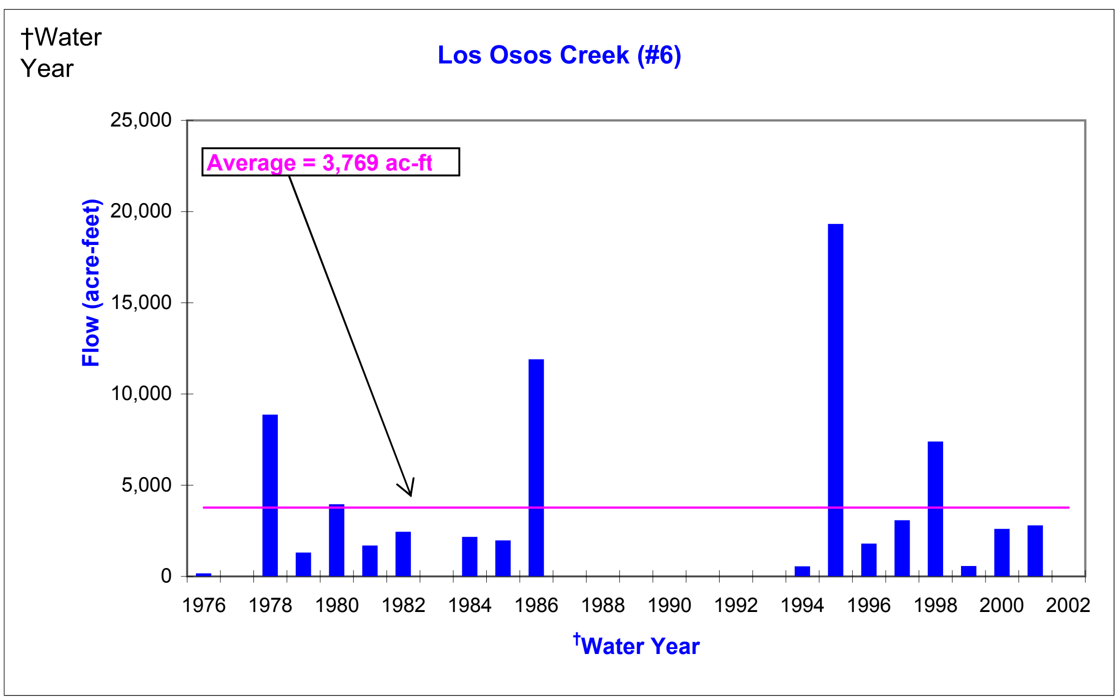
Water Year†	Annual Stream Flow (acre-feet)		Water Year†	Annual Stream Flow (acre-feet)	
1976	110	[1]	1990		[9]
1977	0		1991		[10]
1978	8,810		1992		[11]
1979	1,240		1993		[12]
1980	3,890	[2]	1994	497	
1981	1,630		1995	19,270	
1982	2,390	[3]	1996	1,740	
1983		[4]	1997	3,020	
1984	2,110		1998	7,340	
1985	1,920		1999	505	
1986	11,850	[5]	2000	2,540	
1987		[6]	2001	2,470	
1988		[7]	2002	0	
1989		[8]	2003	NA	[13]

From Annual Stream Flow Records	
Average Flow:	3,769 AFY
Median Flow:	2,110 AFY
Minimum Flow (2002):	0 AFY
Maximum Flow (1995):	19,270 AFY

[1] gage put into operation in February
[2] missing data for one day in February
[3] missing data for various days in February, March, and April
[4] only visual observations were available for this year
[5] missing data for the end of February and beginning of March

[6-12] no data available for this time period
[13] Data not available at the time the report was published

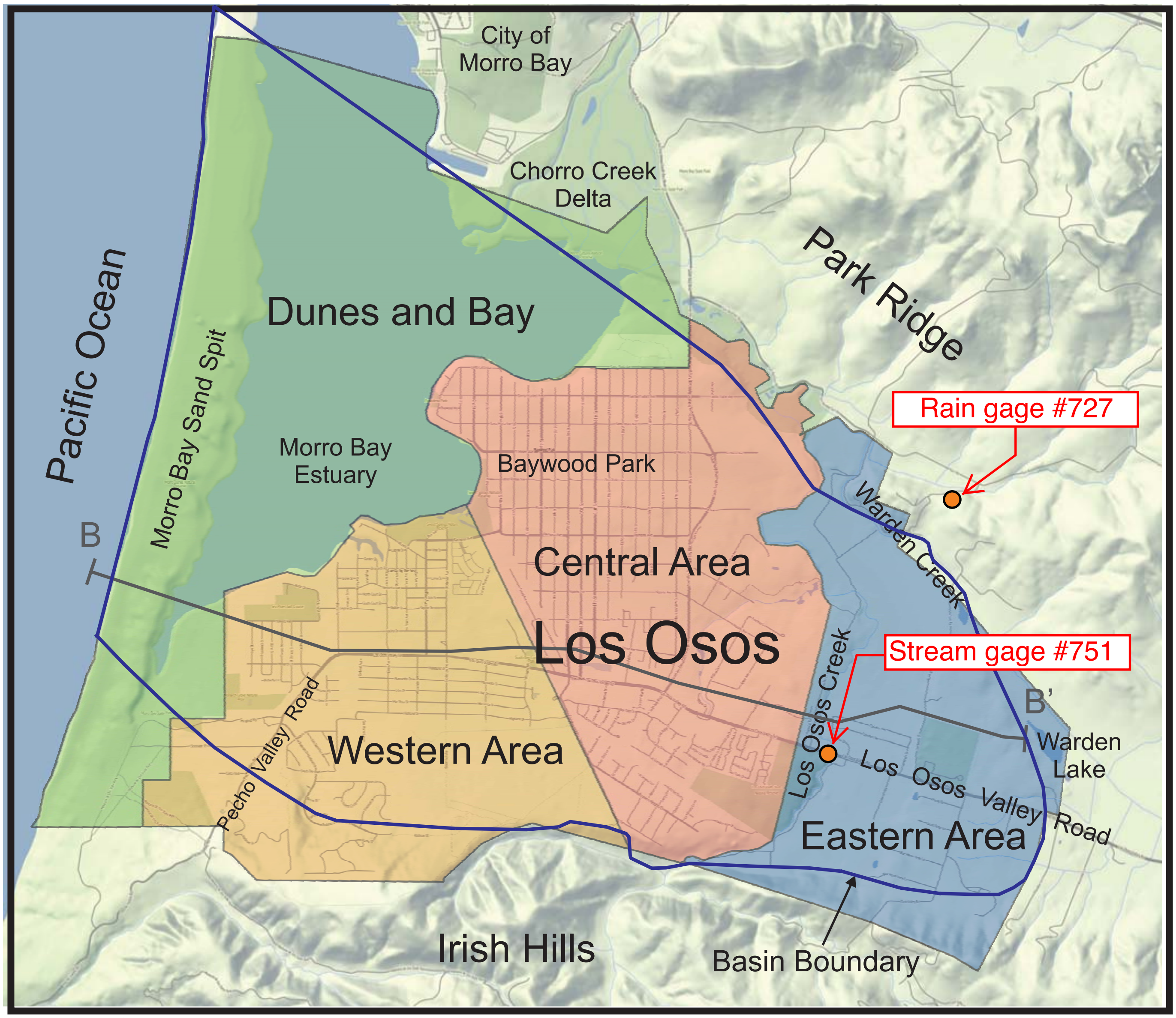
(notations as recorded in San Luis Obispo County stream flow log books)



† October 1 - September 30

Los Osos Groundwater Monitoring Program
2015 Annual Report

Figure 1: Basin Location and Plan Areas
Figure 5: Basin Aquifers



Base Image: Stamen-Terrain

0 2000 4000 6000 8000 ft

Scale: 1 inch ≈ 4,000 feet

Explanation

Basin Plan Areas:

Dunes and Bay Area

Western Area

Central Area

Eastern Area

B B’ Cross-section alignment (Figures 5 and 20). Labeled B-B’ to be consistent with Basin Plan.

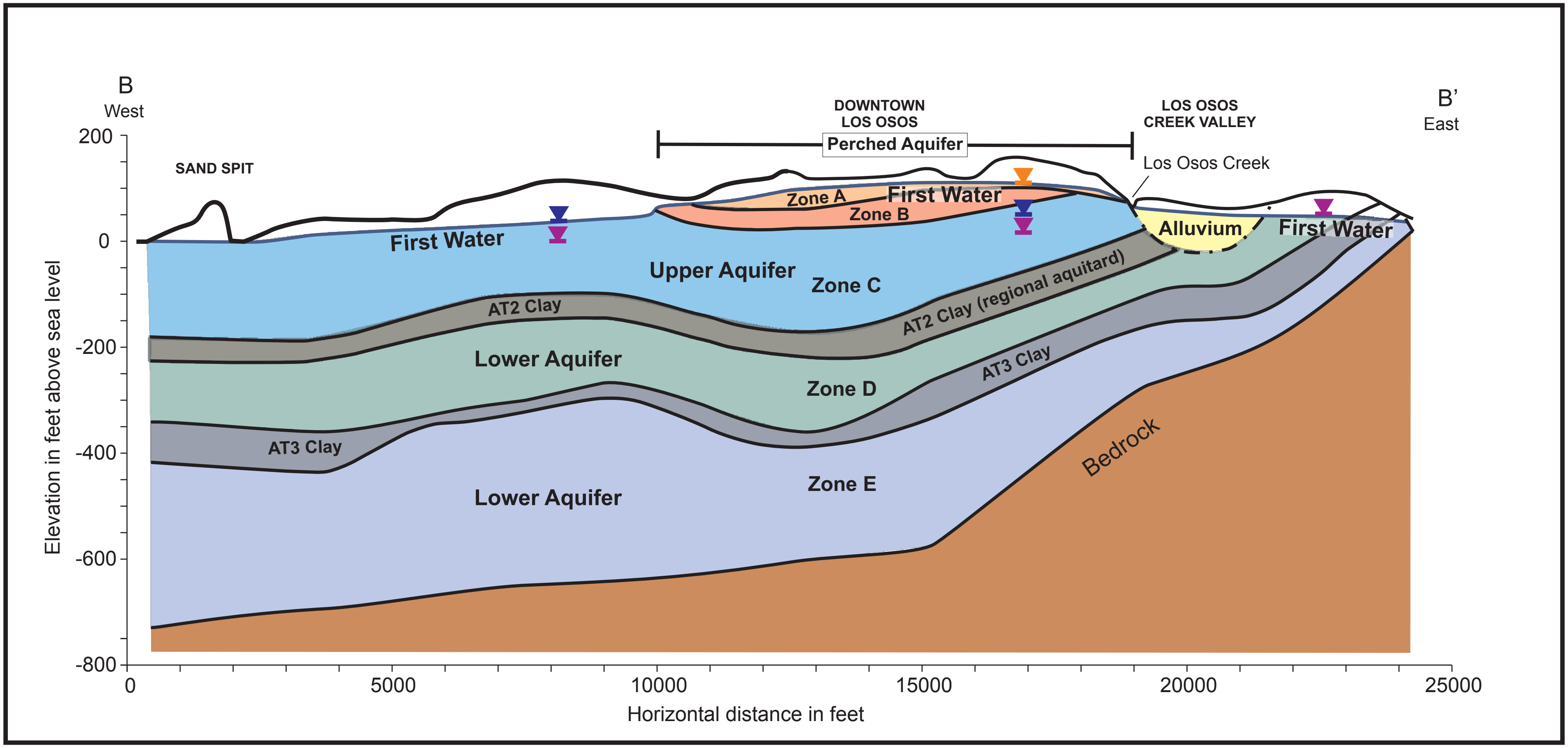
Basin Boundary from Basin Plan

Figure 1
Basin Location and Plan Areas
Los Osos Groundwater Basin
2015 Annual Report

Cleath-Harris Geologists

Added text in red

SOURCE: LOS OSOS GROUNDWATER BASIN 2015 ANNUAL REPORT



Cross-section alignment shown in Figure 1

Explanation

- Perched Aquifer Water level
- Upper Aquifer Water level
- Lower Aquifer Water level

Figure 5
Basin Aquifers
Los Osos Groundwater Basin
2015 Annual Report

Cleath-Harris Geologists

SOURCE: LOS OSOS GROUNDWATER BASIN 2015 ANNUAL REPORT

Water Quality Results - Lower Aquifer Monitoring

Station ID	Well Name	Basin Plan Well ID	Aquifer Zone	Date	HCO3	Total Hardness	Cond	pH	TDS	Cl	NO3	SO4	Ca	Mg	K	Na
					mg/l	mg/l	umhos/cm		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
30S/10E-12J1	MBO5 DWR Obs.	LA11	E	2/14/2005	350	370	1300	8.1	840	77	ND	190	51	58	6.1	110
				11/20/2009	300	360	1150	7.5	732	83	ND	190	51	58	4.4	95
				7/24/2014	360	489	1290	7.7	780	105	ND	212	69	77	5	88
				4/22/2015	360	475	1290	7.8	810	112	ND	189	65	76	5	88
				10/1/2015	250	486	1280	7.3	840	117	ND	188	68	77	4	85
				4/20/2016	330	524	1370	7.3	840	151	ND	193	73	83	5	83
				10/10/2016	350	497	1370	7.1	930	**173**	ND	189	69	79	4	81
30S/10E-13J1*	GSWC Rosina	LA10	D	12/20/2004	72	230	720	7.1	410	150	7	14	38	33	1.4	29
				1/14/2010	35	260	778	6	435	200	7.1	13	41	38	1.5	33
				7/24/2014	80	418	1200	7.3	910	303	7.6	16	67	61	2	39
				4/22/2015	80	431	1230	7.1	750	331	8.3	20	69	63	2	39
				10/5/2015	70	460	1280	7	950	329	7.3	19	74	67	2	41
				4/26/2016	80	412	1170	7.1	840	299	8	18	66	60	2	37
				10/12/2016	60	509	1430	6.8	1100	**389**	8	26.7	82	74	2	44
30S/10E-13M2	Howard East	LA31	C,D	11/22/2004	51	810	2900	7.3	1500	810	2.4	140	60	120	4.7	210
				12/9/2009	55	1100	3740	7.1	2170	1100	2.2	220	160	160	4.8	370
				8/4/2014	60	757	3340	7.1	2450	990	2.5	178	117	113	5	382
				4/21/2015	60	739	3430	7.3	1930	950	2.5	178	117	113	5	382
				10/6/2015	30	756	3370	7.1	2140	960	2.4	185	115	114	5	342
				4/20/2016	50	726	3520	7.2	2190	941	3.1	179	113	108	5	400
				10/19/2016	70	722	3420	7.4	2190	**943**	2.8	182	113	107	4	398
30S/10E-13N	S&T #5	LA8	D	11/23/2004	42	80	390	6.9	200	67	26	9.2	13	12	1.7	38
				11/19/2009	41	89	386	6.8	267	73	27	11	15	13	1.4	38
				7/24/2014	50	100	438	7.4	270	76	31	10	17	14	2	38
				4/21/2015	50	98	445	6.9	280	77	33.9	11	16	14	2	38
				10/6/2015	40	98	422	7.2	310	75	30	10	16	14	1	38
				4/20/2016	20	97.5	446	7	320	76	32	12	16	14	1	38
				10/13/2016	50	104	470	8	320	**79**	31.9	12	17	15	1	40
30S/10E-24C1	GSWC Cabrillo	LA9	D	12/20/2004	64	130	610	7	310	110	20	19	22	19	1.6	50
				11/20/2009	60	150	611	7.1	347	130	18	22	23	22	1.6	52
				7/24/2014	40	69	339	7.6	240	46	37	6	11	10	1	32
				4/22/2015	70	117	530	7.3	320	95	24.2	16	19	17	2	45
				10/5/2015	50	75	349	7.6	270	50	33.4	7	12	11	1	34
				4/26/2016	70	115	499	7	300	90	24.6	16	18	17	2	44
				10/12/2016	70	111	506	7.1	320	**93**	24.4	15.1	18	16	1	44
30S/11E-7Q3	LOCSD 8th St.	LA12	D	11/18/2004	250	270	790	7.5	410	73	ND	39	44	40	2.3	48
				11/19/2009	220	290	782	7.4	465	92	ND	46	46	42	1.9	53
				7/23/2014	290	303	876	7.6	460	91	ND	43	49	44	2	54
				4/21/2015	290	305	897	7.7	500	101	ND	55	48	45	2	59
				10/6/2015	280	298	828	7.4	490	91	ND	46	47	44	2	55
				4/20/2016	190	307	907	7.7	520	91	ND	49	49	45	2	54
				10/11/2016	280	278	827	7.8	490	**93**	ND	46.2	44	41	2	52
30S/11E-17E8	So. Bay Obs. Middle	LA22	D	1/14/2005	150	150	440	7.5	290	34	9.7	11	24	22	1.4	28
				11/20/2009	120	160	455	7.3	255	42	19	12	25	23	1.3	29
				7/23/2014	150	166	500	7.6	270	43	28	10	27	24	2	28
				4/21/2015	150	157	481	7.6	270	49	31.4	13	25	23	1	28
				10/1/2015	120	164	475	7.4	290	44	29.2	10	26	24	1	28
				4/19/2016	150	164	476	6.9	290	45	30.5	12	26	24	1	29
				10/13/2016	140	161	521	7.3	290	**46**	30.6	11.9	25	24	1	29
30S/11E-17N10	GSWC So. Bay #1	LA20	C,D,E	Jan 2003	250	--	510	7.1	290	37	ND	21	41	25	1.3	35
				11/20/2009	230	220	638	7.3	357	41	2.4	30	35	33	1.7	37
				7/24/2014	280	232	646	7.7	370	37	2.3	24	37	34	2	41
				4/22/2015	290	234	653	7.4	360	43	2.5	27	36	35	2	42
				10/5/2015	280	227	614	7.2	370	38	2.4	23	35	34	2	41
				4/26/2016	230	227	629	7.1	360	39	2.6	27	35	34	2	40
				10/12/2016	290	221	631	7	370	**40**	2.5	25.2	34	33	2	40
30S/11E-18K8	10th St. Obs. East (Deep)	LA18	E	1/19/2005	260	290	650	7.5	370	33	ND	38	62	33	2.5	28
				11/20/2009	230	220	620	7.5	378	32	ND	40	51	24	1.8	23
				7/24/2014	290	271	647	7.5	380	28	ND	34	56	32	2	27
				4/21/2015	290	265	634	7.7	400	33	ND	39	55	31	2	27
				10/19/2015	230	256	621	7.3	370	29	ND	33	53	30	2	26
				4/19/2016	190	265	700	7.5	390	31	ND	38	55	31	2	26
				10/18/2016	290	256	615	6.8	370	**31**	ND	35.9	53	30	2	26
30S/11E-18K9	LOCSD 10th St.	LA32	C,D	May 2002	250	--	550	6.9	320	37	1	26	31	32	--	39
				11/20/2009	180	160	539	7.2	307	36	4.6	27	27	24	1.3	32
				7/23/2014	220	190	546	7.7	300	32	4.3	20	30	28	1	35
				4/21/2015	190	108	504	7.6	270	38	7	20	17	16	1	27
				10/6/2015	50	62	248	7.2	190	31	26.2	3	10	9	ND	21
				4/20/2016	130	121	382	7.5	220	32	14.6	12	19	18	1	27
				10/11/2016	200	168	511	6.6	270	**36**	5.3	21.5	26	25	1	34
30S/11E-18L2***	LOCSD Palisades	LA15	D,E	11/18/2004	220	330	880	7.3	420	120	ND	31	54	48	2.2	40
			D,E	11/19/2009	200	590	1460	7.2	890	360	1.8	39	94	86	2	44
			D	7/23/2014	250	293	783	7.8	390	90	1.8	26	48	42	2	40
			D	4/29/2015	80	78	348	7.4	230	43	22	10	13	11	ND	30
			D	10/28/2015	230	288	782	7.4	420	104	2.8	29	46	42	ND	36
			D	4/27/2016	230	264	796	7.3	450	93	4.1	28	43	38	2	36
			D	10/11/2016	200	221	694	7	380	**91**	7.3	25.5	36	32	1	35

ND = Not Detected

Chloride Metric Wells in Green (13J1 weighted x2); **current chloride concentrations in red**

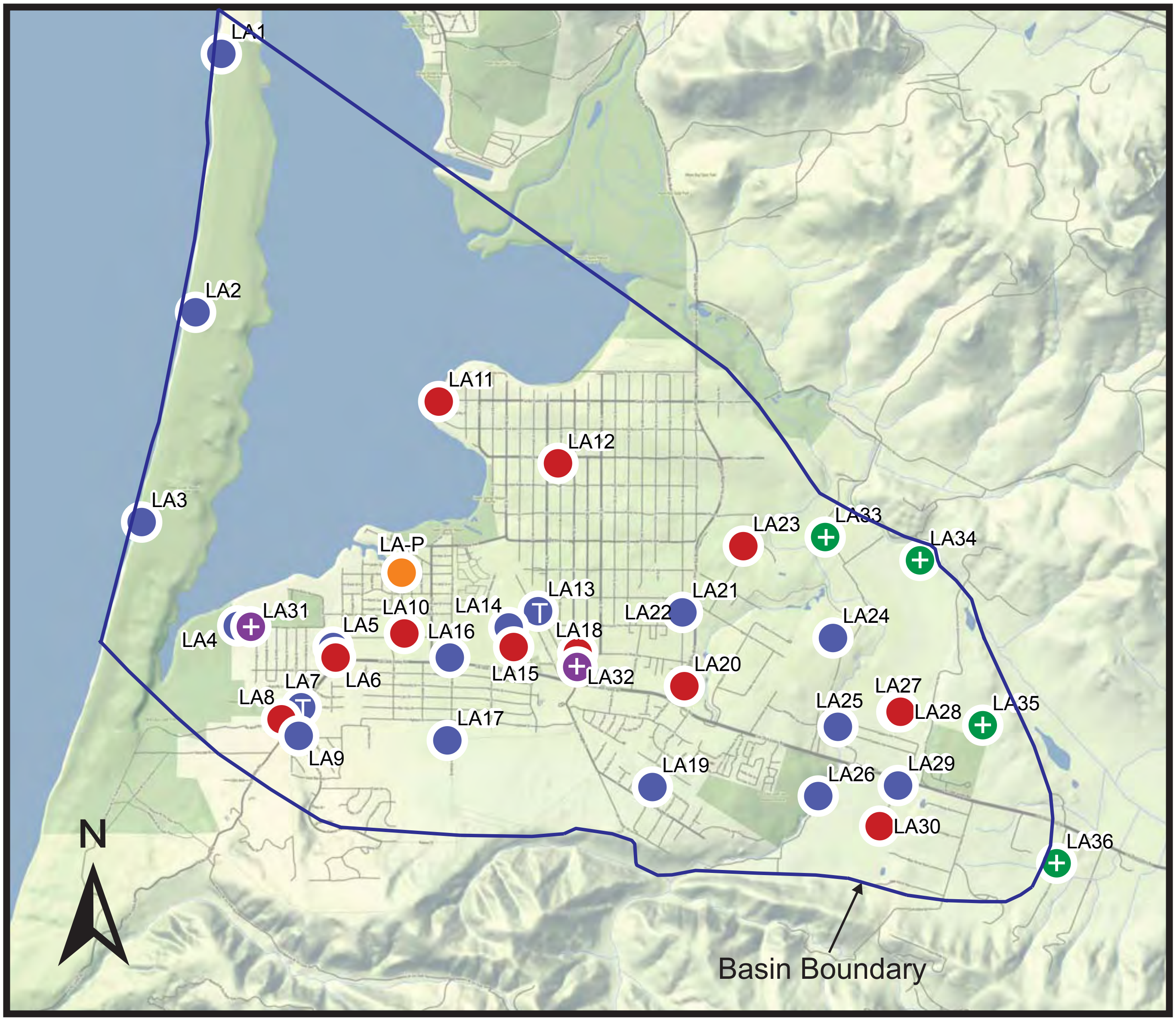
*Chloride concentrations at 13J1 have varied seasonally by 100+ mg/l, and are affected by well production, so fluctuations are expected.

***Water from 18L2 affected by borehole leakage/upper aquifer influence when inactive

Water Quality Results - Legend and Detection Limits

Constituent	Description	Practical Quantitation Limit*
HCO3	Bicarbonate Alkalinity in mg/L CaCO3	10.0
Total Hardness	Total Hardness in mg/L CaCO3	--
Cond	Electrical Conductance in μmhos/cm	1.0
pH	pH in pH units	--
TDS	Total Dissolved Solids in mg/L	20.0
Cl	Chloride concentration in mg/L	1.0
NO3	Nitrate concentration in mg/L	0.5
SO4	Sulfate concentration in mg/L	2.0
Ca	Calcium concentration in mg/L	1.0
Mg	Magnesium concentration in mg/L	1.0
K	Potassium concentration in mg/L	1.0
Na	Sodium concentration in mg/L	1.0

*where dilution not required



Base Image: Stamen-Terrain

0 2000 4000 6000 8000 ft

Scale: 1 inch ≈ 4,000 feet

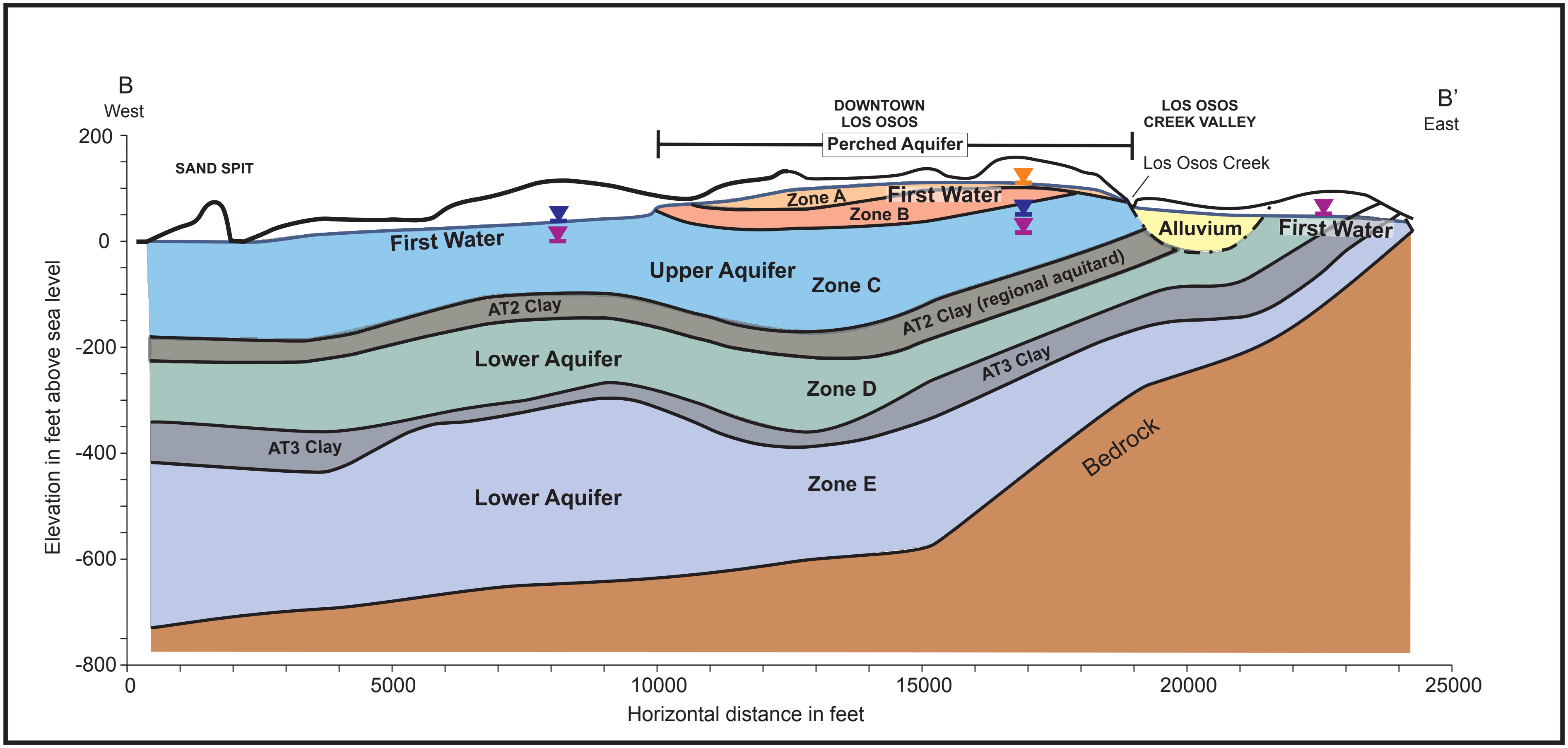
Explanation

- Water Level Monitoring Well
- Recommended Water Level Monitoring Well Addition (existing well)
- Water Level Transducer
- Water Level and Water Quality Monitoring Well
- Water Level Transducer and Water Quality Monitoring Well
- Recommended Water Quality Monitoring Well Addition (existing well)
- Planned New Monitoring Well Construction

Note: LA24 and FW24 are nested wells (same location)

Figure 4
Groundwater Monitoring Program
Lower Aquifer Wells
Los Osos Groundwater Basin
2015 Annual Report

Cleath-Harris Geologists



Cross-section alignment shown in Figure 1

Explanation

Perched Aquifer Water level
Upper Aquifer Water level
Lower Aquifer Water level

Figure 5
Basin Aquifers
Los Osos Groundwater Basin
2015 Annual Report

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