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Technical Memorandum

Date: August 24, 2018

From: Spencer Harris, HG 633

To: Rob Miller, P.E., District Engineer
Los Osos Community Services District

SUBJECT: **Well survey and Groundwater Impacts Evaluation related to Site C Expansion Well, Los Osos Groundwater Basin.**

Dear Mr. Miller:

Cleath-Harris Geologists (CHG) has completed a survey of available Well Completion Reports and has evaluated potential impacts to private domestic wells from a Program C Expansion Well being considered in the vicinity of Andre Avenue (Site C), Los Osos. The purpose of the work is to provide the Los Osos Community Services District (LOCSD) with technical information to share at a community workshop and to assist in Expansion Site selection. This memorandum presents the results of the well survey and impacts evaluation.

Background

Program C is an infrastructure program in the Los Osos Basin Plan (LOBP) that includes Expansion Wells for shifting municipal groundwater production within the Lower Aquifer from the Western Area to the Central Area of the Los Osos Groundwater Basin (Figure 1). Implementation of Program C would have a direct, beneficial impact on mitigating seawater intrusion. (LOBP; ISJ, 2015).

Three Expansion Wells were originally planned under the existing population scenario, the first of which was completed by GSWC at Los Olivos Avenue (Expansion Well No. 1; Figure 1). A recent evaluation of Program C, with updated basin water use estimates for existing conditions, recommended construction of only one more well to complete the program. A geologic cross-section of the basin aquifers with the Site C Expansion Well is shown in Figure 2.

Four sites (Site A through Site D) are under consideration for Expansion Well No. 2 (Figure 1). One of the sites (Site C) is located along Andre Avenue, where there is a relatively high concentration of private domestic water wells, compared to the other sites. Evaluating potential impacts on local domestic water supply wells from an Expansion Well at Site C is the focus of this analysis.

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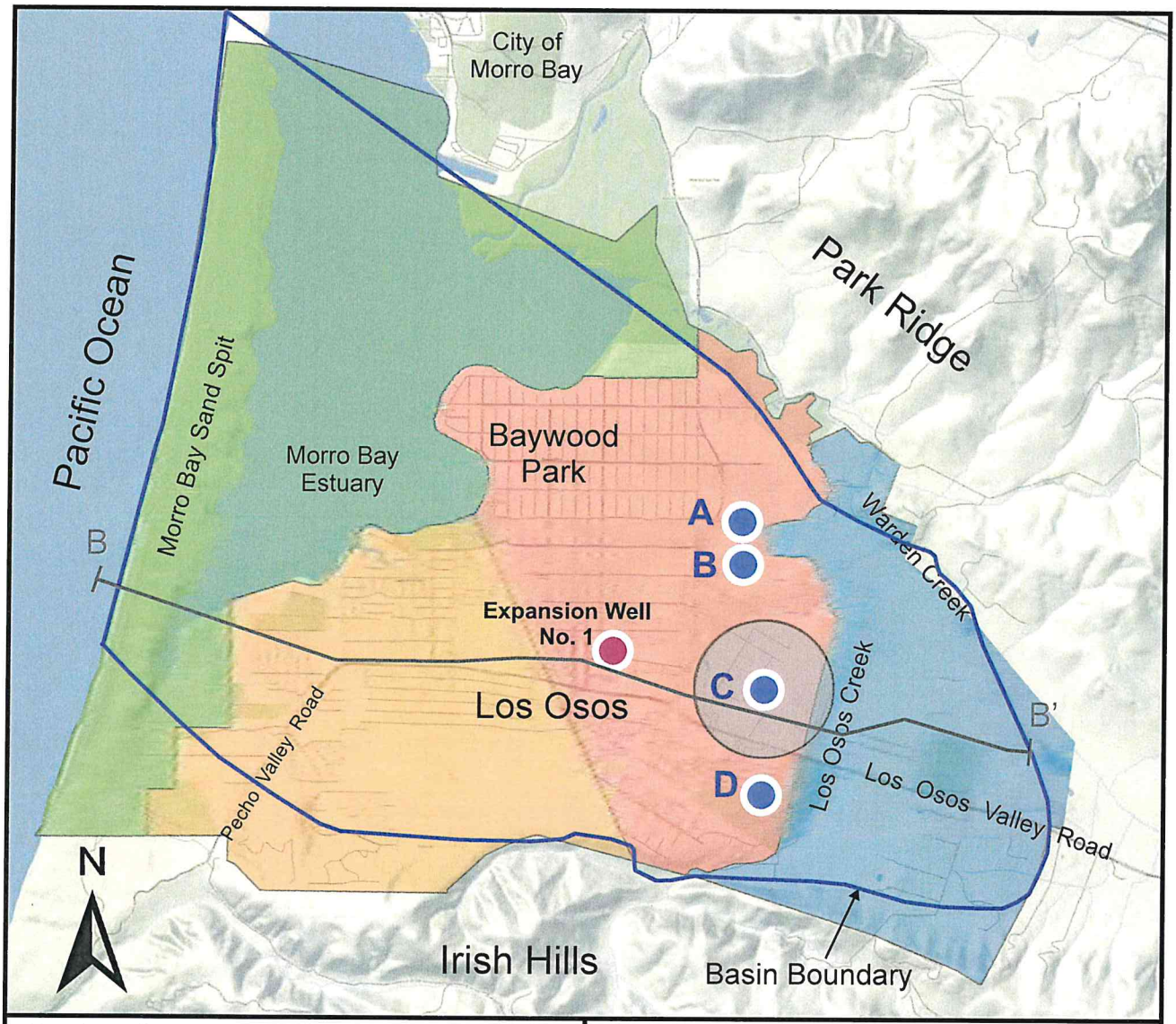

Base Image: Stamen-Terrain

Explanation

Los Osos Basin Plan Areas:

- Dunes and Bay Area
- Western Area
- Central Area
- Eastern Area

C Potential Site for Expansion Well No.2

Study Area for Site C Expansion Well

B — B' Cross-section alignment (Figures 2). Labeled B-B' to be consistent with Los Osos Basin Plan.

Basin Boundary from Los Osos Basin Plan

0 2000 4000 6000 8000 ft

Scale: 1 inch ≈ 4,000 feet

Figure 1
Basin Plan Areas and
Potential Expansion Well Sites
Site C Expansion Well TM
Los Osos CSD

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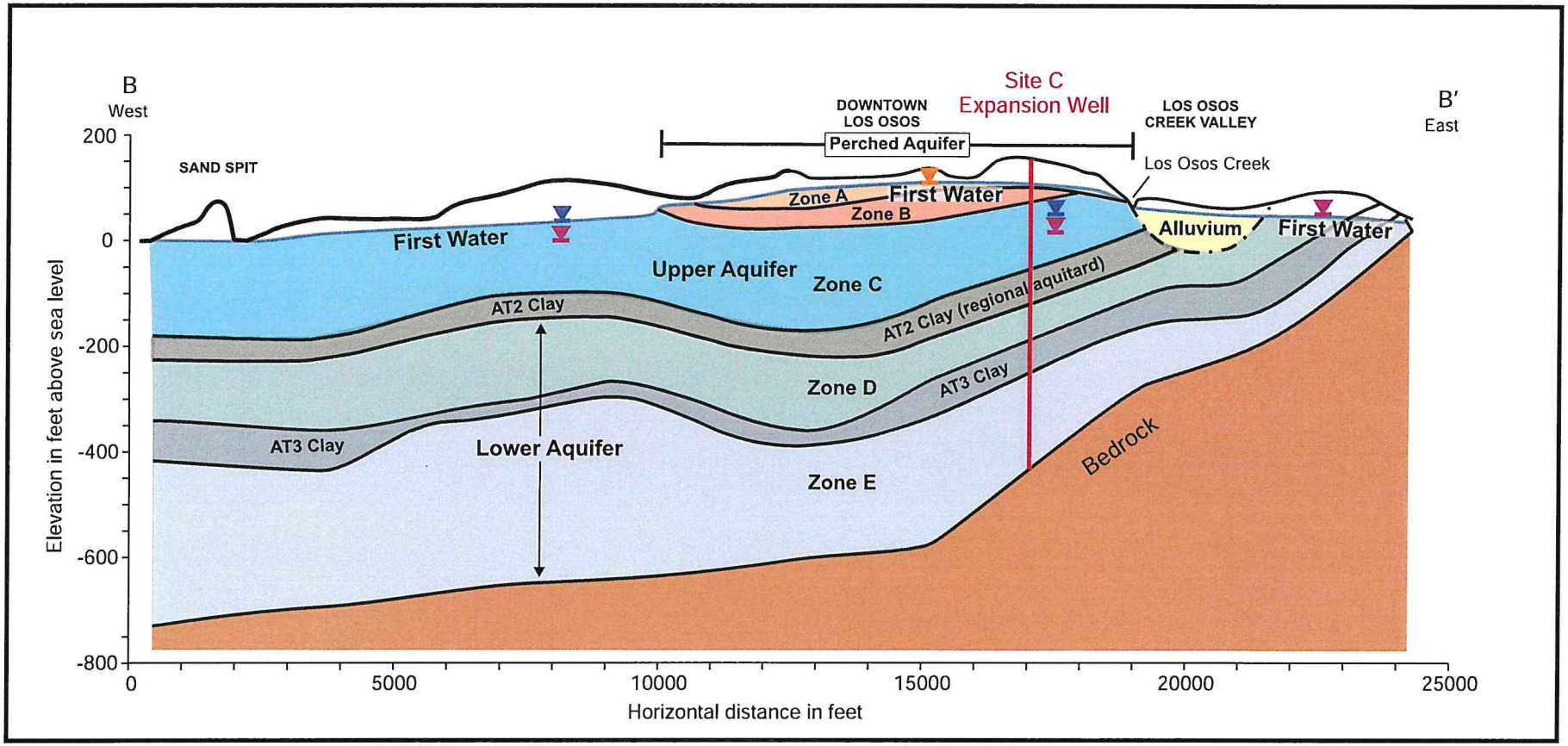

Cross-section alignment shown in Figure 1

Explanation

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

Figure 2
Aquifer Zones
Los Osos Groundwater Basin
Site C Expansion Well TM
Los Osos CSD

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Well Completion Report Survey

A Well Completion Report, also referred to as a drillers report or well log, is a form submitted to the Department of Water Resources (DWR) by the drilling contractor which contain information about a new well. This information typically includes the well owner, well location, geologic log, well construction, planned use, water level and yield.

CHG performed a database search of well logs and identified 37 wells within a 1,700-foot radius of Site C. The 1,700-foot search radius extends from Willow Creek to Los Osos Creek. There are additional wells on developed parcels within the survey radius, but the available well logs are representative of the typical depths and aquifers tapped by wells in the area. Results of the well survey are shown in Figure 3 and Tables A1 and A2 (Attachment A).

Of the 37 wells with information, one well was completed in the Perched Aquifer, 29 were Upper Aquifer wells, and 7 were mixed Upper and Lower Aquifer wells. The Perched Aquifer well was 60 feet deep, Upper Aquifer wells averaged 160 feet deep, and the mixed aquifer wells averaged 260 feet deep. By comparison, a Lower Aquifer Expansion Well at Site C would be about 600 feet deep.

Nine of the Upper Aquifer Well Completion Reports reported discharge information averaging 60 gallons per minute (gpm). Five of the mixed aquifer Well Completion Reports reported discharge information averaging 70 gpm. Discharge with water level drawdown information are reported in five Upper Aquifer wells. The specific capacities range from 0.4 gallons per minute per foot of water level drawdown (gpm/ft) to 1.8 gpm/ft, averaging 1.2 gpm/ft.

Static water levels reported in Upper Aquifer wells following well completion averaged 35 feet above sea level, while mixed aquifer wells averaged 6 feet above sea level. There was an average of 78 feet of water column reported in the Upper Aquifer wells at the time of well completion, and an average of 136 feet of water column in the mixed aquifer wells. The water column is measured from the top of the water surface to the bottom of the well.

Information from the well survey has been used herein to help to characterize the potential groundwater impacts from operating an Expansion Well at Site C.

Water Level Trends

Water level hydrographs for a representative Upper Aquifer well and a mixed aquifer well in the general study area are presented in Figure 4. The Upper Aquifer well hydrograph shows an overall decline in water levels of 10 feet since monitoring at the well started in 1989, with spring water levels highest between 1993 and 1996, and lowest between 2014 and 2016. The mixed aquifer well shows similar trends, with high spring water levels in the early 1990's and low water levels during the recent drought period. The mixed aquifer well data covers a longer period of

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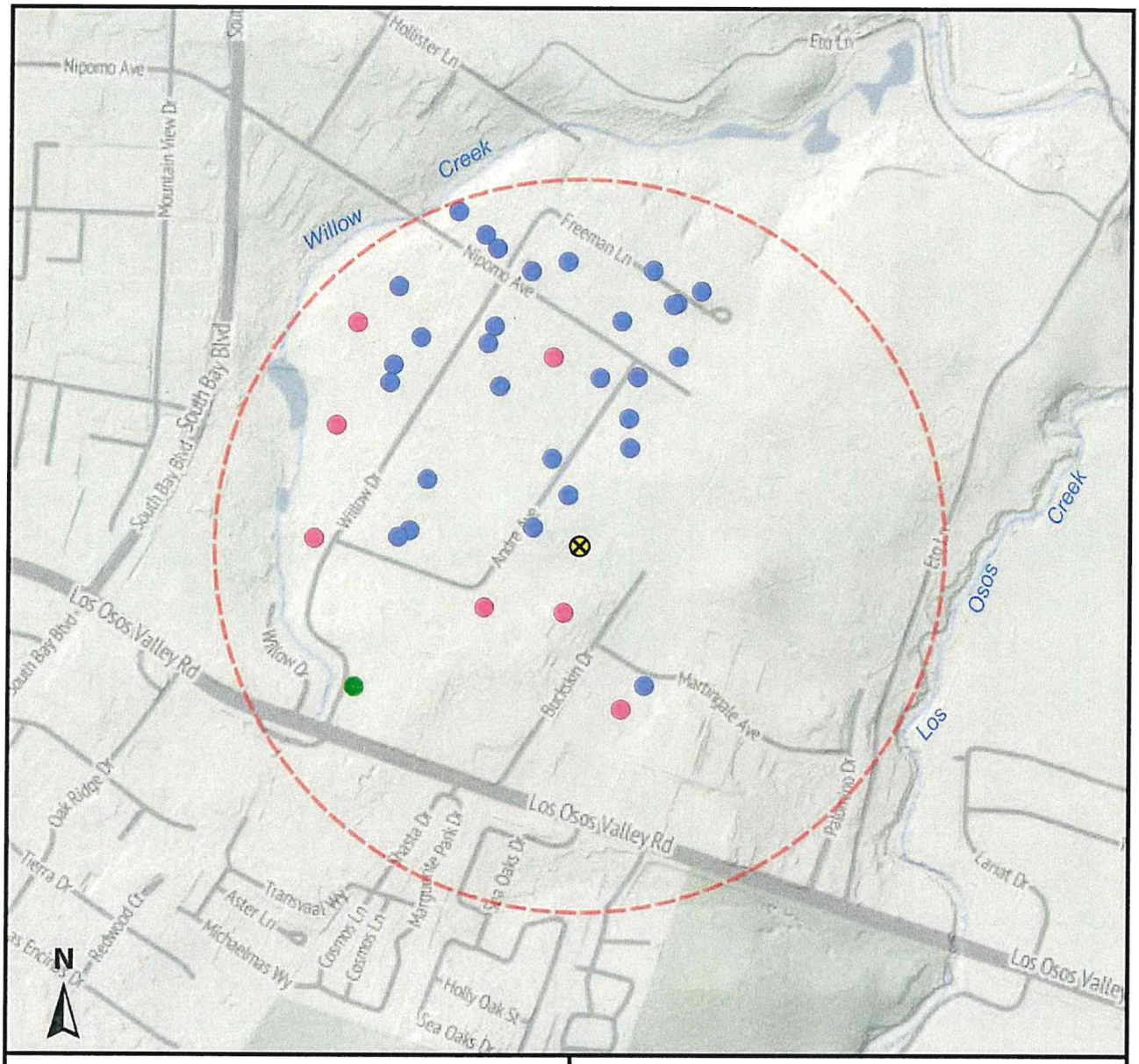

Base Image: Stamen-Terrain

Explanation

- Site C Study Area
- Site C Expansion Well

Study Area Wells*

- Perched Aquifer
- Upper Aquifer
- Mixed (Upper/Lower Aquifer)

*Only wells with information from Well Completion Reports are shown

0 375 750 1125 1500 ft

Scale: 1 inch ≈ 750 feet

Figure 3
Well Survey
Site C Expansion Well TM
Los Osos CSD

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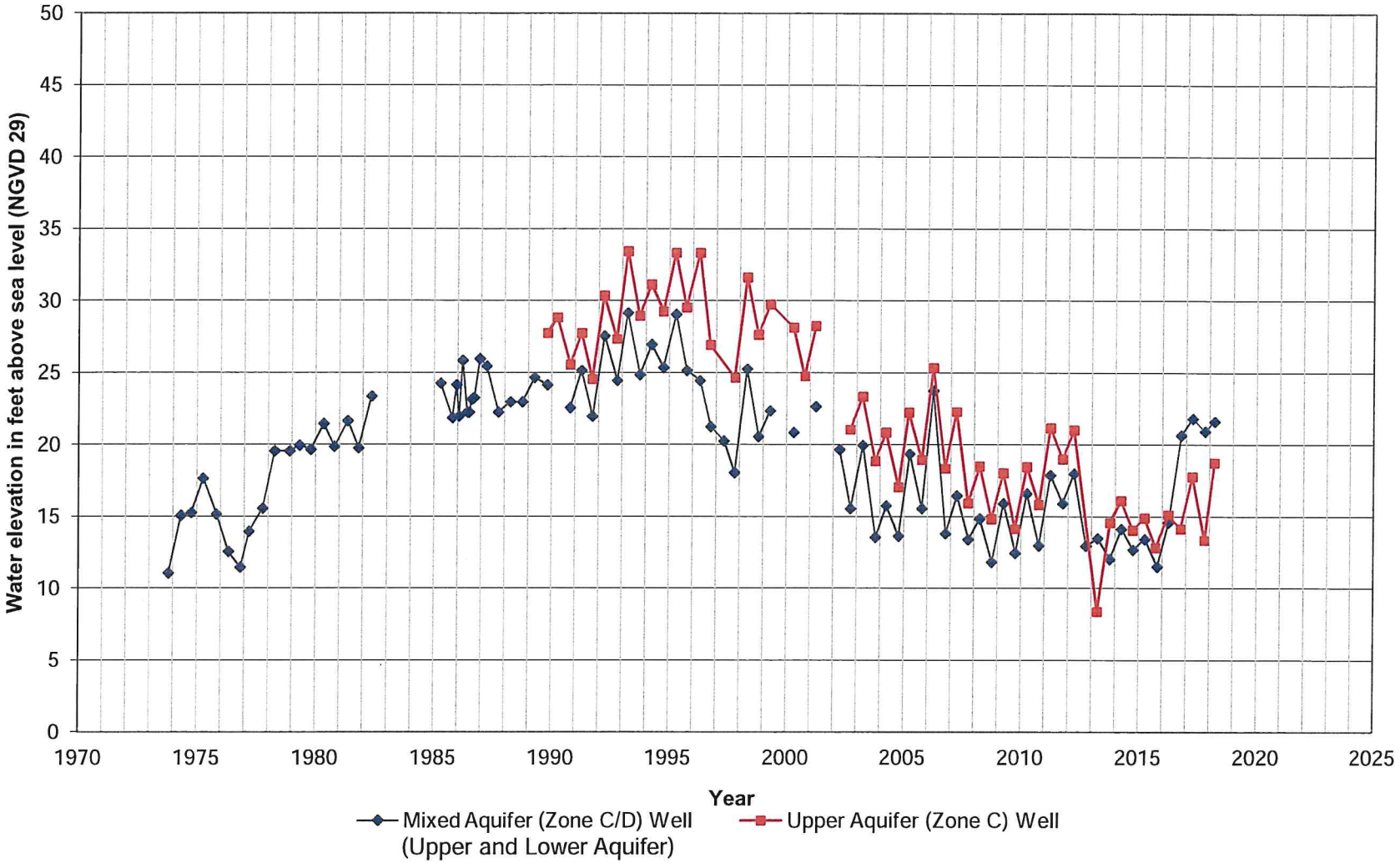

Wells are located in eastern portion of Central Area
(representative of Site C Study Area)

Figure 4
Water Level Hydrographs
Los Osos Groundwater Basin
Site C Expansion Well TM
Los Osos CSD

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record, however, and shows another water level low during the mid-1970's drought. The overall trend in local water levels since the 1970's appears relatively stable.

Groundwater Impacts Evaluation

The same amount of well interference can cause a problem for one well but not for another. Well construction, pump flow rate, pump depth setting, and specific capacity are some of the factors to consider. In order to identify an impact threshold for water level declines in the study area, the following local criteria were established to represent a reliable domestic supply well:

- The well pump operates at a nominal 10 gpm. This would be a typical flow rate for a well serving a domestic system with a pressure tank.
- Specific capacity of the well is 0.4 gpm/ft (assumes low end of reported range).
- The well pump is set 10-20 feet above the bottom of the well (typical).
- At least 10 feet of water is above the well pump during operation.

Using the above criteria, a pumping rate of 10 gpm would require 25 feet of available drawdown. Given another 10 feet of water above the pump and 15 feet of water below the pump for safe operation, a minimum of 50 feet of total water column would be needed to meet the above criteria.

For screening purposes, there would be a potentially significant impact if interference from a new Expansion Well resulted in less than 50 feet of (static) water column remaining in neighboring wells during drought conditions. Wells with less than 50 feet of water column may still be reliable, but are at greater risk of problems (pump failure, excessive sand production, low water pressure) during severe drought.

For example, a 5 gpm well pump with a specific capacity of 0.4 gpm/ft would need only 13 feet of water level drawdown during typical pumping cycles, and a well could be reliable with a 38-foot water column. For comparison, most private residences are on 1-acre lots in the study area use between an estimated 0.6 AFY and 1.4 AFY (CHG, 2009), which is less than 1 gpm continuous flow.

Given the historical performance of wells in the area (averaging 60 gpm to 70 gpm discharge with air-lift pumping), however, a 10 gpm well pump would have been be a logical choice to maintain a domestic pressure system, making it easier to maintain delivery pressure at the higher flow rates during peak demand periods. If the reliability criteria are not met during drought, an existing 10 gpm pump might fail and require downsizing to a smaller pump (with a larger pressure tank), which would be considered a significant impact.

Well Interference

Interference between wells occurs when a pumping well causes the water level to decline in a nearby well. Multiple wells can interfere with each other. This analysis is specific to the interference of a new Expansion Well on pre-existing wells.

The amount of well interference caused by a Site C Expansion Well has been estimated using the results of an interference test performed at a Lower Aquifer irrigation well on Sage Avenue during the Expansion Well Site B evaluation for the LOCSD in 2016 (CHG, 2016). The pumping test consisted of pumping the irrigation well for 36 hours while monitoring water levels in two nearby Upper Aquifer wells.

Data from the Sage Avenue pumping test was analyzed using AQTESOLV, a commercial software package, and calibrated to an analytical model of the Neuman-Witherspoon (1969) solution for a pumping test in a semi-confined (leaky), two-aquifer system. The solution can be used to analyze data from observation wells screened in an unpumped aquifer overlying an aquitard and a pumped aquifer, which matched the hydrogeologic conceptual model for the area, and is similar to Site C along Andre Avenue (although the Lower Aquifer beneath Site C is thicker than at Site B). The Upper Aquifer at both sites is also conservatively interpreted to be semi-confined by overlying clays associated with the Perched Aquifer. Where the Upper Aquifer is unconfined, interference would be significantly less due to the greater amount of water available from storage per foot of water level decline.

The Neuman-Witherspoon solution allows for no-flow and constant head (recharge) boundary conditions. Basin boundaries to the north and south were assigned as no-flow barriers, while the Los Osos Creek valley on the east and the edge of the Perched Aquifer on the west were assigned constant-head boundaries. Unconfined conditions significantly reduce potential well interference where the Upper Aquifer meets the Los Osos Creek valley and west of the Perched Aquifer, even during drought). As a conservative measure, no percolation of precipitation or leakage from the overlying Perched Aquifer was included in the analysis.

For the maximum interference analysis, the Site C Expansion Well is assumed to pump up to 200 acre-feet per year (AFY; equivalent to 125 gpm continuous flow), using daily pumping cycles of 15 hours each at 200 gpm. The duration of pumping was extended to reach steady-state conditions (no further water level drawdown). To account for intermittent pumping, estimated drawdown from steady-state pumping (125 gpm) was added to the estimated drawdown from one pumping cycle at 75 gpm, which is the difference between the steady-state rate and the operating rate.

Since the Expansion Well pumps from the Lower Aquifer, interference is greater in the Lower Aquifer, compared to the Upper Aquifer. For mixed aquifer wells, interference is assumed to be an average of the Upper Aquifer and Lower Aquifer drawdown. Table 1 presents the results of interference estimates at the neighboring wells closest to the proposed Site C Expansion Well.

Contours of the projected interference in feet of water level drawdown for Upper Aquifer and mixed aquifer wells are shown in Figures 5 and 6.

Table 1 - Estimated Well Interference

Well Completion Report #	Approximate Distance from Site C (feet)	Producing Aquifer	Estimated Interference* (feet of water level drawdown)
(data sheet only)	230	Upper	6.2
E0223861	250	Upper	6.2
E029925	320	Mixed	8.5
E0223930	430	Upper	5.6
5332	510	Upper	5.3
5339	530	Mixed	6.4
782515	770	Mixed	5.1
182597	900	Mixed	4.6

*Interference assumes Site C Expansion Well producing 200 AFY

A Site C Expansion Well would pump only from the Lower Aquifer, resulting in greater interference (for the same horizontal distance) at the mixed aquifer wells, compared to Upper Aquifer wells. As Lower Aquifer water levels declined in response to pumping, a greater vertical pressure differential would develop across the regional aquitard (Figure 2), which would increase the amount of vertical leakage from the Upper Aquifer into the Lower Aquifer.

Potentially Impacted Wells

Fall 2016 was at the end of an exceptional drought (the highest severity). The Upper Aquifer water level contour map for Fall 2016 was used to represent severe drought conditions in the study area (Attachment B). Drought water levels from the contour map were assigned to each Upper Aquifer well and reduced by the estimated well interference. Any well with a static water column of 50 feet or less would not meet the locally-established reliable well criteria. Table 2 summarizes the groundwater impacts evaluation.

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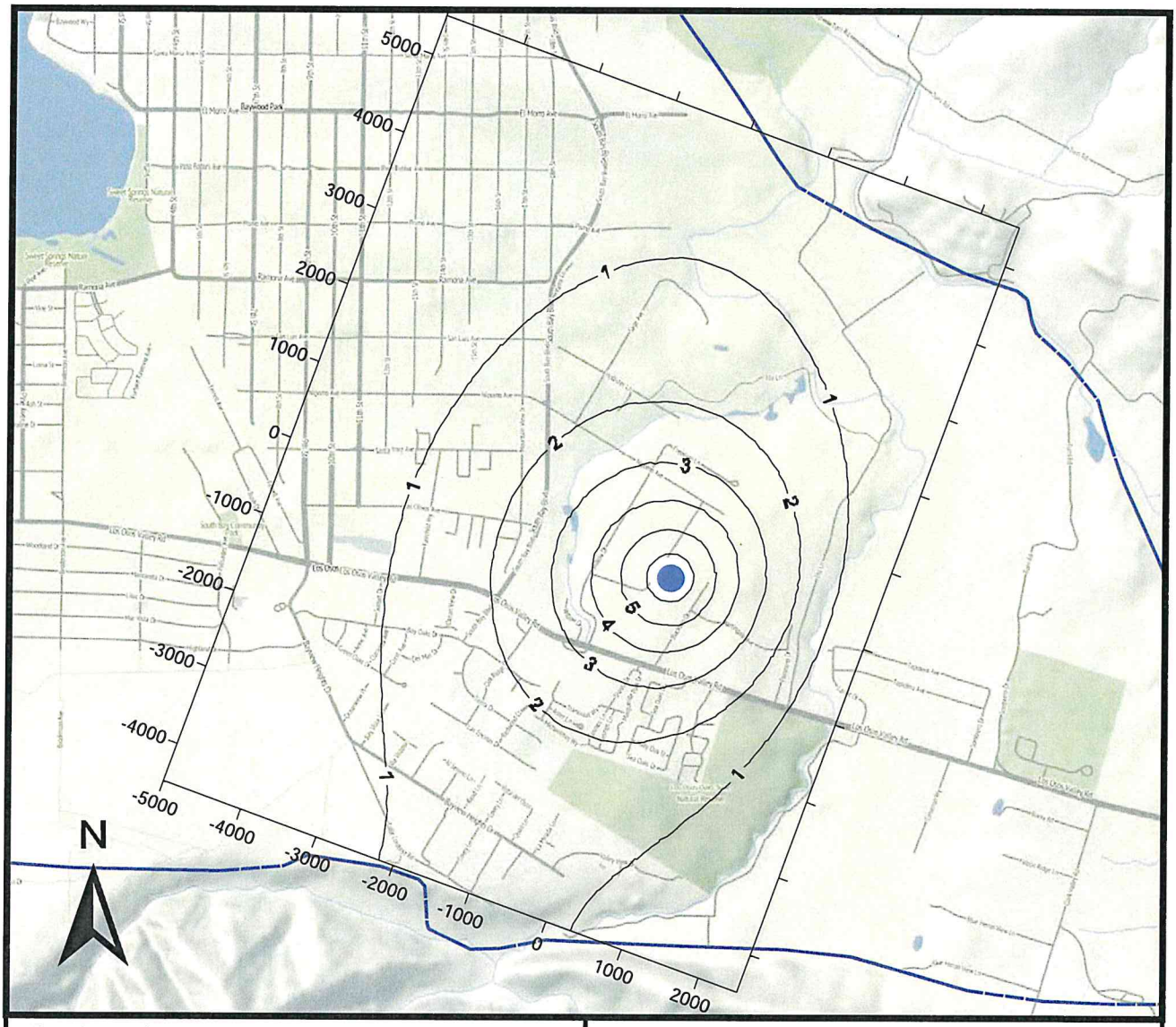

Base Image: Stamen-Terrain

Explanation

Estimated interference from Site C Expansion Well in feet of water level drawdown in Upper Aquifer

Site C Expansion Well

Basin Boundary from Los Osos Basin Plan

0 1000 2000 3000 4000 ft

Scale: 1 inch ≈ 2,000 feet

Figure 5
Interference in Upper Aquifer Wells
Site C Expansion Well TM
Los Osos CSD

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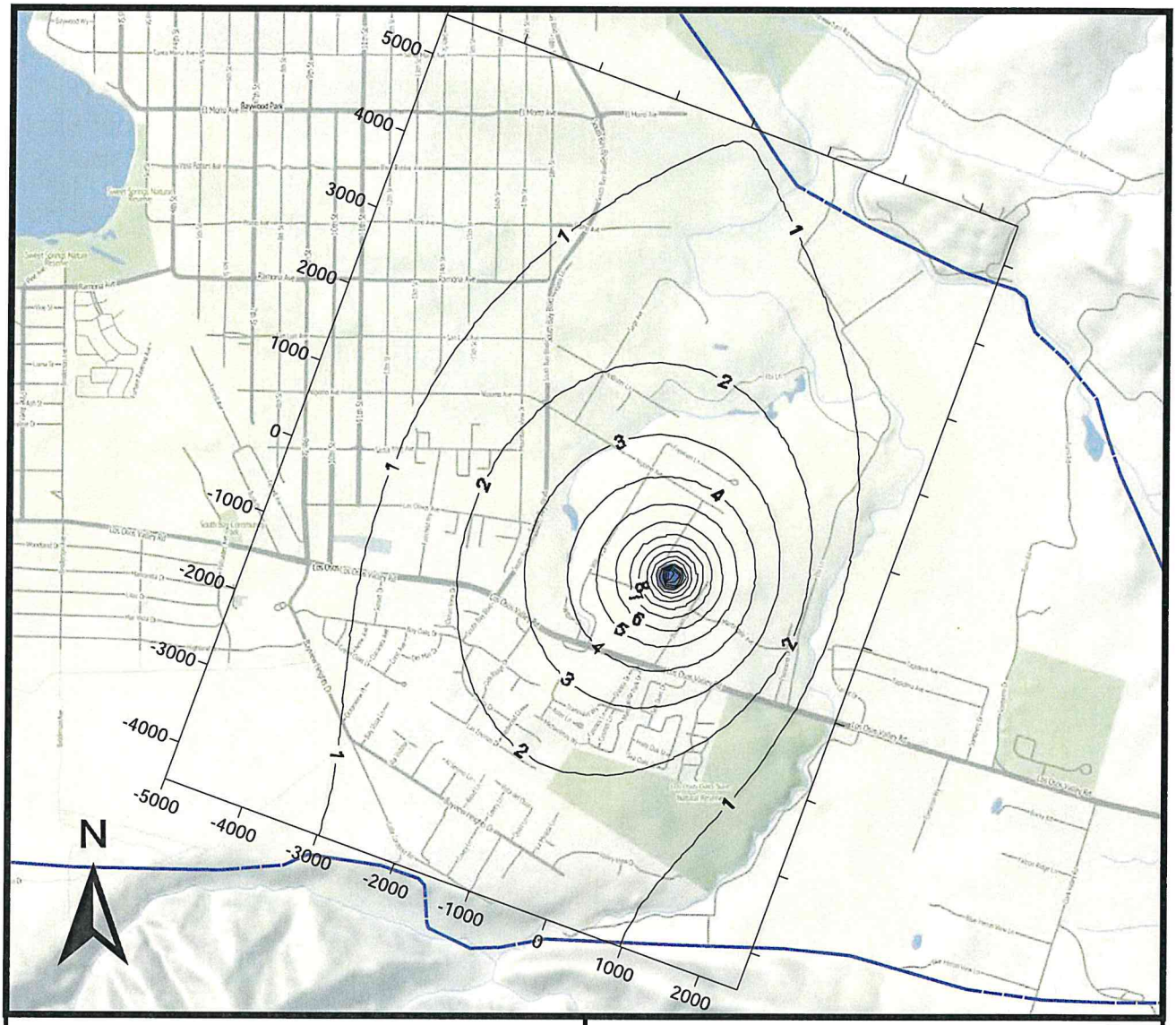

Base Image: Stamen-Terrain

Explanation

Estimated interference from Site C Expansion Well in feet of water level drawdown at mixed Upper/Lower Aquifer wells

Site C Expansion Well

Basin Boundary from Los Osos Basin Plan

0 1000 2000 3000 4000 ft

Scale: 1 inch ≈ 2,000 feet

Figure 6
Interference in Mixed Upper/Lower Aquifer Wells
Site C Expansion Well TM
Los Osos CSD

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Table 2 - Drought Water Level Impact Evaluation					
Well Completion Report #	Static Water Level Fall 2016	Estimated Well Bottom Elevation	Fall 2016 water column	Estimated Well Interference	Drought water column with interference
	ft above msl		ft	ft drawdown	ft
(data sheet only)	26	-7	**33**	6.2	**27**
E0223861	26	-12	**38**	6.2	**31**
E0223930	24	-35	59	5.6	53
5332	26	-43	69	5.3	64
E0223880	25	-40	65	5	60
E0223863	34	-15	**49**	4.8	**44**
E0223851	22	-3	**25**	4.6	**20**
E0223157	22	-47	69	4.6	65
341527	24	-65	89	4.5	84
E0138810	21	-77	98	4.4	93
242285	24	-64	88	4.4	83
E0223864	23	-21	**44**	4.4	**40**
102397	25	-54	79	4	75
E0248216	19	-45	64	3.8	61
61109	20	-32	52	3.8	**48**
E0223873	19	-47	66	3.7	62
E0223881	20	-20	**40**	3.6	**36**
E0223867	22	-60	82	3.5	79
E0223158	19	-42	61	3.5	58
102383	22	-59	81	3.5	78
E0223159	19	-49	68	3.4	65
61116*	139	100	**39**	<1	**39**
61149	18	-54	72	3.3	69
102382	24	-51	75	3.3	72
E0223875	19	-62	81	3.3	78
102387	20	-51	71	3.2	68
E0223879	19	-23	**42**	3.1	**38**
E0223872	19	-92	111	3	108
E0223155	19	-16	**35**	2.9	**32**
E0223156	19	-48	67	2.7	64

*Perched Aquifer (drought water level from Fall 2016 Perched Aquifer contour map)

ft above msl = estimated feet above mean sea level

ft drawdown = feet of water level drawdown

Bolded wells potentially impacted during severe drought

The average water column estimated in Upper Aquifer wells during Fall 2016 was 65 feet, with most wells meeting the criteria for providing reliable domestic supply (Table 2). An estimated 8 of the 29 Upper Aquifer wells surveyed in the study area did not meet the criteria in Fall 2016, even without an Expansion Well at Site C.

With an Expansion Well pumping a maximum of 200 AFY, interference at Upper Aquifer wells in the study area is estimated to range from 3 to 6 feet, resulting in one additional well (9 total) falling below the 50-foot minimum water column threshold. The average depth of the Upper Aquifer wells subject to potentially significant water level impacts during drought is 140 feet (ranging from 110 feet to 160 feet deep). Reductions in Expansion Well pumping would result in an equivalent percent reduction in well interference.

The Perched Aquifer identified in the well survey well did not meet the reliability criteria, but would likely not be significantly affected by Expansion Well operation. Water levels in the Perched Aquifer well are close to 100 feet higher than local Upper Aquifer water levels, and the amount of downward leakage through the perching clays would not be impacted by a few feet of decline in Upper Aquifer water levels. All of the mixed aquifer wells (and any Lower Aquifer wells in the area) are projected to meet the reliable well criteria established for this analysis with Expansion Well interference.

Conclusions

Conclusions of the well survey and Site C Expansion Well impacts evaluation are as follows:

- A total of 37 well logs were located within the Site C study area, which is between the Willow Creek drainage and Los Osos Creek. One well was completed in the Perched Aquifer, 29 were Upper Aquifer wells, and 7 were mixed Upper and Lower Aquifer wells. The Perched Aquifer well was 60 feet deep, Upper Aquifer wells averaged 160 feet deep, and the mixed aquifer wells averaged 260 feet deep. There was an average of 78 feet of water column reported in the Upper Aquifer wells at the time of well completion, and an average of 136 feet of water column in the mixed aquifer wells.

- In order to identify an impact threshold for water level declines, local criteria were established to represent a reliable domestic supply well. These criteria were used to develop a 50-foot threshold for the minimum height of the water column in a well. Wells with less than 50 feet of water column may still be reliable, but are at greater risk of problems (pump failure, excessive sand production, low water pressure) during severe drought. The average estimated water column height in Upper Aquifer wells during Fall 2016 (severe drought) was 65 feet above the bottom of the well, with most wells meeting the criteria for providing reliable domestic supply.

- An estimated 8 of the 29 Upper Aquifer wells surveyed in the study area did not meet the reliable well criteria in Fall 2016, even without an Expansion Well at Site C. With the Expansion Well pumping a maximum of 200 AFY, interference for Upper Aquifer wells in the study area is estimated to range from 3 to 6 feet, resulting in one additional well falling below the 50-foot minimum water column threshold. The average depth of the Upper Aquifer wells subject to potentially significant water level impacts during drought is 140 feet (ranging from 110 feet to 160 feet deep).

- The Perched Aquifer well did not meet the reliability criteria, but would likely not be significantly affected by Expansion Well operation. All of the mixed aquifer wells (and any Lower Aquifer wells in the area) are projected to meet the reliable well criteria established for this analysis.

Recommendations

The following steps are recommended if a Site C Expansion Well is pursued:

- Establish a voluntary Site C groundwater monitoring program for wells within the study area that are 160 feet deep or less.

- Determine the actual pumping rate, pump depth setting, and specific capacity for wells in the Site C groundwater monitoring program, or any well in the study area per well owner request, regardless of depth. Recalculate the impacts threshold for each well using site specific information, including minimum water column above the pump.

- Provide owners of those wells not meeting site-specific impacts threshold with options to mitigate potential impacts from a Site C Expansion Well. These could include lowering the well pump, reducing pump size with increased pressure tank capacity, and cleaning the well to remove sand and increase specific capacity. Mitigation options would be offered at no cost to well owner.

- Monitor actual interference from the Expansion Well at wells in the Site C groundwater monitoring program. If the interference causes a private domestic well to become unreliable to a level that would not support the existing use, the impact would be mitigated at no cost to well owner. The appropriate mitigation measure would be determined at that time.

References

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ATTACHMENTS

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ATTACHMENT A:

Well Completion Report Survey

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TABLE A1
UPPER AQUIFER AND PERCHED AQUIFER WELLS
WELL COMPLETION REPORT SURVEY

Well Completion Report #	Approx. Ground Elevation	Completion Date	Casing	Borehole Depth	Completed Depth	Perforted Interval	Reported Discharge		Static Water Level at Completion
	ft above msl			ft bgs			gpm	type	ft bgs
(data sheet only)	151	1/13/77	6"	158	158	78-158			
E0223861	138	12/8/76	6" Steel	160	150	90-150			
E0223930	135	2/15/74	6"	170	170	110-170			120
5332	137	6/19/78	6" PVC	180	180	120-180	25		120
E0223880	125	1/16/78	8" Steel	165	165	90-165	125	Pump test	90
E0223863	145	7/21/75	8" Steel	160	160	70-160	60	Pump test	70
E0223851	137	2/15/74	6"	140	140	80-140			102
E0223157	113	8/29/77	6" Steel	160	160	60-160			
341527	135	4/5/90	6" PVC	200	200	140-200	40	Airlift	130
E0138810	120	10/6/11	5" PVC	200	197	97-197			98
242285	116	7/31/84	6" PVC	180	180	100-180	60	Airlift	70
E0223864	134	2/11/71	6" Steel	160	155	85-155	15	Pump test	80
102397	106	2/25/75	6" Steel	200	160	120-160			76
E0248216	115	4/10/73	6" Steel	160	160	120-160			69
61109	108	8/2/73	6" Steel	140	140	100-140			86
E0223873	113	1/30/76	6" PVC	160	160	125-160	30	Pump test	55
E0223881	120	7/29/76	6"	171	140	60-100, 120-140			80
E0223867	100	2/23/76	6" Steel	160	160	120-160			75
E0223158	118	1/16/78	12" Steel	160	160	90-160	60		90
102383	101	10/22/74	6" Steel	180	160	100-160			75
E0223159	113	1/10/78	12" Steel	162	162	90-160	60		90
61116*	160	8/7/73	6" Steel	60	60	40-60			10
61149	106	2/27/74	6" Steel	200	160	120-160			70
102382	99	10/22/74	6" Steel	180	150	99-150			76
E0223875	98	9/10/76	6" PVC	175	160	120-160			70
102387	99	2/19/75	6" Steel	180	150	110-150			
E0223879	102	2/27/79	6" PVC	140	125	85-125			70
E0223872	98	8/22/77	6" PVC	200	190	140-190			82
E0223155	94	3/20/71	Steel	166	110	90-110			37
E0223156	82	10/25/72	8" Steel	130	130	65-130	80	Pump test	40

*Perched Aquifer (one well only)
ft above msl = feet above mean sea level estimated from topographic map
ft bgs = feet below ground surface
gpm = gallons per minute

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TABLE A2
MIXED UPPER/LOWER AQUIFER WELLS
WELL COMPLETION REPORT SURVEY

Well Completion Report #	Approx. Ground Elevation	Completion Date	Casing	Borehole Depth	Completed Depth	Perforted Interval	Reported Discharge		Static Water Level at Completion
	ft above msl			ft bgs			gpm	type	ft bgs
E029925	163	9/21/05	5" PVC	300	300	160-300	50	Airlift	160
5339	155	6/27/78	6" PVC	240	240	180-240	30		180
782515	152	9/20/01	5" PVC	300	300	140-300	50	Airlift	150
182597	109	3/25/88	5" PVC	210	210	110-210			87
5307	126	3/20/78	6" PVC	260	260	180-260			200*
E047418	113	2/2/07	5" PVC	240	240	100-240	100	Airlift	95
E047419	108	2/1/07	5" PVC	300	290	140-290	100	Airlift	90

*static data point suspect (more than 30 feet below sea level) and not used for averaging
ft above msl = feet above mean sea level estimated from topographic map
ft bgs = feet below ground surface
gpm = gallons per minute

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ATTACHMENT B

Fall 2016 Upper Aquifer Water Level Contour Map
2016 Annual Groundwater Monitoring Report

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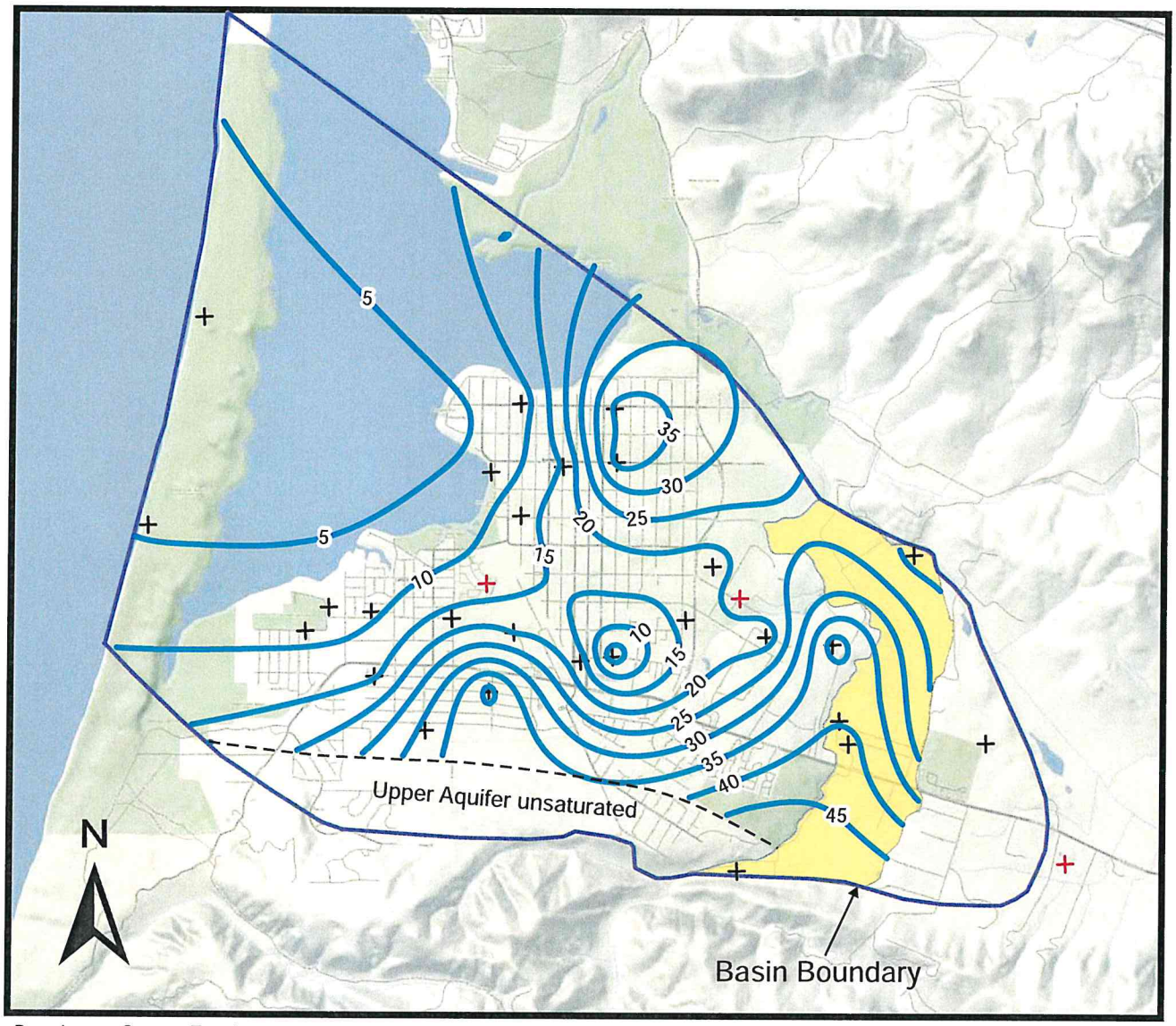

Base Image: Stamen-Terrain

0 2000 4000 6000 8000 ft

Scale: 1 inch ≈ 4,000 feet

Explanation

40 Groundwater elevation contour in feet above sea level (NAVD 88 datum)

Limits of Alluvial Aquifer

\+ Fall 2016 groundwater elevation data point (contours not applicable outside of Upper Aquifer and Alluvial Aquifer limits)

\+ Alternate date groundwater elevation data point (December 2016 for LOWRF program private wells)

NOTE: Area where Upper Aquifer is unsaturated along southern Basin boundary determined from comparison of water levels with aquifer base contours. This condition was present in 2015 but not shown in 2015 Annual Report.

Figure 13
Fall 2016 Water Level Contours
Upper Aquifer and Alluvial Aquifer
Los Osos Groundwater Basin
2016 Annual Report

Cleath-Harris Geologists