Groundwater Evaluation Report for
Last Chance Basin
City and Borough of Juneau
Juneau, Alaska

September 5, 2013

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GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

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TABLE OF CONTENTS

Page

1.0 INTRODUCTION 4

2.0 PREVIOUS REPORTS AND DATA 5
- 2.1 Previous Reports 5
- 2.2 Hydrologic Data 5
- 2.3 Pumping Test Analysis and Results 5

3.0 CONCEPTUAL HYDROGEOLOGICAL MODEL 7
- 3.1 Hydrologic Conditions 8
- 3.2 Hydrostratigraphy 9
- 3.3 Groundwater Flow 9
- 3.4 Well Operation 10
  - 3.4.1 Pumping Well PW-1 11
  - 3.4.2 Pumping Well PW-2 11
  - 3.4.3 Pumping Well PW-3 11
  - 3.4.4 Pumping Well PW-4 12
  - 3.4.5 Pumping Well PW-5 12
- 3.5 Last Chance Basin (LCB) Water Budget 13

4.0 NUMERICAL MODELING 14
- 4.1 Modeling Code and Graphical User Interface (GUI) 14
- 4.2 Domain and Mesh 14
- 4.3 Model Calibration 15
  - 4.3.1 Steady-state Calibration 15
  - 4.3.2 Transient Calibration 17
- 4.4 Future Pumping Scenarios 20
  - 4.4.1 Base Case (November 2010 – October 2011) 20
  - 4.4.2 Future Scenarios 20
  - 4.4.3 Simulation Results 21
- 4.5 Model Limitations and Uncertainty 22

5.0 CONCLUSIONS AND RECOMMENDATIONS 22

6.0 REFERENCES 24

Draft

TABLE OF CONTENTS (cont.)

Page

TABLES

1 Pumping Test Rates 2009 (Kleinfelder) 6
2 Aquifer Properties Based on Analysis of 2009 Pumping Test Data 7
3 Last Chance Basin Water Budget 14
4 Final Modeled Hydraulic Properties 16
5 Final Steady-state Pre-Development Modeled Water Budget 16

FIGURES

1 Vicinity Map
2 Gold Creek Watershed
3 Annual Precipitation at Juneau Airport Station – 1950 – 2006
4 Gold Creek Stream Gauge Data 2000 - 2006
5 Groundwater Levels for Observation Well TW-2 2010 – 2013
6 Groundwater Levels for Observation Well TW-2B 2010 – 2013
7 PW-1 Specific Capacity 2008 – 2013
8 PW-2 Specific Capacity 2008 – 2013
9 PW-3 Specific Capacity 2008 – 2013
10 PW-4 Specific Capacity 2008 – 2013
11 PW-5 Specific Capacity 2008 – 2013
12 Model Domain and Mesh
13 LCB Model Layering in Sections
14 LCB Model Domain and Mesh – Oblique View
15 Simulation of Gold Creek in Unconfined Aquifer Layer
16 1959 Pre-development Interpreted Groundwater Contours
17 Modeled Groundwater Levels – Unconfined Aquifer for Calibration
18 Modeled Groundwater Levels – Semi-Confined Aquifer for Calibration
19 Steady-state Pre-development Calibration Results
20 Reported Monthly Pumping – 2003-05
21 Simulated Monthly Pumping for 2003 – 05 Transient Calibration
22 2003-05 Calibration – Well PW-1
23 2003-05 Calibration – Well PW-2
24 2003-05 Calibration – Well PW-3
25 2003-05 Calibration – Well PW-4
26 2003-05 Calibration – Well PW-5
27 Simulated Pumping for May 2009 Pumping Test at PW-3
28 May 2009 Pumping Test Recorded Groundwater Level Changes
29 2009 Pumping Test Calibration – Well PW-3
30 2009 Pumping Test Calibration – Observation Wells
31 Summer 2011 Calibration – Simulated Daily Pumping
32 Observed Groundwater Levels in Pumped Wells – Summer 2011

Draft

TABLE OF CONTENTS (cont.)

FIGURES (cont.)

33 Summer 2011 Calibration – Well PW-1
34 Summer 2011 Calibration – Well PW-2
35 Summer 2011 Calibration – Well PW-3
36 Summer 2011 Calibration – Well PW-4
37 Summer 2011 Calibration – Well PW-5
38 Summer 2011 Calibration – Observation Wells TW-2 & TW-2B
39 Simulated Monthly Pumping for Base Case
40 Baseline Case – Simulated Drawdown Hydrographs
41 Scenarios 1A & 1B – Simulated Monthly Pumping
42 Scenarios 2A & 2B – Simulated Monthly Pumping
43 Scenario 1A – Simulated Heads in July
44 Scenario 1B – Simulated Heads in July
45 Scenario 2A – Simulated Heads in July
46 Scenario 2B – Simulated Heads in July
47 Simulated Drawdown Hydrographs – Well PW-1
48 Simulated Drawdown Hydrographs – Well PW-2
49 Simulated Drawdown Hydrographs – Well PW-3
50 Simulated Drawdown Hydrographs – Well PW-4
51 Simulated Drawdown Hydrographs – Well PW-5
52 Simulated Drawdown Hydrographs – Well TW-T
53 Simulated Change in Discharge to/from Gold Creek

APPENDIX

Important Information About Your Geotechnical/Environmental Report

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GROUNDWATER EVALUATION REPORT FOR LAST CHANCE BASIN CITY AND BOROUGH OF JUNEAU JUNEAU, ALASKA

1.0 INTRODUCTION

Shannon & Wilson, Inc. (SWI) was retained by the City and Borough of Juneau (CBJ) to perform an aquifer capacity assessment of the Last Chance Basin (LCB) wellfield to estimate a safe long term yield, determine if additional wells within the basin are feasible, and provide recommendations regarding maintenance and operation of the existing wells in LCB. The LCB is located to the east of downtown Juneau in a steep glacially carved valley that has been impacted by an ancient landslide (Figure 1).-

Our assessment efforts consisted of reviewing existing well operating data, meeting with City staff during a visit to the wellfield, reading previous reports regarding the geology and hydrogeology of the LCB wellfield, and developing a preliminary numerical flow model. Specifically these efforts included:

- Review of historic wellfield operating records, groundwater level, and other relevant hydrologic data provided by the City;
- Evaluation of current performance and operations of the LCB wellfield;
- Development of a conceptual groundwater model of the LCB wellfield;
- Preparing a water budget for the basin based on the conceptual model;
- Estimating long-term (sustainable) yield from LCB wellfield using analytical methods;
- Constructing a three-dimensional groundwater flow model of the LCB that includes the LCB wellfield;
- Potential future wellfield operation simulations using the calibrated model; and
- Preparation of a summary report that documents our efforts and provides conclusions and recommendations on future well field alternatives.

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2.0 PREVIOUS REPORTS AND DATA

2.1 Previous Reports

SWI reviewed a total of 10 reports in an effort to obtain information relevant to the assessment of the groundwater conditions in the LCB wellfield. The reports dated from 1959 to 2012 and provided details on previous drilling, water resource studies, hydrogeologic and hydrologic evaluations, installation of production water supply wells, assessment and rehabilitation of existing production wells, and current condition and vulnerability assessments for the LCB and the surrounding drainage area. SWI used information from these reports to develop a conceptual groundwater model and numerical model for the LCB. See the references section at the end of this report for additional information regarding reports reviewed.

2.2 Hydrologic Data

SWI obtained historic hydrologic data in order to develop a conceptual model that could serve as the basis for design of a preliminary numerical groundwater model of the LCB. Hydrologic data that we collected and reviewed consisted of:

- Precipitation data from stations located at: (a) downtown Juneau, (b) West Juneau, and (c) the Juneau Airport;
- Stream gauge data from near the top of the LCB (U.S. Geological Survey [USGS] Station #15049900) and near the bottom of LCB (USGS Station #15050000);
- Pumping data provided by CBJ for the LCB wellfield production wells PW-1 through PW-5.

2.3 Pumping Test Analysis and Results

SWI reviewed the step-rate and constant rate pumping tests performed in 2009 on wells PW-1 through PW-5 to estimate aquifer properties for development of the numerical model, and evaluate current and future well pumping conditions and scenarios in the LCB wellfield. The pumping tests were completed between April 7 and May 28, 2009, after rehabilitation of each of the five wells. The pumping tests were run on each well immediately following rehabilitation work on that well. Table 1 provides the step-pumping rates and constant pumping rates for each well during the tests.

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TABLE 1
PUMPING TEST RATES 2009

	Well				
	PW-1	**PW-2**	**PW-3**	**PW-4***	**PW-5**
Step Pumping Rate Test	600 700 800	400 500 600	400 600 800 970	700 1000 1300 1600 1,850	700 1,000 1,300 1,500
24-hour constant Rate Test	700	500	850 and 1,100	1,500	1,300

Notes:
* The constant rate test on Well 4 was run for 46 hours.
All pumping rates are in gallons per minute; from Kleinfelder, 2009.

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We initially reviewed the previous pumping test data to better understand the groundwater flow conditions during the pumping tests. For the tests using well PW-3, these data sets consisted of changes in groundwater level versus time for PW-3, and test wells TW-2 (located near PW-2) and TW-2B (located near PW-1). The data sets for the remaining wells consisted of changes in groundwater level versus time in only the pumped well. We analyzed the data sets using the Theis method (1935) for a confined aquifer. The Theis method involves matching the observed drawdown data from the test with a suite of "type curves" that represent theoretical aquifer transmissivity and storativity values, plotted on a log-log scale. We used the commercial software program AQTESOLV (Duffield, 2010) to perform the curve-matching analysis. Curve matching is performed by superimposing the measured time-drawdown data on the type curve and adjusting the overlay until most of the observed data points fall on the curve. A match point is selected and values of time and drawdown are substituted into the Theis equations to calculate transmissivity and storativity. Table 2 presents a summary of the calculated aquifer properties calculated from the five constant rate pumping tests.

TABLE 2
AQUIFER PROPERTIES BASED ON ANALYSIS OF 2009 PUMPING TEST DATA

Well ID	Specific Capacity (gpm/ft)	Transmissivity (T)		Hydraulic Conductivity (K) ft/day	Storativity (S) -
		(gpm/ft)	(sf/day)		
PW-1	17.4 – 18.7	38,135	5,100	102	2E-05
PW-2	14.0 – 16.1	26,932	3,600	72	5E-04
PW-3	29.3 – 36.8	58,172	7,780	156	1E-03
PW-4	71.2 – 87.5	152,971	20.450	409	4E-04
PW-5	29.4 – 36.5	53,863	7,200	144	4E-04
Average	**31.9 – 38.9**	**66,015**	**8,820**	**176**	**5E-04**

Notes:
ft/d = feet per day
gpm/ft = gallons per minute per day
sf/day = square feet per day

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The pumping tests noted in Table 2 were all single-well tests with the exception of the test at PW-3. The constant rate test at PW-3 included data from two observation wells. However, due to other wells operating during the PW-3 test, the observation well data was not suitable for calculating aquifer properties. Therefore, all constant rate pumping tests were treated as single-well tests. The use of a single-well test to estimate transmissivity, hydraulic conductivity, and storativity is less accurate than when observation well data can be used.

The specific capacity values in Table 2 are based on a range of pumping rates used during the step-rate pumping tests. They represent the condition of the wells immediately following rehabilitation and, as such, represent an optimal value. The specific capacity of a well is affected by aquifer properties, the efficiency of the well, and the rate at which the well is pumped. The specific capacity was consistently the highest in Well PW-4 (average of 79.4 gallons per minute per foot [gpm/ft]), whereas the specific capacity was consistently lowest in wells PW-1 and PW-2 (averages of 18.0 and 14.8 gpm/ft, respectively).

3.0 CONCEPTUAL HYDROGEOLOGICAL MODEL

Based on our review of the existing hydrogeologic and well operation, we developed a conceptual hydrogeologic model for the LCB that formed the basis for a preliminary numerical groundwater flow model capable of simulating the existing LCB wellfield and potential future

wells. The key components of the conceptual model are the hydrogeologic conditions, hydrostratigraphy, groundwater flow, and pumping within LCB as detailed in the following sections.

3.1 Hydrologic Conditions

The hydrologic components of the LCB include direct precipitation and recharge to the shallow aquifer, surface flow in Gold Creek and its tributary streams, and minor subsurface inflow from groundwater in up-basin sediments and fractured rock.

The direct precipitation consists of rainfall and snowfall that infiltrates and recharges the aquifers in the LCB. The annual average precipitation at a rain gauge in downtown Juneau is estimated as 98 inches (National Climatic Data Center, 2013). The annual average precipitation on Mt. Juneau is estimated as 285 inches (Murphy and Schamach, 1965). Our conceptual model for the entire Gold Creek Watershed (Figure 2) uses a range of annual precipitation values from 98 to 285 inches. The Juneau Airport precipitation data (Figure 3) indicates that precipitation at the airport is less than in downtown Juneau. The proximity of the mountain front to downtown Juneau likely provides an orgographic effect resulting in the increased precipitation at the downtown gauge versus the airport gauge. Seasonal variations in precipitation occur similarly at the downtown Juneau and Juneau Airport gauges. In general, precipitation is higher from later summer into early winter and lower from later winter into early summer.

The entire Gold Creek Watershed area is approximately 9.5 square miles. Above LCB, the Gold Creek Watershed area is approximately 8.4 square miles. The upper parts of the watershed contain numerous creeks that form the main Gold Creek on the basin floor. The two USGS stream flow gauges operated intermittently. Figure 4 shows the frequent flow data (daily) for the downstream gage (Station #15050000) and the less frequent flow data (55 readings total) for the upstream gage (Station # 15049900) between June 2000 and March 2006. On the 55 days for which both stations had readings, the flow at the upstream gage was mostly higher than at the downstream gage (by between 2 and 68 cubic feet per second [cfs]) during fall, winter and spring months (October through April). Gold Creek would also receive significant inflow from numerous side-valley tributaries during the fall and spring months. Conversely, the flow at the downstream gage was typically higher (by up to 119 cfs) during the summer months (May through September). These data suggest that Gold Creek in the LCB loses water to the shallow aquifer during winter (despite being fed by the tributaries) and gains from the shallow aquifer in the summer (when the tributaries contributions are low).

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3.2 Hydrostratigraphy

The following is a summary of our interpretation of the hydrostratigraphy in the LCB based on the data we were provided and reviewed:

- An upper, unconfined interbedded sand and gravel aquifer exists from land surface to depths of 15 to 50 feet. The estimated hydraulic conductivity for the upper aquifer is between 150 and 500 feet per day (ft/day) based on an estimated transmissivity of 62,500 gallons per day per foot (gpd/ft) (8,350 sf/day) (James M. Montgomery, Consulting Engineers, Inc., 1985).
- The groundwater elevation in the unconfined aquifer is likely similar to the average creek stage of Gold Creek. Based on visual observation, the Gold Creek bed material consists of sand, gravel, cobbles, and boulders with relatively little fine-grained (silt and clay) sediment. This bed material is assumed to have a relatively high hydraulic conductivity. This indicates that the upper aquifer and the creek are in direct hydraulic communication.
- The upper aquifer is underlain by a leaky aquitard, which is 10 to 35 feet thick. The soils consist mainly of interbedded silty sand and sand with silt. The leaky aquitard has a lower hydraulic conductivity than the overlying (and underlying aquifer) and restricts the flow of groundwater between the aquifers.
- A lower, confined aquifer exists beneath the leaky aquitard and has a groundwater elevation near or above ground surface. The lower aquifer thickness varies from about 15 to more than 75 feet. The aquifer appears to thicken toward the center and west end of the valley. The estimated hydraulic conductivity for this aquifer is between 72 and 409 feet per day (ft/day) (see Table 2). The aquifer consists of interbedded sand and gravel with zones of silty sand and sand with silt.
- A lower aquitard consisting of sand and gravel with silt and clay underlies the semi-confined aquifer. Exploration boring TW-4 (drilled in 1959 by CBJ) describes the soil conditions to a total depth of 235 feet. The aquitard has a lower hydraulic conductivity than the overlying aquifer and restricts the flow of groundwater to and from the aquifer from below. No aquifer testing has been performed in this deep unit.

3.3 Groundwater Flow

The groundwater flow for our conceptual model used results of the initial groundwater study in 1959 (Alaska Department of Health Section of Sanitation and Engineering, 1959) before pumping commenced from the initial three wells (PW-1, PW-2, and PW-3). The 1959 report estimated a gradient of 0.017 with flow from the east (upper end of the LCB) to the west (lower end of LCB at Basin Road Bridge). This gradient was based on water level measurements at multiple monitoring well locations installed for the 1959 study.

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Groundwater flow through the unconfined aquifer in LCB was estimated using Darcy's equation (that states that the groundwater flow/discharge equals the product of hydraulic conductivity, hydraulic gradient, and the cross sectional area). The estimated pre-development flow through the unconfined aquifer in the LCB ranges from 1.0 to 2.0 cfs. The groundwater flow estimates used hydraulic conductivity values of 150 to 500 ft/day (noted in Section 3.2), a hydraulic gradient of 0.017 (based on the 1959 report), and cross sectional areas of 12,000 to 60,000 sf (based on aquifer thicknesses noted in Section 3.2 and estimated aquifer widths from previous reports).

Groundwater flow through the semi-confined aquifer in the LCB was also estimated using Darcy's equation. The estimated pre-development flow through this aquifer ranges from 0.2 to 7.2 cfs. The groundwater flow estimates used hydraulic conductivity values of 72 to 409 ft/day (see Table 2), a hydraulic gradient of 0.017, and cross sectional areas of 12,000 to 90,000 sf (based on aquifer thicknesses noted in Section 3.2 and estimated aquifer widths from previous reports).

Therefore, the total groundwater flow through LCB includes flow through the unconfined and semi-confined aquifers and ranges from 1.2 to 8.9 cfs.

CBJ has collected frequent groundwater level readings in test wells TW-2 (located 80 feet north of well PW-2) and TW-2B (located 90 feet west of well PW-1) since December 2009 (Figures 5 and 6, respectively). These wells are completed in the semi-confined aquifer similar to the pumping wells. Both test wells react to pumping of the wells in the LCB. When local pumping is reduced, the groundwater level in these wells is higher than land surface (as indicated by the flat line in the hydrographs). When pumping is active, the groundwater levels decline by more than 15 feet. As the actual static groundwater levels for these wells are not known, the true drawdown due to pumping cannot be deduced from these data.

3.4 Well Operation

CBJ operates five pumping wells in the LCB wellfield (PW-1, PW-2, PW-3, PW-4, and PW-5). PW-3 feeds the Mill Tunnel Reservoir and the remaining four wells pump directly to the CBJ water distribution system. Construction and pumping details for each well are discussed in the following sections. We estimated specific capacities for these five wells in the June months between 2008 and 2013 using the most similar pumping rates for each well. However, the specific capacity values used should be considered approximate because operation of other wells in LCB can affect the drawdown in any particular well which is used to calculate specific capacity.

3.4.1 Pumping Well PW-1

Pumping well PW-1 was constructed in 1960 to a depth of approximately 92 feet with a screen interval from about 52 to 91 feet. Therefore, well PW-1 is screened in the upper part of the leaky-confined aquifer.

CBJ appears to pump from PW-1 as water demand increases beyond the capacities of PW-4, PW-5, and PW-2. Operating data from 2010 to 2011 indicate periods of up to three months annually where no pumping occurred in PW-1. Data during the 2010 to 2011 time period were utilized in our assessment because manual readings of the pumping wells and transducer readings at the two observation wells were available.

Based on the daily City records, pumping rates for PW-1 from 2010 to 2011 vary from 117 to 758 gpm and, when the pump is on, average 420 gpm. The specific capacity values (Figure 7) declined from 2011 to 2013.

3.4.2 Pumping Well PW-2

Pumping well PW-2 was constructed in 1960 to a depth of approximately 96 feet with a screen interval from about 54 to 95 feet. Therefore, well PW-2 is screened in the upper part of the leaky-confined aquifer.

CBJ pumps PW-2 as water demand increases beyond the capacities of PW-4 and PW-5. Operating data from 2010 to 2011 indicate periods of up to 1.5 months where no pumping occurred in PW-2. Data during the 2010 to 2011 time period was utilized in our assessment because manual readings of the pumping wells and transducer readings at the two observation wells were available. Based on the daily City records, pumping rates for PW-2 from 2010 to 2011 vary from 193 to 562 gallons per minute (gpm) and, when the pump is on, average 421 gpm.

The specific capacity values indicate fluctuations in specific capacity from 2009 to 2013 (Figure 8).

3.4.3 Pumping Well PW-3

Pumping well PW-3 was constructed in 1977 to a depth of approximately 96 feet with a screen interval from about 61.5 to 96 feet. Therefore, well PW-3 is screened in the upper part of the leaky-confined aquifer.

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PW-3 is used to maintain water levels in the Jalupa Tunnel. Operating data from 2010 to 2011 indicate periods of up to 1.5 months where no pumping occurred in PW-3. Data during the 2010 to 2011 time period was utilized in our assessment because manual readings of the pumping wells and transducer readings at the two observation wells were available. Based on the daily City records, pumping rates for PW-3 from 2010 to 2011 vary from 501 to 1,099 gpm and, when the pump is on, average 1,006 gpm. The specific capacity was estimated for the month of June, using the most similar pumping rates, from 2008 to 2013. The specific capacity values, shown in Figure 9, indicate a decline in specific capacity from 2010 to 2013.

3.4.4 Pumping Well PW-4

Pumping well PW-4 was constructed in 1989 to a depth of approximately 132 feet with a screen interval from about 86 to 126 feet. Therefore, well PW-4 is screened in the upper to middle part of the leaky-confined aquifer.

PW-4 is the first well that operates as water demand increases. Operating data from 2010 to 2011 indicate periods of up to three days where no pumping occurred in PW-4. Data during the 2010 to 2011 time period was utilized in our assessment because manual readings of the pumping wells and transducer readings at the two observation wells were available. Based on the daily City records, pumping rates for PW-4 from 2010 to 2011 vary from 454 to 1,068 gpm and, when the pump is on, average 943 gpm. The specific capacity was estimated for the month of June, using the most similar pumping rates from 2008 to 2013. The specific capacity values, shown in Figure 10, indicate a decline in specific capacity from 2009 to 2013.

3.4.5 Pumping Well PW-5

Pumping well PW-5 was constructed in 1989 to a depth of approximately 133 feet with a screen interval from about 74 to 129 feet. Therefore, well PW-5 is screened in the upper to middle part of the leaky-confined aquifer.

PW-5 is the second well that operates as water demand increases beyond the capacity of PW-4. Operating data from 2010 to 2011 indicate periods of up to three days where no pumping occurred in PW-5. Data during the 2010 to 2011 time period was utilized in our assessment because manual readings of the pumping wells and transducer readings at the two observation wells were available. Based on the daily City records, pumping rates for PW-5 from 2010 to 2011 vary from 200 to 987 gpm and, when the pump is on, average 661 gpm. The specific capacity was estimated for the month of June, using the most similar pumping rates from 2008 to 2013. The specific capacity values, shown in Figure 11, indicate a decline in specific capacity from 2009 to 2013.

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3.5 Last Chance Basin (LCB) Water Budget

The water budget is another key component of the conceptual and numerical model for LCB. The following variables were used in estimating the water budget:

- Recharge to the unconfined aquifer from direct precipitation and snow melt on the floor of LCB;
- Indirect recharge (valley edge) from precipitation and snow melt that falls outside of LCB but within Gold Creek Watershed, and flows to LCB through Gold Creek and its tributaries;
- In-stream flows in Gold Creek;
- Underflow into and out (springs) of LCB; and
- Pumping from LCB wellfield.

Precipitation gauges in downtown Juneau, West Juneau, and at the Juneau Airport along with Mt. Juneau precipitation data from Murphy and Schamach (1965) were used to estimate the annual precipitation within LCB. The average annual precipitation is:

- Downtown Juneau (2004 to 2006): 98 inches
- West Juneau (2003 to 2006): 73 inches
- Juneau Airport (2009 to 2012): 63 inches
- Mount Juneau (1965): 285 inches

SWI's conceptual model assumes that the annual precipitation in LCB and the Gold Creek Watershed is between 98 (downtown Juneau) and 285 inches (Mount Juneau). Assuming an estimated surface area of LCB of 0.1 square mile, the total direct precipitation per year is 2.9×10^7 ft^3 to 8.3×10^7 ft^3.

The remainder of the Gold Creek Watershed outside LCB is approximately 8.4 square miles. The total annual precipitation volume outside of LCB is 1.9×10^9 ft^3 to 5.5×10^9 ft^3.

Annual flow volume for Gold Creek from June 2000 to June 2005 based on intermittent data from Stations 15049900 (top of LCB) and 15050000 (bottom of LCB) were estimated using a six-year average. Average annual flow into LCB from Gold Creek is 2.8×10^9 ft^3 and out of LCB via Gold Creek is 2.9×10^9 ft^3.

Underflow through LCB is discussed in Section 3.3 of this report. The estimated underflow through LCB is 1.0 to 7.0 cfs.

Table 3 provides a summary of the average water budget for the LCB based on available data.

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TABLE 3
LAST CHANCE BASIN WATER BUDGET

Variable	Annual Volume (cfs)			
	In		Out	
	Min	Max	Min	Max
Direct Precipitation to LCB Floor	0.9	2.6	-	-
Indirect Precipitation (valley walls N+S)*	8	16	-	-
Gold Creek (for upper basin)	60	87	60	98
Underflow to west (both aquifers)			1	7
LCB Pumping			3.3	10.0
Sum of Variables	**68.9**	**105.6**	**64.3**	**115.0**

Notes:
*Indirect precipitation is estimated based on valley wall area of 1.0 square miles.
N+S = north and south
LCB = Last Chance Basin

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4.0 NUMERICAL MODELING

4.1 Modeling Code and Graphical User Interface (GUI)

We constructed a groundwater flow model of the project area using the USGS's advanced computer program MODFLOW-NWT (Hughes and others, 2012). We employed the GUI program GMS (version 9) to facilitate model development, calibration, and simulation. MODFLOW-NWT discretizes the model domain into a prescribed number of layer and cells and calculates piezometric head for each cell and flows between cells. MODFLOW-NWT is a robust model capable of simulating the diverse hydrologic conditions found in the project area. It is widely used and accepted by the groundwater modeling profession and regulatory agencies, and is considered appropriate for this application. It has the advanced capability of simulating drying and wetting non-linearities associated with unconfined (water table) conditions.

4.2 Domain and Mesh

The overall model domain is rectangular in area (approximately 3,500 by 1,500 feet). The western boundary coincides with the former USGS stream gage, and the eastern boundary is close to the LCB Mining Museum. The model's northern and southern limits coincide with the interpreted edge of the alluvial sediments and bedrock contact. The model uses a viable computational grid size which ranges from 20 by 20 feet at the model boundaries to 5 by 5 feet at the existing five pumping wells (Figure 12).

The model uses seven discrete layers to represent the hydrostratigraphy (Figures 13 and 14), as follows:

- Layer 1 – represents the shallow, unconfined aquifer, consisting of sands and gravels. This layer is between 25 and 40 feet thick. No pumping occurs in this aquifer. However, Gold Creek is hydraulically connected to this model layer (Figure 15).
- Layer 2 – represents the leaky aquitard, which consist of interbedded silty sand and sand with silt. The modeled thickness of this layer is typically 25 feet;
- Layers 3 and 4 – represent the thick main, confined aquifer, consisting of interbedded sand and gravel with zones of silty sand and sand with silt. The two layers have equal thickness in the model and have a combined thickness of between 50 and 125 feet in the center of the basin. The pumping from the five existing wells is assigned to these model layers.
- Layers 5 and 6 – represent a unit of undifferentiated sediments beneath the main aquifer, which extend to the bedrock surface at depth. This unit consists of sand and gravel with silt and clay. The base of this unit in the model in the wellfield area is between elevations 125 and 175 feet. Although some exploration of this unit was conducted in 1959, no pumping or monitoring wells exist.

4.3 Model Calibration

Model calibration is the process of adjusting the model properties, boundary conditions, and sources/sinks (recharge and discharge features) to match observed field data. The calibration process consisted of both steady-state and transient calibration.

4.3.1 Steady-state Calibration

The steady-state calibration consisted of the 1959 pre-development conditions portrayed in the CBJ report. This consisted of a groundwater contour map showing piezometric levels in the main aquifer based on non-pumped observations at that time. We used this as a means of establishing a starting point for more robust (pumping) transient calibration. The individual well groundwater levels consisted of picks at the five (future) pumping wells, and test wells in the unconfined (six points) and main confined (10 points) aquifers. Figure 16 shows the interpreted observed and model-simulated piezometric levels for the calibration case, and Figures 17 and 18 show the results for the unconfined and semi-confined aquifers, respectively, in plan view. Overall, the modeled groundwater levels are all within ±5 feet of the observed and inferred groundwater levels (Figure 19). This is a reasonable calibration match for starting more robust, transient calibration testing.

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Table 4 presents the final calibrated hydraulic properties for the principal hydrogeologic units in the model.

TABLE 4
MODELED HYDRAULIC PROPERTIES

Layer (Unit)	Kh, Kv (ft/day)	Specific Storage (ft^{-1}); Specific Yield (-)	Notes
1 (Unconfined aquifer)	100, 10	NA; 0.2	
2 (Confining unit)	0.5, 0.05	5×10^{-7}; 0.1	
3, 4 (Semi-confined aquifer	200, 20	5×10^{-5}; 0.2	
5, 6 (Deeper aquitard)	10, 1	5×10^{-5}; 0.2	Properties estimated based on soil types reported for boring TW-4*

Note:
* Cornell, Howland, Hayes and Merryfield Engineers and Consultants, 1960, An Engineering Study of a Municipal Water Supply System, A Report to the City Council of Juneau, Alaska: Report prepared by Cornell, Howland, Hayes and Merryfield Engineers and Consultants for the City Council of Juneau, Alaska, May, 75 p.

Table 5 summarizes the steady-state water budget for the pre-development version of the model

TABLE 5
STEADY-STATE PRE-DEVELOPMENT MODELED WATER BUDGET
(TO BE CONFIRMED)

Feature	Inflow (gpm)	Outflow (gpm)	Comments
Precipitation- and snow-derived recharge	180	0	Applied to the valley floor in model layer 1.
Mountain-valley edge recharge	1,400	0	Represents steep-surface runoff recharging northern and southern basin edges.
Subsurface Flow	1,270	1,280	Subsurface inflow and outflow eastern and western boundaries .
Gold Creek	50	1,620	Seepage from/to the creek from shallow groundwater (net = 3.5 cfs).
Total	2,900	2,900	

Notes:
cfs = cubic feet per second
gpm = gallons per minute

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4.3.2 Transient Calibration

The transient calibration consisted of three parts:

- The three years between January 2003 and December 2005, inclusive, using monthly computational stress periods;
- The May 2009 pumping test at well PW-3; and
- The period June through August 2011, using daily stress periods.

January 2003 – December 2005

Figure 20 shows the monthly pumping reported by Juneau for the five wells. The report combines the pumping records for well PW-1, PW-2, PW-4, and PW-5, and provides individual totals for well PW-3. To assign individual pumping rate for the four "lumped" wells for modeling purposes, we evaluated likely pumping capacities based on historical records. Figure 21 shows the simulated monthly well pumping for the 36 months between January 2003 and December 2005, inclusive. These rates are monthly averages based on Juneau's reported data sheets. Within each month, individual daily pumping rates may have been substantially higher or lower than the monthly averages.

Figures 22 through 24 show the reported changes in water column height in the wells and the modeled drawdown (from pre-development static levels) for well PW-1 through PW-5, respectively. As the actual elevation of the groundwater surface in the well is unknown, these comparisons are at best approximate. The results indicate the following:

- For well PW-1, the model predicted up to 55 feet of operational drawdown in the well during the three-year period. The average predicted drawdown is 40 feet. However, the observation data are erratic and do not provide a reliable comparison with the model output. For instance, the sharp changes in water column height do not appear to correspond to pumping.
- For well PW-2, the model predicted up to 50 feet of operational drawdown in the well during the three-year period, and an average drawdown is 35 feet. The observed groundwater level changes are also erratic. However, the well appears to experienced drawdowns of up to 70 feet and an overall decline of 20 feet.
- For well PW-3, the model predicted up to 45 feet of operational drawdown in the well during the three-year period, and an average drawdown is 30 feet. The observed groundwater levels in this well demonstrate a 25-foot band between pumped and unpumped conditions. The model-predicted declines during periods of sustained pumping (such as during the summer of 2004) are greater than those observed in the well, suggesting that the actual transmissivity of the aquifer is greater than modeled.

Draft

- For well PW-4, the model predicted up to 55 feet of operational drawdown in the well during the three-year period, and an average drawdown is 40 feet. This well was pumped at the highest rates during this period. The observed groundwater levels in this well demonstrate a 25- to 30-foot band between pumped and unpumped conditions. The model reproduces the observed groundwater level declines and recoveries reasonably well for well PW-4.
- For well PW-5, the model predicted up to 60 feet of operational drawdown in the well during the three-year period, and an average drawdown is 40 feet. Only well PW-4 was pumped at higher rates during this period. The observed groundwater levels in this well demonstrate a 40- to 50-foot band between pumped and unpumped conditions. Although the model over-predicts the groundwater level decline during the summer of 2004, it predicts the decline in the summer of 2005 reasonably well.

PW-3 Pumping Test (May 2009)

Figure 26 shows the simulated well pumping for the step-drawdown and 48-hour constant pumping testing performed at PW-3 in May 2009 (see Table 2). Well PW-3 was pumped at four rates (between 400 and 970 gpm) as part of the step-test, and at two rates (850 and 1,100 gpm) during the constant rate test. The other four wells were also known to be pumped during this test period, as evidenced by the recovery in the groundwater level in well TW-2 and TW-2B to above pre-test static (Figure 27). We were only able to estimate the magnitude of pumping and the on-off timing of the other wells for this simulation.

Figures 28 and 29 show the interpreted drawdown from static and the modeled for well PW-3 (Figure 28) and monitoring wells TW-2 and TW-2B (Figure 29) during the test period. The results indicate the following:

- For well PW-3, the model under-predicts the observed drawdown in the pumped well by a between a factor of 1.5 and 2. However, the general shape of the drawdown and recovery phases is reasonably good. The reason for the model under-predicting the observed drawdowns on may be related to PW-3's operational efficiency. The observed drawdown in the well is a function of the aquifer losses and well losses. At this stage of development, the model only accounts for aquifer losses and so would tend to predict less drawdown than that observed in the well.
- In test wells TW-2 and TW-2B, the model reproduces the general drawdown and recovery in the two test wells during the step-drawdown test and the recovery of groundwater levels during the early stages of the constant rate test. However, the model under-predicts the observed sharp recovery (of more than 10 feet) in well TW-2 midway through the constant rate test (when well nearby PW-2 is believed to have stopped pumping). The reason for this discrepancy is not clear. However, it is possible that the pumping rate that we assigned for well PW-2 may have been lower than the actual rate and that well PW-4 may have also stopped pumping mid-test.

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Summer 2011 Simulation

Figure 30 shows the simulated daily groundwater pumping from each of the five wells during the three summer months in 2011 based on Juneau's data reports. We made some interpolation of daily pumping rates during weekends and holidays during which no pumping readings were made. Figure 31 shows the observed height of the water column above the respective transducers in the five wells. We were unable to convert these levels to true elevations at this time. However, the data show that the groundwater levels fluctuated in the pumped wells by between 9 feet (well PW-4) and 51 feet (well PW-5).

Figures 32 through 36 show the interpreted changes in groundwater level and the modeled drawdown (from pre-development levels) for well PW-1 through PW-5, respectively. The results indicate following:

- For wells PW-1, PW-2, and PW-3, the model reproduces the timing and magnitude of the observed groundwater level changes reasonably well during the three-month period. The fits are best during June and July when pumping was highest, and the 20-foot decline in groundwater levels in well PW-1 during July.
- The model also reproduces the observed changes in groundwater levels in well PW-4 during June and July reasonably well. However, it appears that during August the actual pumping in this well may have been greater than that simulated, as groundwater levels remained less than 5 feet below initial levels, whereas the model predicted a sharp recovery (by up to 20 feet).
- The model's reproduction of groundwater levels in well PW-5 is more variable throughout the three months. In general, the model under-predicts the observed drawdowns.
- Figure 37 shows the observed and modeled groundwater level changes for the two observation wells TW-2 and TW-2B during the three-month period. The model reproduces the decline in levels in these two wells during June and July (by up to 5 feet) reasonably well. However, the model over-predicts the recovery of groundwater levels during August. (It should be noted that the groundwater levels in these two wells returned to be artesian during August when wellfield pumping was 30 percent less than during July. However, we do not know the true piezometric level in these wells).

Overall, the model appears to reproduce observed changes in groundwater level reasonably well during the three simulation periods. As most of the groundwater level data are for the five pumped wells, these changes are affected by the well's efficiency as well as the pumping rate at any time. This makes accurate calibration a challenging process. Despite this

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limitation, we considered model to be sufficiently calibrated at this stage to simulate basic expansions of the LCB wellfield.

4.4 Future Pumping Scenarios

4.4.1 Base Case (November 2010 – October 2011)

We developed and simulated four potential future wellfield pumping options using the calibrated model. These scenarios were based on the inferred pumping pattern for the period from November 2010 through October 2011 based on Juneau's daily data records. This 12-month period formed the Base Case, and included monthly average pumping rates for the five wells. The model simulated five cycles of this 12-month period (60 periods in total). As was the case for the transient calibration, we made some interpretation of pumping records during weekends and holidays for which data were not collected. Figure 38 shows the simulated monthly pumping. The highest monthly pumping occurred during July 2011 (3,186 gpm) and the lowest occurred during December 2010 (2,271 gpm). It should be noted that the maximum daily pumping rate during the 12-month period was 3,924 gpm (during late July 2011). Therefore, individual daily pumping rates could be 20 percent or more than the respective simulated monthly rate.

Figure 39 shows the model-predicted piezometric levels in the unconfined aquifer (model layer 1) and semi-confined aquifer (model layer 4) during July of the final year of the Base Case. Localized cones of depression are predicted for the pumping wells in the semi-confined aquifer. Groundwater in the unconfined aquifer is generally feeding Gold Creek in the middle of the modeled part of the basin. Figure 40 shows the model-predicted changes in piezometric levels in the five existing pumping for the Base Case. The model predicted groundwater levels would be up to between 50 and 60 feet lower than under pre-development conditions, and up to between 10 and 25 feet lower than levels after pumping has commenced after November 2010.

4.4.2 Future Scenarios

The first two future cases (Scenarios 1A and 1B) involved installing one new pumping well (PW-6) into the semi-confined aquifer at one of two locations, and assigning this new well the same pumping pattern for PW-4 (which has typically had the highest pumping rate and capacity). These monthly rates ranged between 826 and 1,020 gpm (Figure 41). The highest monthly pumping for these cases was 4,186 gpm (in July). For Scenario 1A, the new well PW-6 was located approximately 250 feet east of well PW-5 along the existing access track. For Scenario 1B, well PW-6 was located approximately 225 feet south of well PW-4 along the track that leads from well PW-3 to Gold Creek.

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Two other future cases, Scenarios 2A and 2B, also involved simulating one new well (also called PW-6) at the same location and depths as for Scenarios 1A and 1B, respectively. However, the individual monthly pumping rates were increased by a factor of 20 percent (that is, multiplied by 1.2) compared to those assigned for Scenarios 1A and 1B (Figure 42). As a result, the highest monthly total rate was 5,000 gpm (in July), and the pumping rates for wells PW-4 and PW-6 ranged between 991 and 1,224 gpm.

The Base Case and the four future scenarios were simulated using the steady-state (pre-development) conditions. This resulted in a rapid decrease in groundwater levels in the model during the first month (November). Thereafter, the groundwater levels responded to changes in the wellfield pumping. The precipitation/snow-derived and mountain edge recharge inputs were maintained at uniform rates for these simulations. In reality, the recharge to the basin likely varies seasonally. At this stage, insufficient data exists to determine the seasonal recharge distribution.

4.4.3 Simulation Results

Figures 43 through 46 show the model-predicted piezometric levels in the unconfined aquifer (model layer 1) and semi-confined aquifer (model layer 4) during July of the final year of the simulations for the four future scenarios.

Figures 47 through 52 show the model-predicted changes in piezometric levels in the five existing pumping wells and in shallow piezometer MW-T (that Juneau installed in the unconfined aquifer near Gold Creek) for the Base Case and four future scenarios.

- The predicted increase in drawdown in wells PW-1, PW-2, and PW-3 for the four future cases compared to the Base Case range from 5 to 30 feet.
- The predicted drawdown in wells PW-1 and PW-3 for the four future cases compared to the Base Case are highest for Cases 1B and 2 B compared to 1A and 2A, respectively. This indicates that the addition of the new well PW-6 to the southeast of these three wells would have a greater effect on levels in these wells than if it were located east of well PW-5.
- The predicted increase in drawdown in well PW-4 for the four future cases compared to the Base Case ranges from 10 to 30 feet. At this well, the predicted increase in drawdown would be similar for Scenarios 1B and 2A (up to 20 feet). Therefore, locating new well PW-6 to the east of well PW-5 would be more effective than to the south of well PW-4.
- For well PW-5, the predicted increases in drawdown for the four future cases compared to the Base Case ranges from 10 to 25 feet. However, the drawdown increases are similar for Scenarios A and 1B, and for Scenarios 2A and 2B.

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- For the shallow, unconfined aquifer (TW-T), the four scenarios would result in the water table lowering by between 0.5 foot (Case 1A) and 1.5 feet (Case 2B). The likely result of this would be a reduction in the groundwater seepage to Gold Creek in the middle of the basin. At this stage, the model has not been adequately calibrated to estimate this reduction in seepage.

4.5 Model Limitations and Uncertainty

We developed the numerical flow model using the available field investigation data, records and reports, and interpretation of field testing. The following are the main limitations:

- The model uses a fixed recharge applied to the water table (model layer 1) on the valley floor and at the northern and southern edges based on our average water budget for the entire Gold Creek watershed. In reality, the recharge varies seasonally; this is expected to be highest during spring (when rainfall and snowmelt occur), and lowest during the early fall. This may affect the modeled response to pumping by flattening out changes in groundwater levels.
- The assignment of pumping to the five wells for the calibration and simulations required some interpretation and assumptions. This may have resulted in some error in pumping.
- The well testing indicated that the transmissivity of the semi-confined aquifer at each well differs considerably (ranging between 3,600 and 20,450 sf/day). However, the model uses the same hydraulic conductivity for the semi-confined aquifer (200 ft/day) and the modeled transmissivity in the LCB wellfield area ranges between 9,600 and 23,000 sf/day. This may in part explain the variations in the transient calibration between wells.
- No reliable storage coefficients have been developed for the aquifer from well testing. The values used in the model were best estimates based on soil types and observed changes in groundwater levels to pumping.
- The representation of Gold Creek as a discharge/recharge feature is approximate at best due to the absence of prolonged gaging data.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The groundwater flow modeling scenarios indicate that the LCB should be able to sustain at least one additional well (located either east of PW-5 or south of PW-4) at rates similar to those recently pumped in PW-4. The expanded wellfield should also be capable of sustaining a peak monthly average rate of at least 5,000 gpm from six wells.

The expanded well field would likely have some additional impact on flow in Gold Creek. Although the model simulations indicate a change of up to 1.5 cfs, the model has not been adequately calibrated at this stage in the unconfined aquifer.

Based on our assessment of LCB, and the conclusion that additional pumping is feasible, SWI recommends the following:

- Complete a geophysical survey of potential well sites to determine which site provides the greatest aquifer thickness and most permeable aquifer materials;
- Install and complete pumping tests on a test well at the selected well site, with the option of converting the test well to a production well;
- Install piezometers in the unconfined aquifer and perform the pumping test of the test well during a period of low flow in Gold Creek, to determine the effect on the unconfined aquifer and Gold Creek when pumping from the confined aquifer;
- Convert transducer data to water level elevation to enable more accurate model calibration;
- Revise the numerical model based on geophysical and pumping test results; and
- Consider rehabilitation and/or replacement of existing wells in the wellfield to increase well yield.

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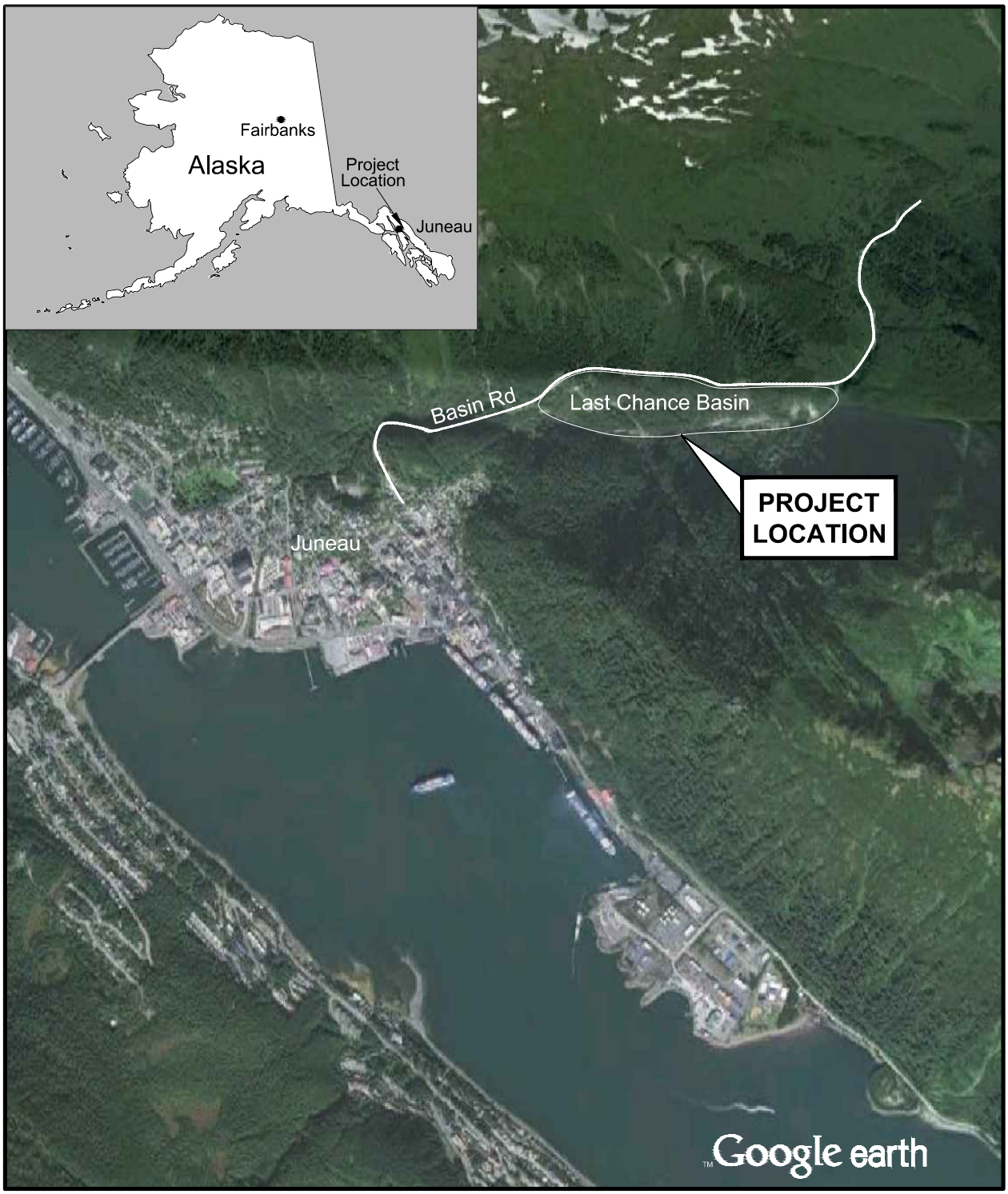

0 2000 4000

Approximate Scale in Feet

NOTE

Map adapted from aerial imagery provided by Google Earth Pro, reproduced by permission granted by Google Earth ™ Mapping Service.

Last Chance Basin
Juneau, Alaska

VICINITY MAP

September 2013 21-1-12416-001

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FIG. 1

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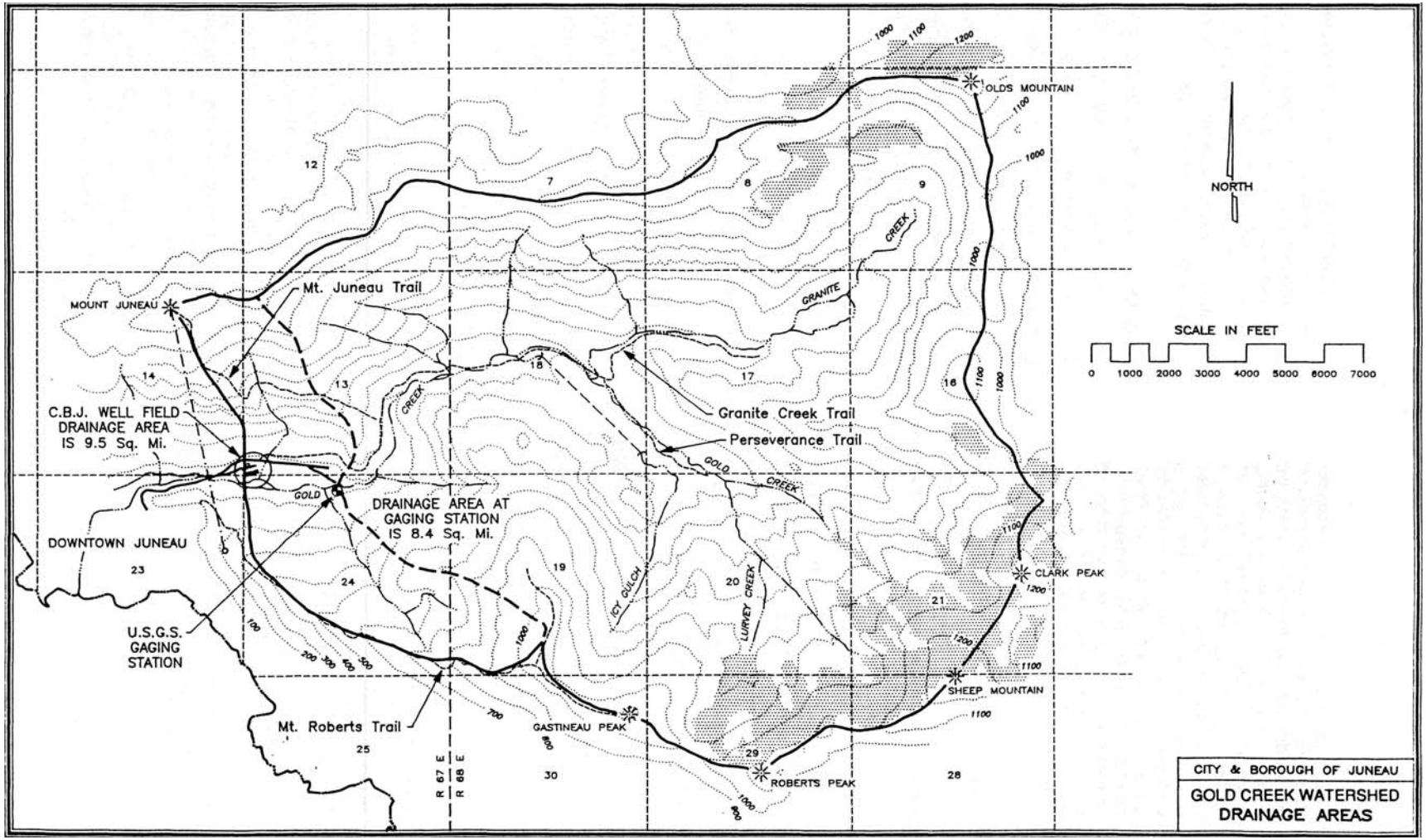

Figure from: City and Borough of Juneau, 1995, Watershed Control and Wellhead Protection Program Gold Creek Source, A Component of the City and Borough of Juneau Comprehensive Plan

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Last Chance Basin Wellfield Assessment

Gold Creek Watershed and Last Chance Basin

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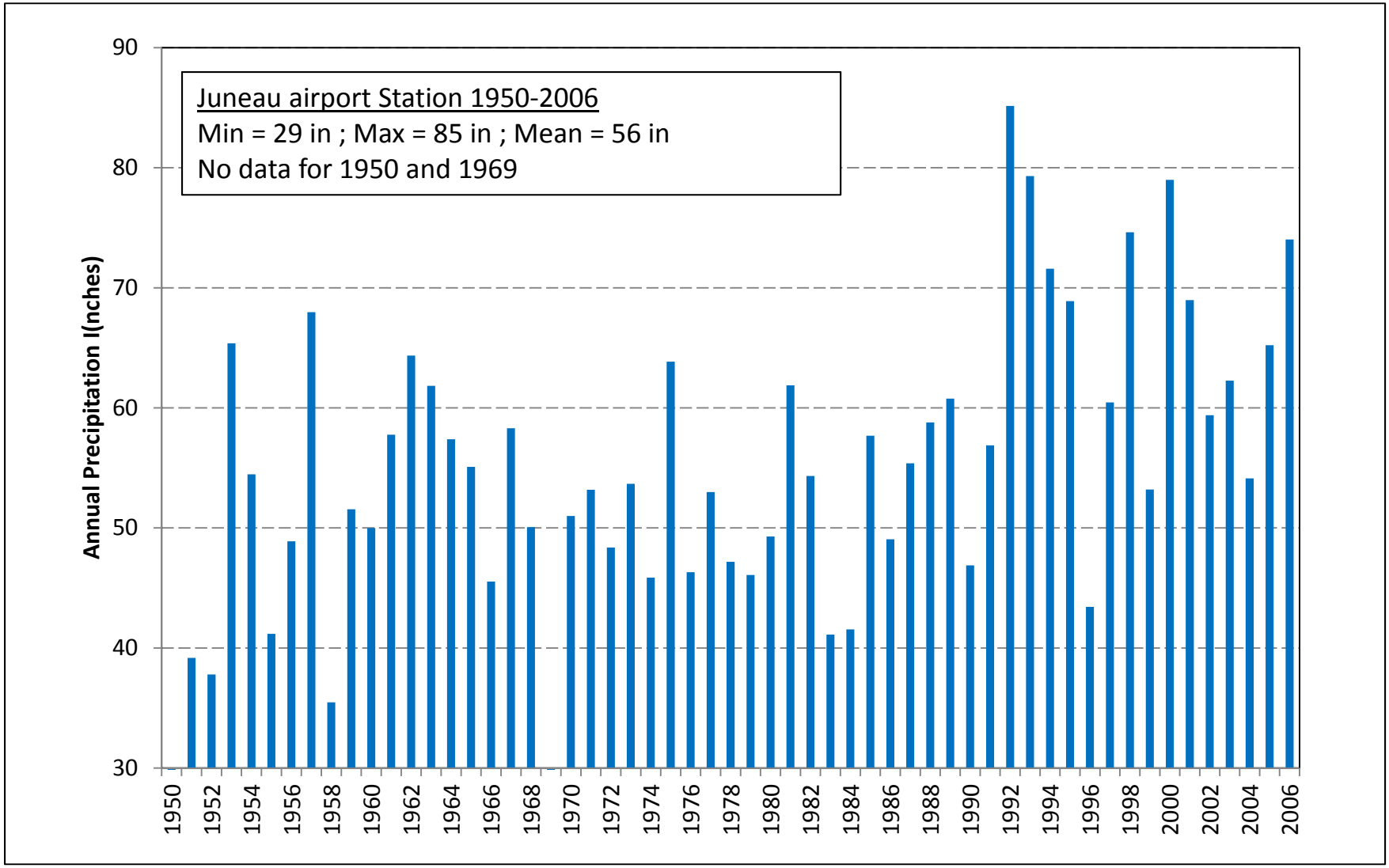
FIG. 2



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Annual Precipitation at Juneau Airport Station – 1950-2006

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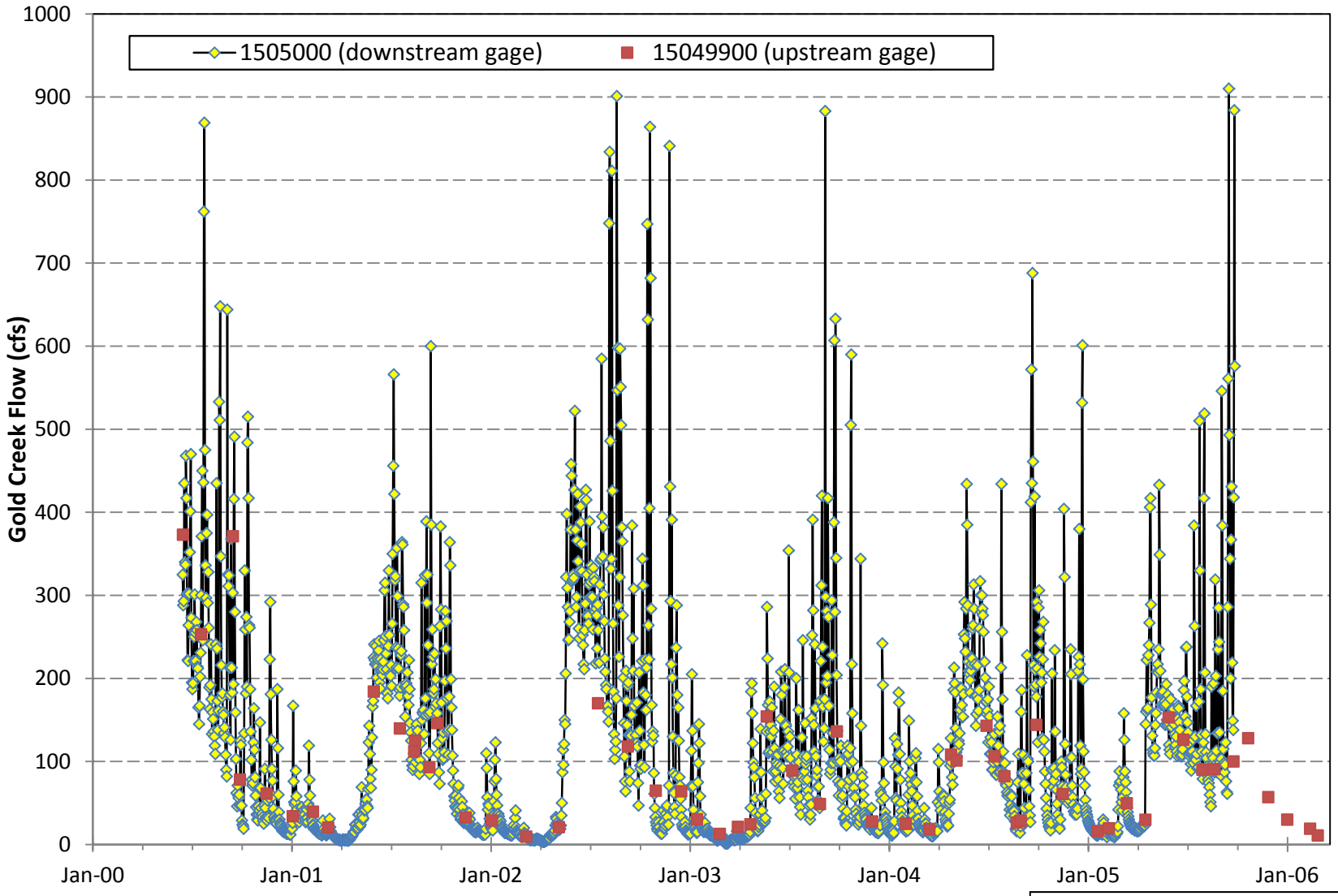
FIG. 3



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Gold Creek Stream Gauge Data

2000-2006

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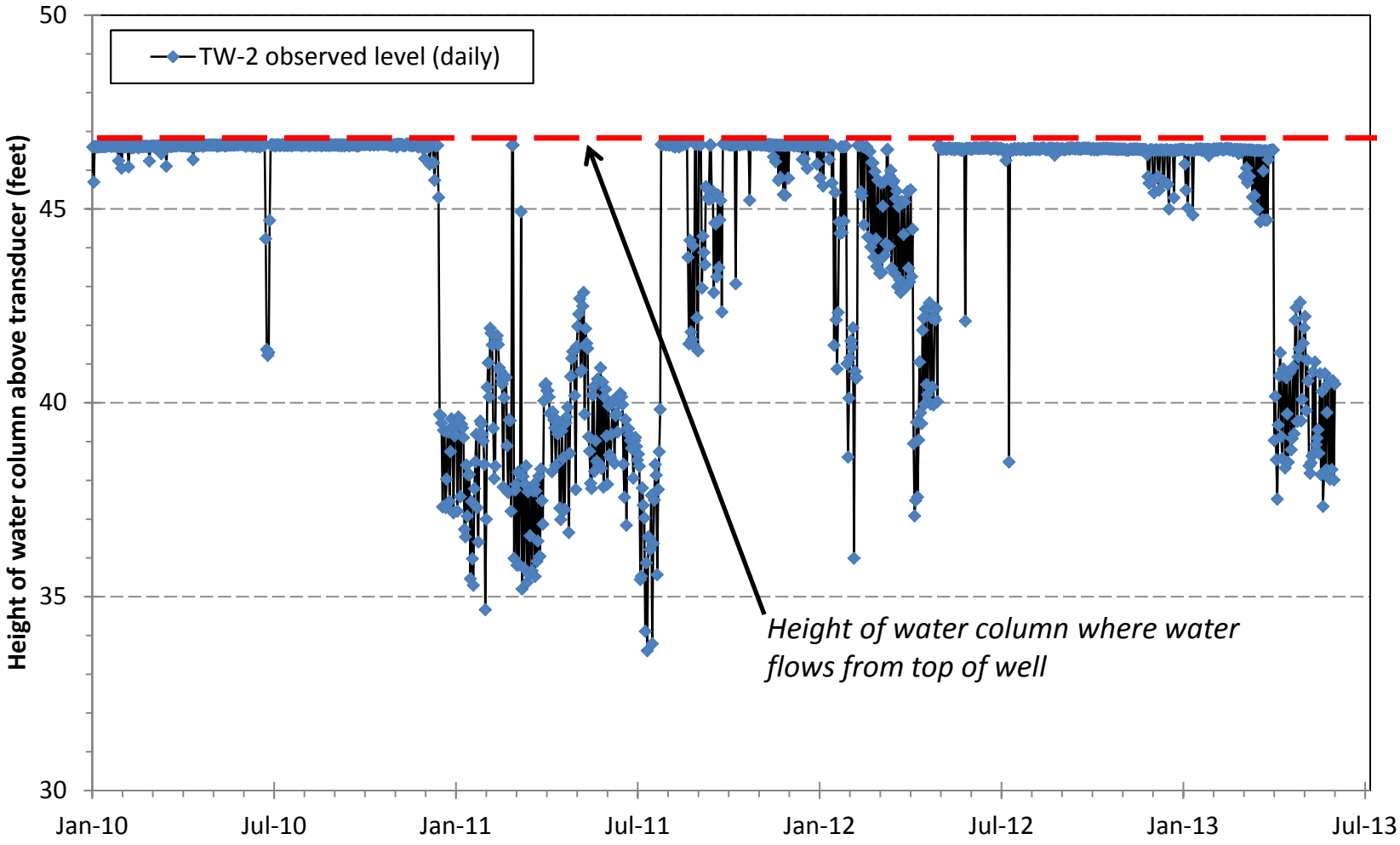
FIG. 4



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Last Chance Basin Wellfield Assessment

Groundwater Levels for TW-2 – 2010-13

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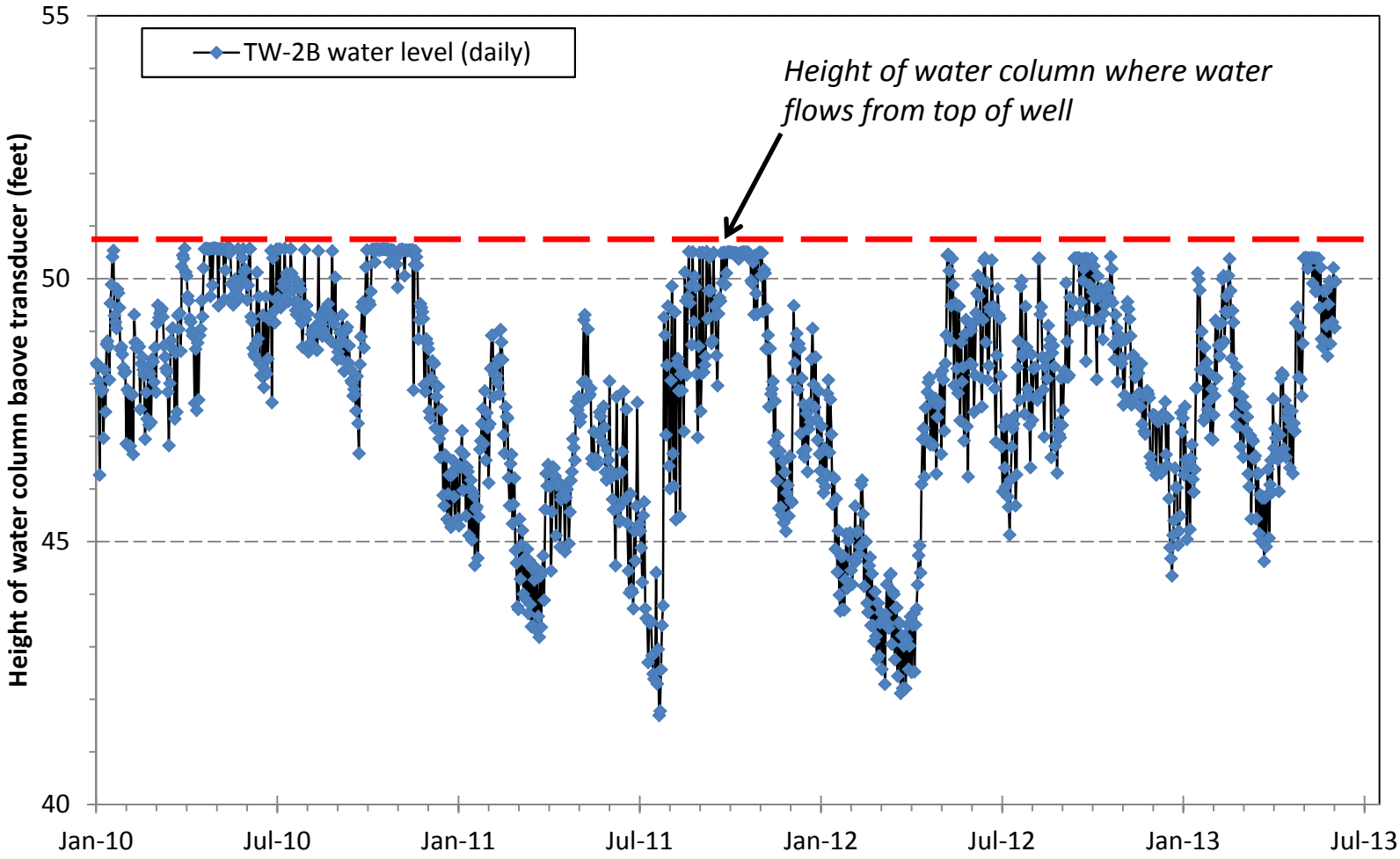
FIG. 5



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Groundwater Levels for TW-2B - 2010-13

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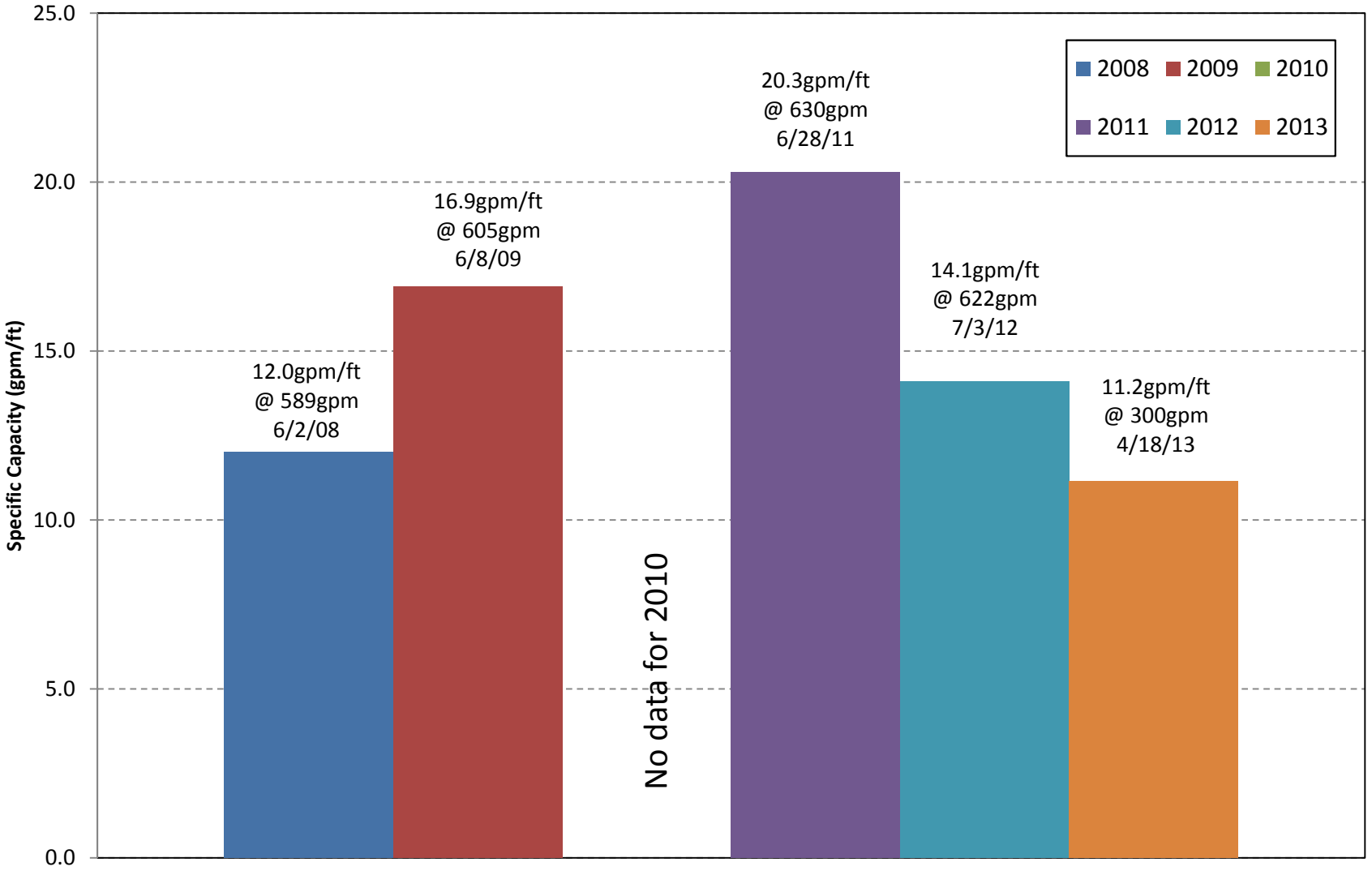
FIG. 6



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Last Chance Basin Wellfield Assessment

PW-1 Specific Capacity 2008-13

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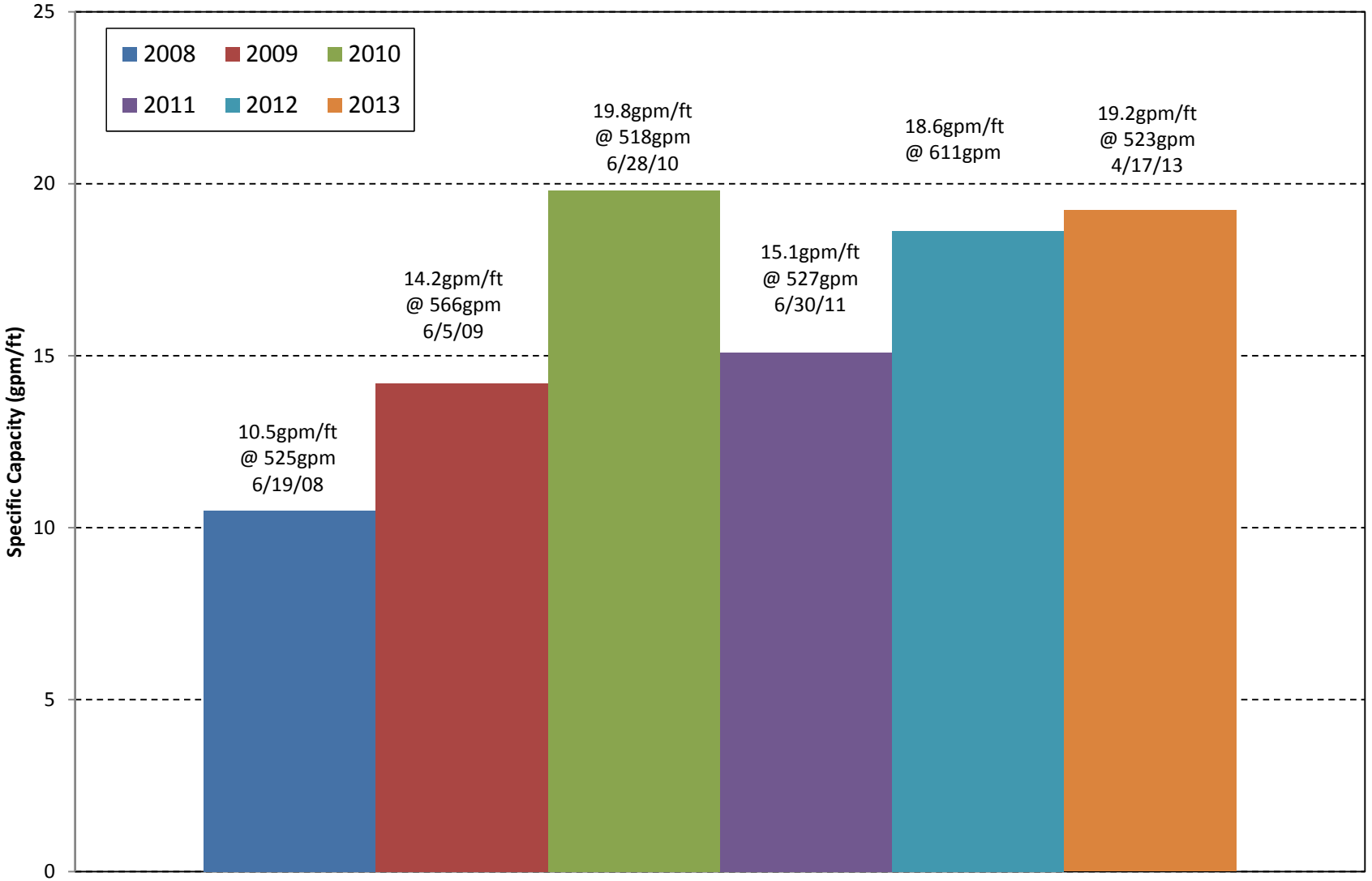
FIG. 7



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PW-2 Specific Capacity - 2008-13

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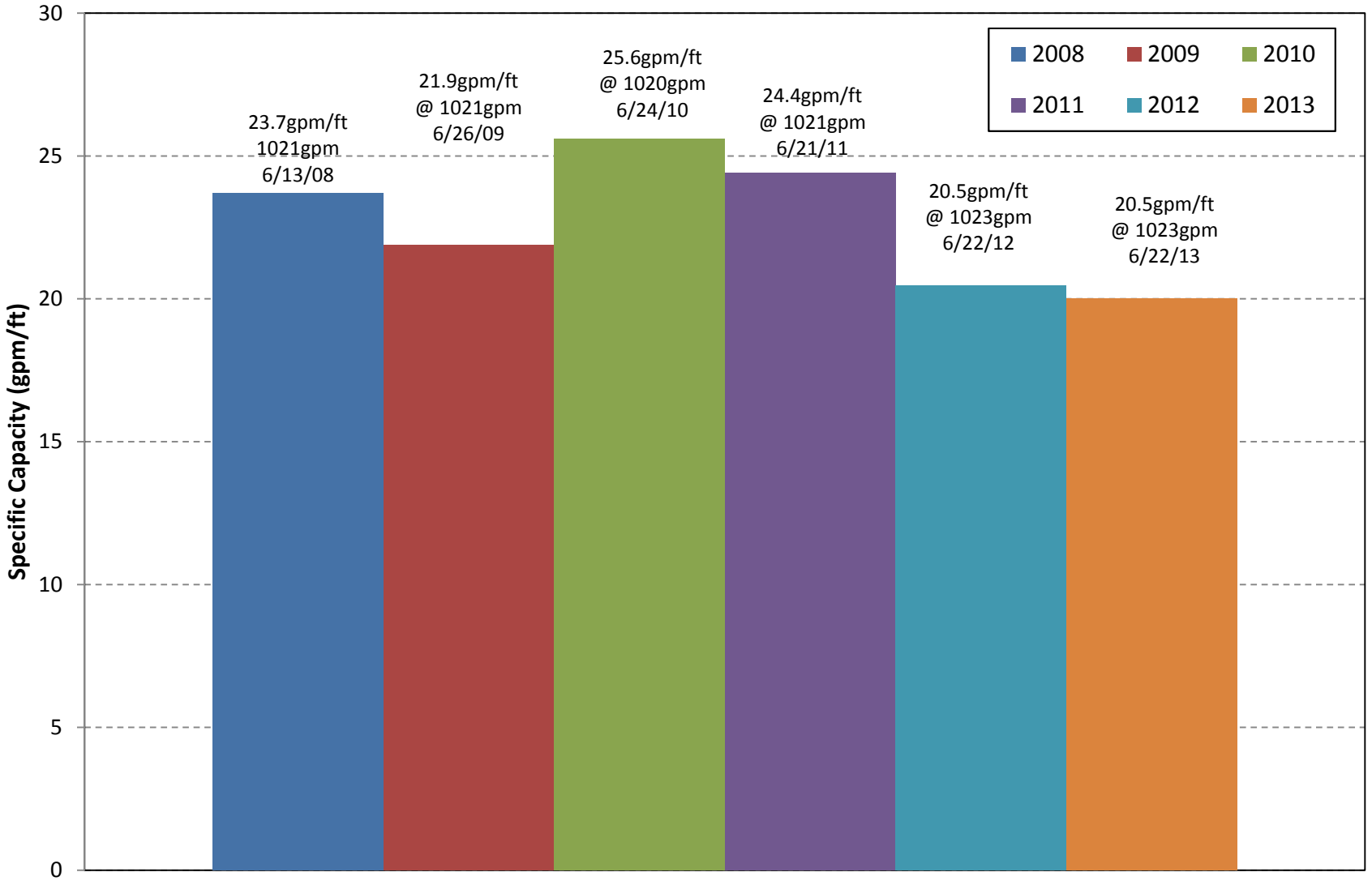
FIG. 8



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PW-3 Specific Capacity – 2008-13

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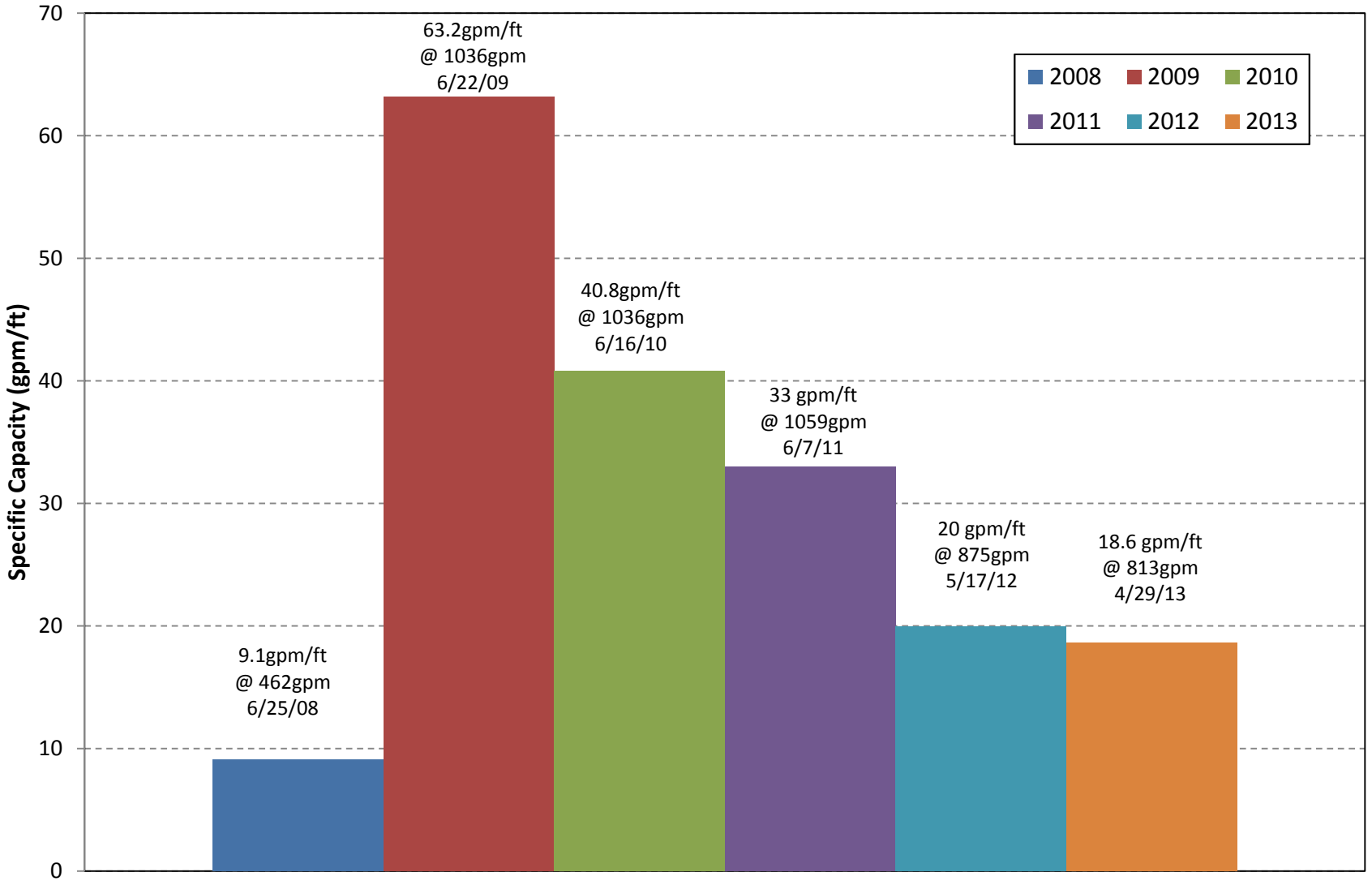
FIG. 9



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PW-4 Specific Capacity – 2008-13

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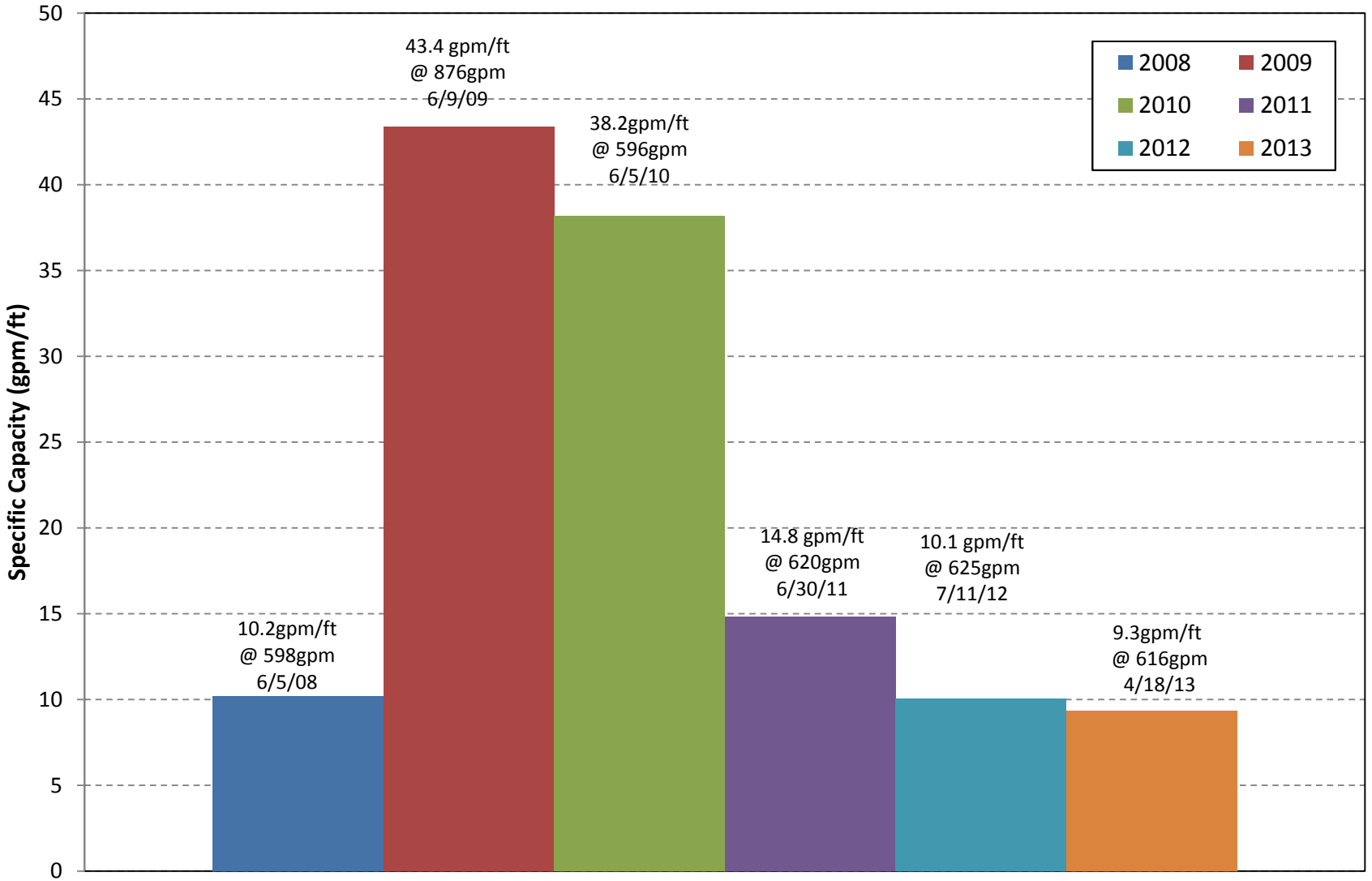
FIG. 10



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PW-5 Specific Capacity – 2008-13

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FIG. 11



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Last Chance Basin Wellfield Assessment

Model Domain & Mesh

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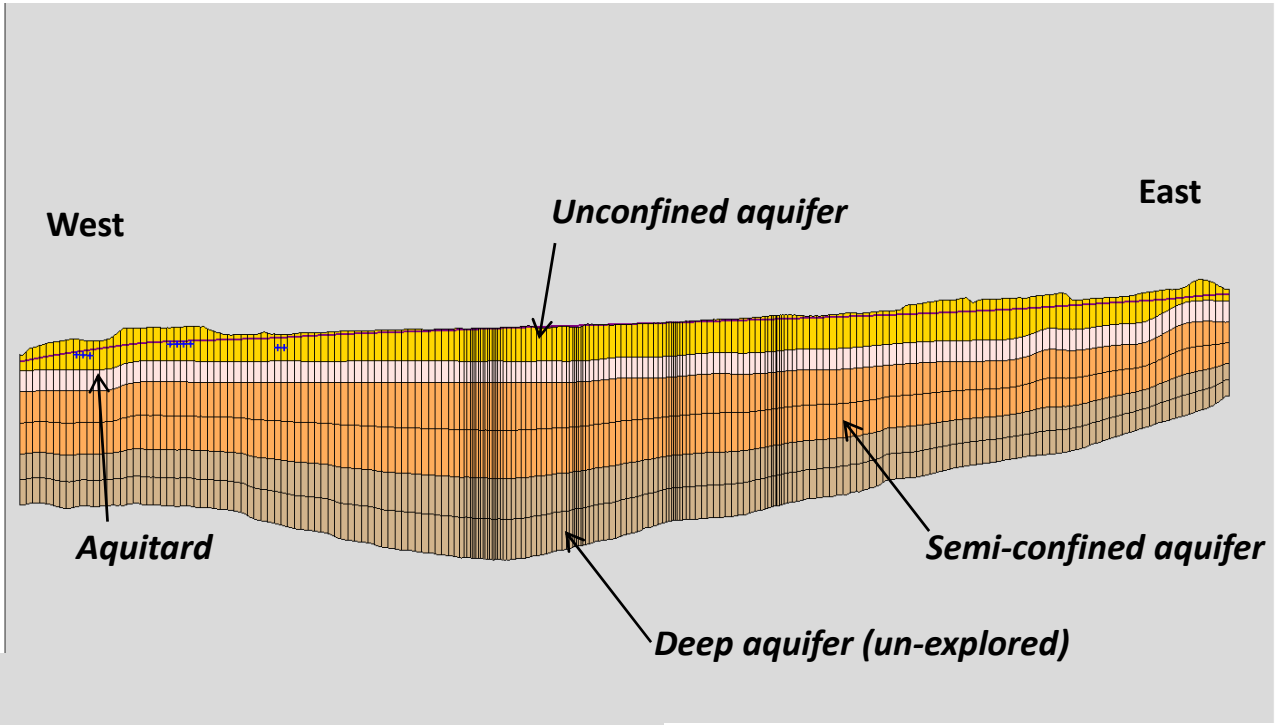
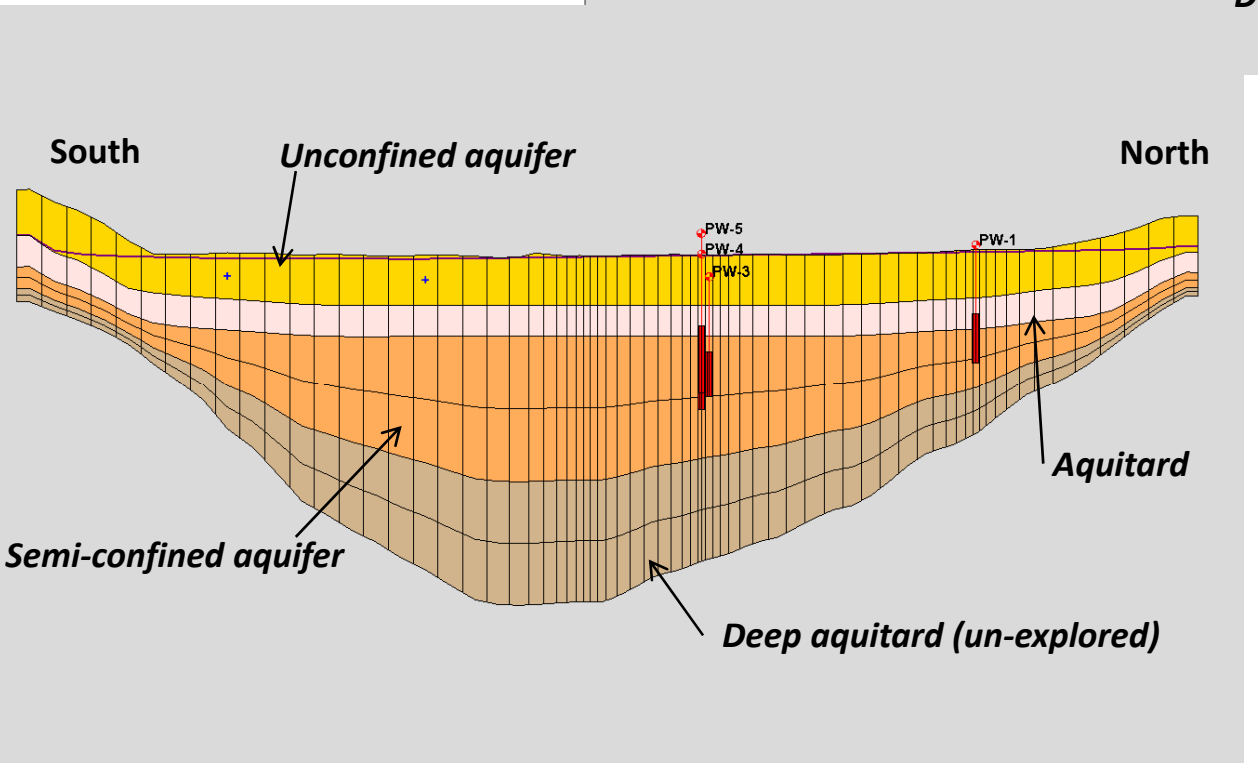
FIG. 12





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LCB Model Layering in Sections

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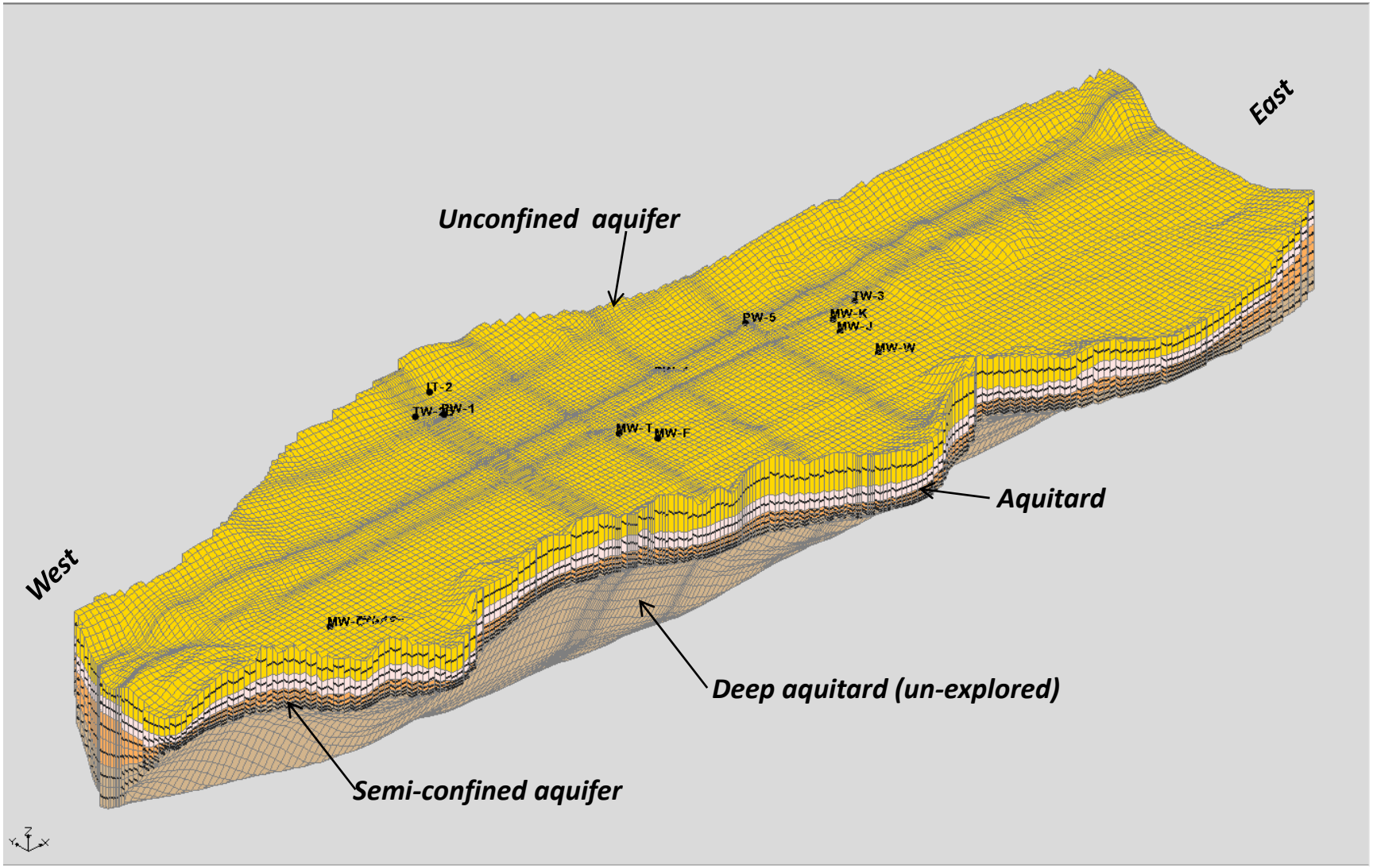
FIG. 13



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Last Chance Basin Wellfield Assessment

LCB Model Domain and Mesh – Oblique View

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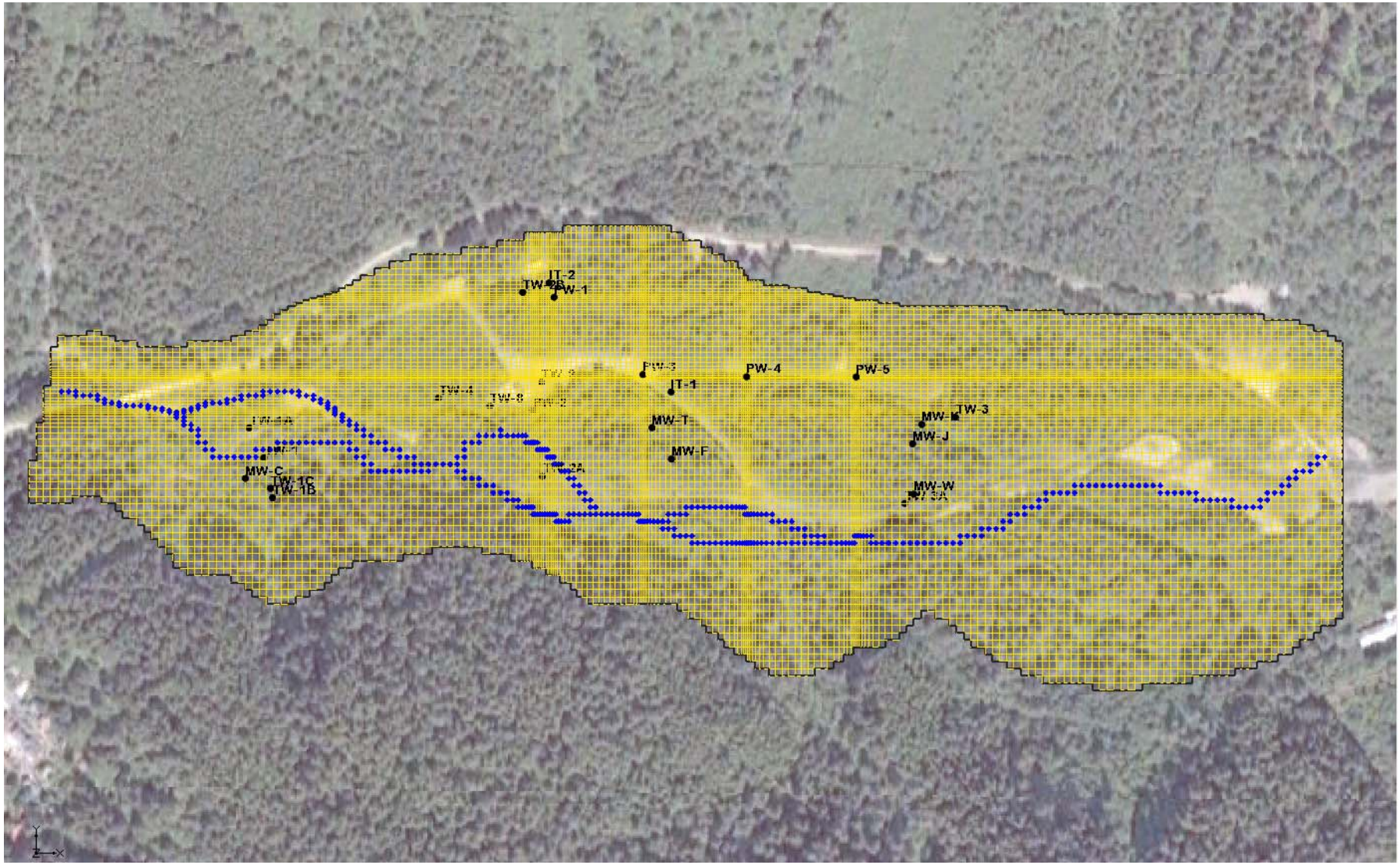
FIG. 14



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Last Chance Basin Wellfield Assessment

Simulation of Gold Creek in Unconfined Aquifer Layer

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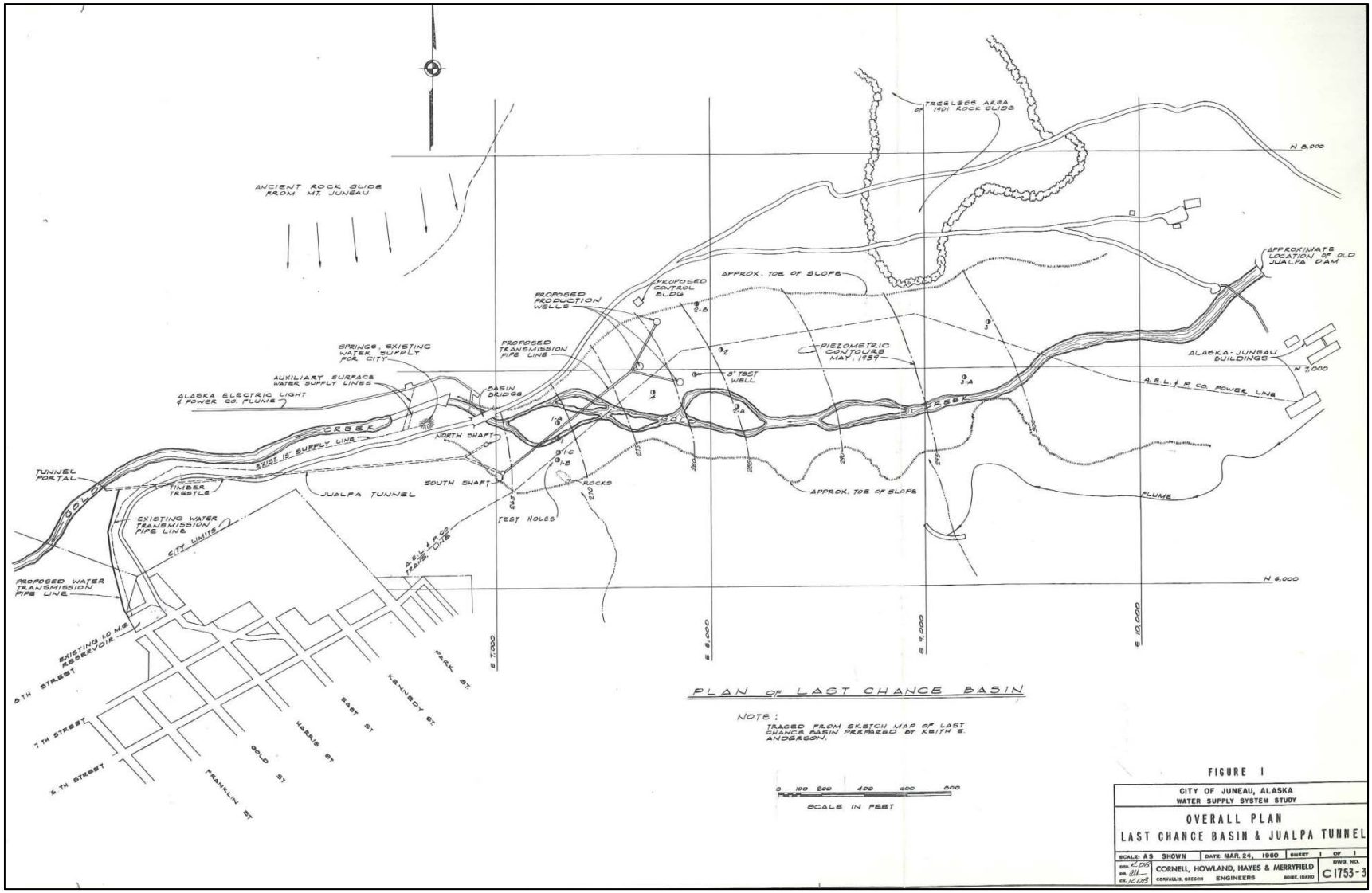
FIG. 15



Source: CBJ, 1959

City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

1959 Pre-development Interpreted Groundwater Contours

September 2013 21-1-12416

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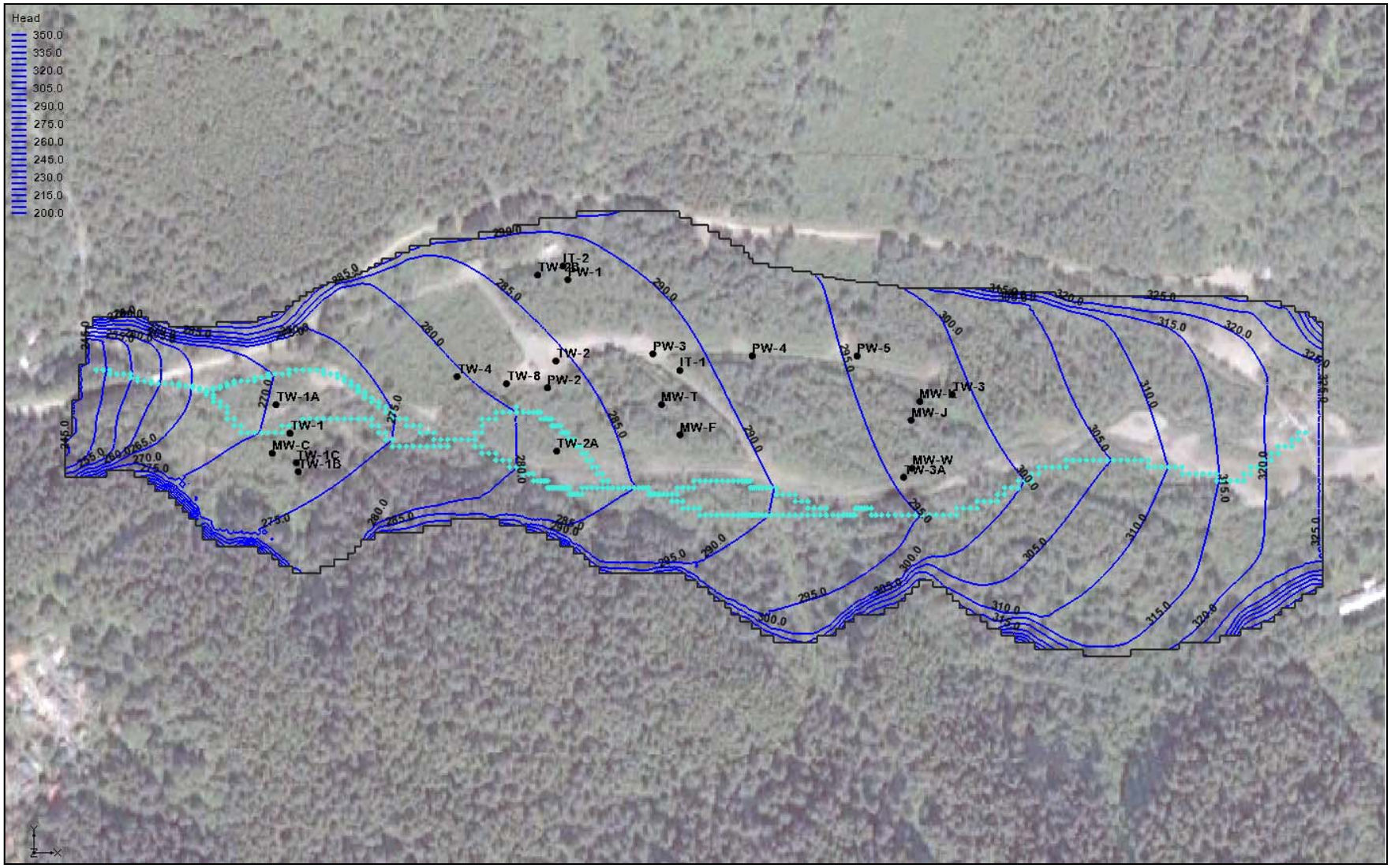
FIG. 16



250 Simulated Piezometric Level (feet msl)

+++++++ Gold Creek

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City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

Modeled Groundwater Levels - Unconfined Aquifer for Calibration

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FIG. 17



250 Simulated Piezometric Level (feet msl)

PW-4 Calibration Well Target

green = error ± 0-2.5 feet

yellow = error ± 2.5-5 feet

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Last Chance Basin Wellfield Assessment

Modeled Groundwater Levels - Semi-Confined Aquifer for Calibration

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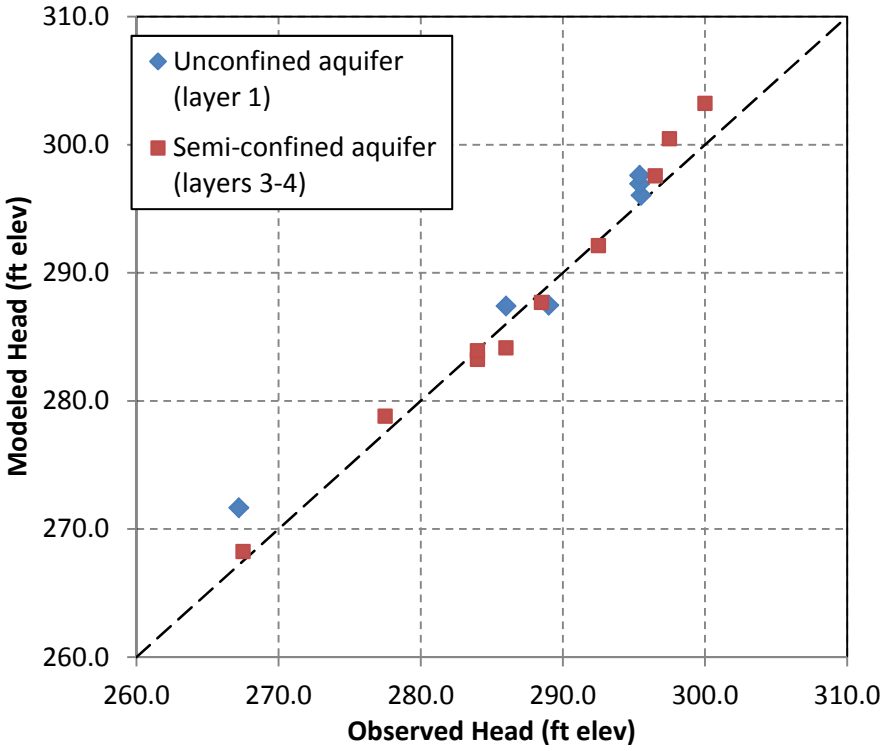
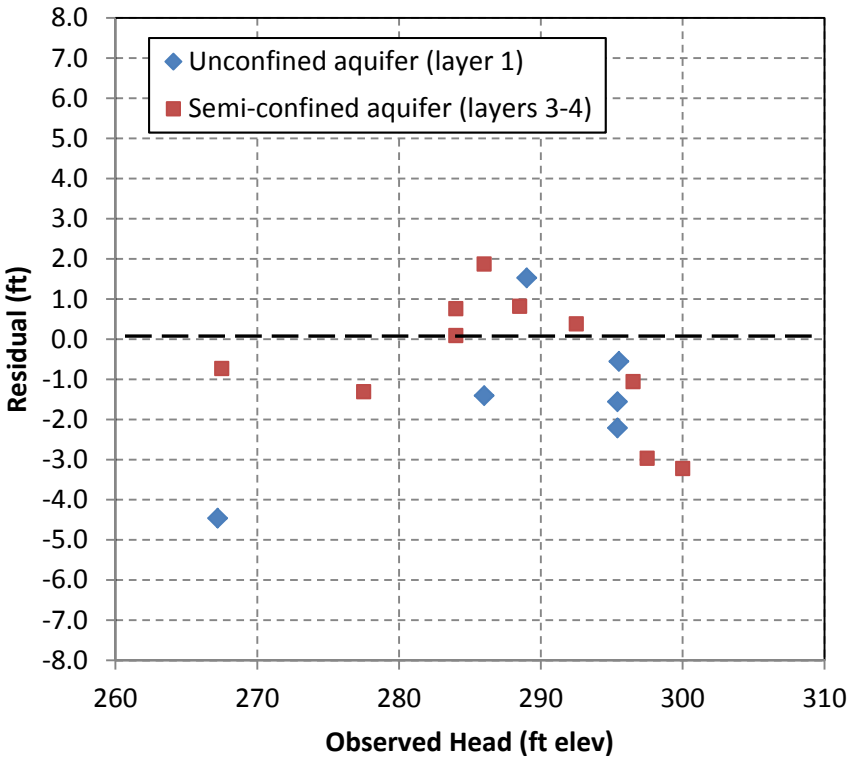
FIG. 18





No. wells = 16
Range of residuals = -4.5 to +1.9 feet
Mean of absolute residuals = 3.5 feet

City & Borough of Juneau, Alaska
Last Chance Basin Wellfield Assessment

Steady-state Pre-development Calibration Results

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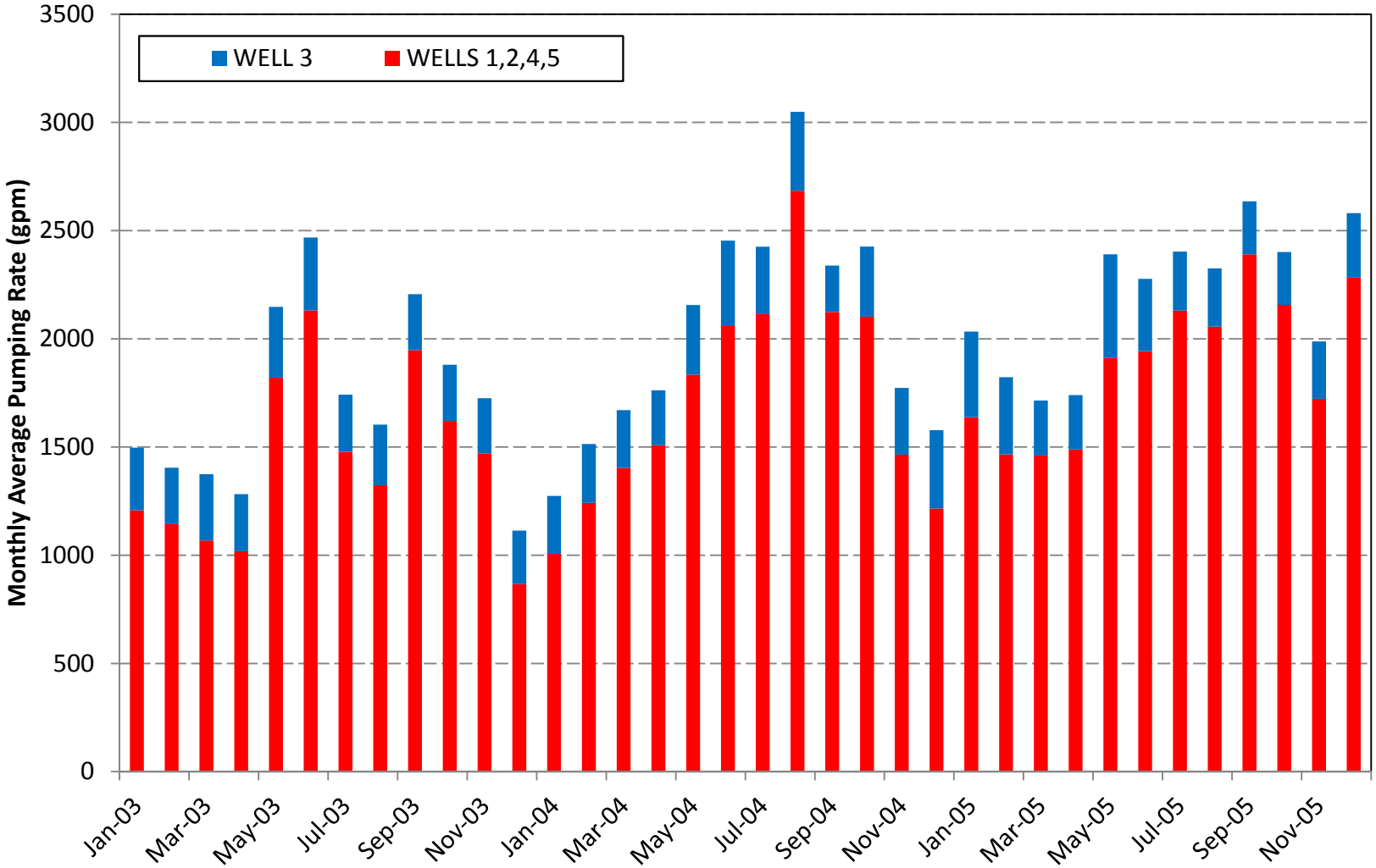
FIG. 19



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Last Chance Basin Wellfield Assessment

Reported Monthly Pumping - 2003-05

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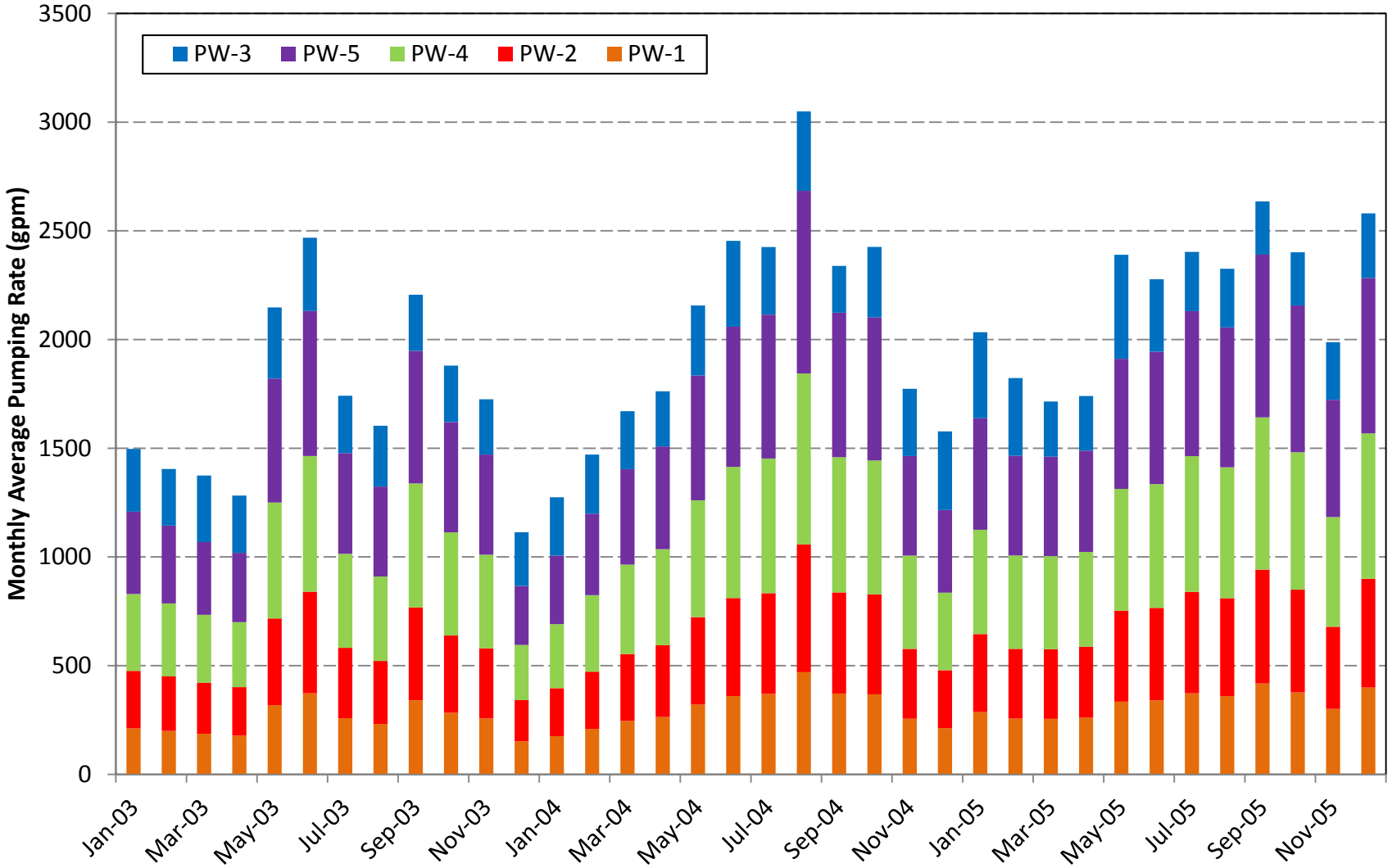
FIG. 20



City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

Simulated Monthly Pumping for 2003-05 Transient Calibration

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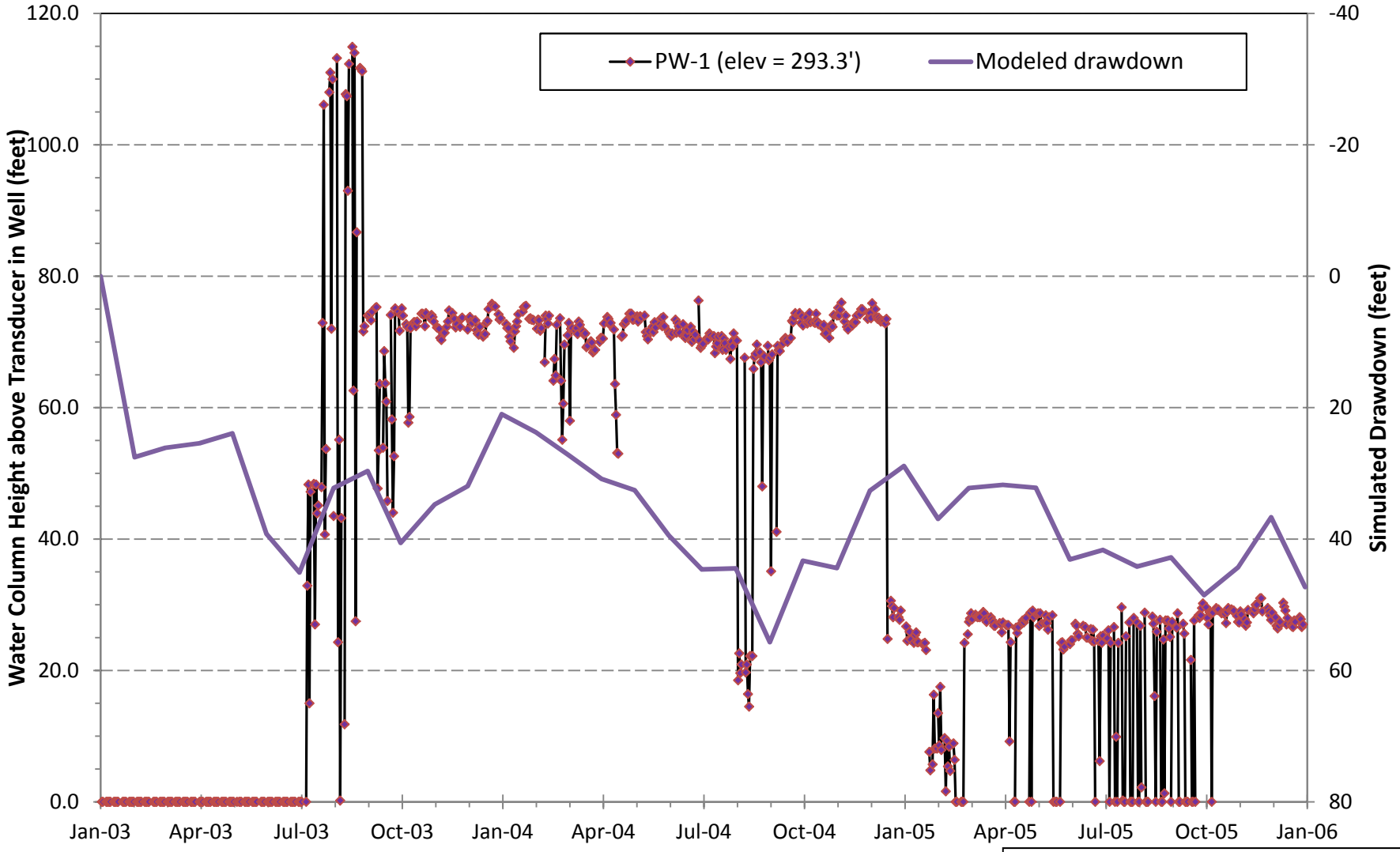
FIG. 21



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Last Chance Basin Wellfield Assessment

2003-05 Calibration - Well PW-1

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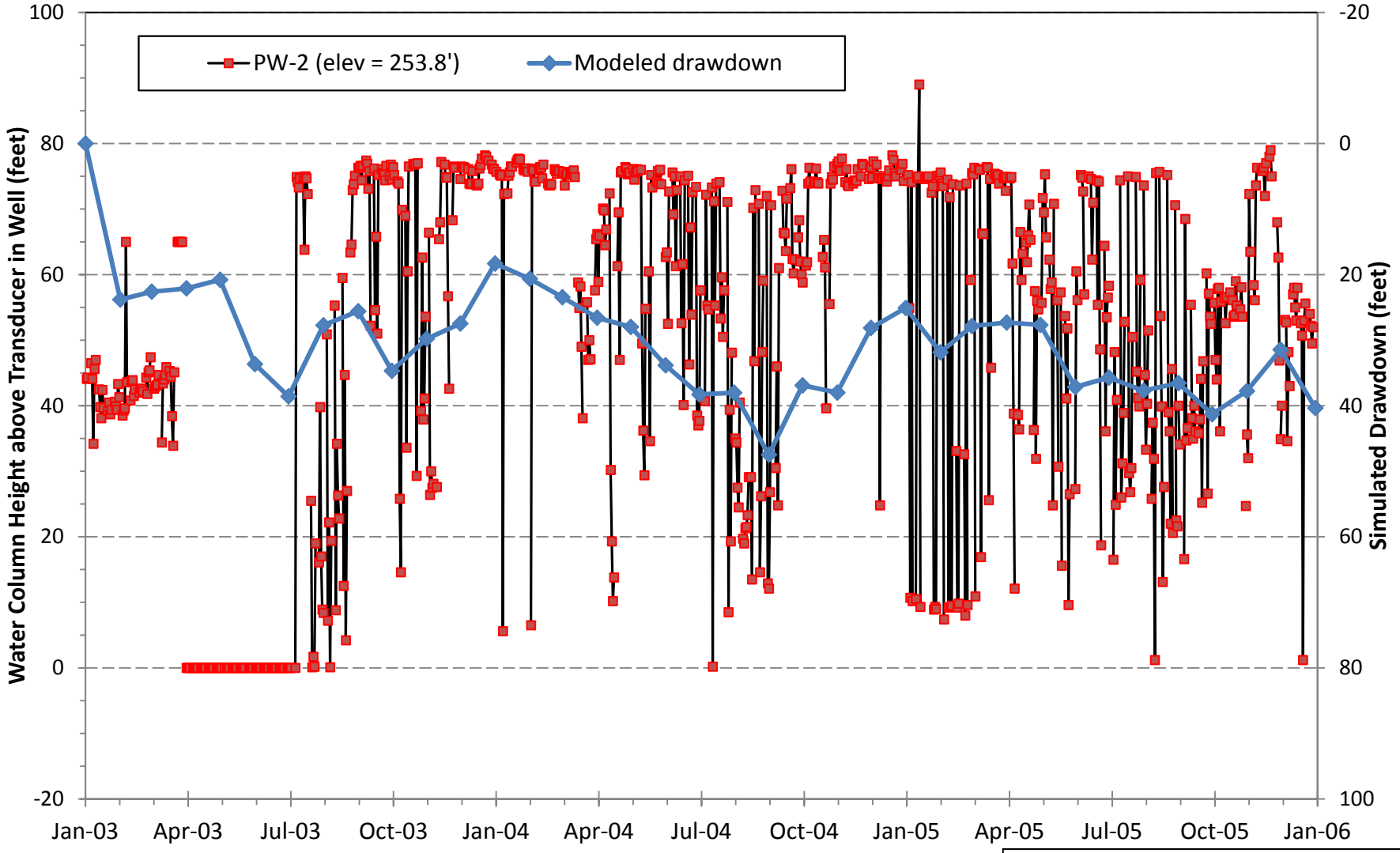
FIG. 22



City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

2003-05 Calibration Well PW-2

September 2013 21-1-12416

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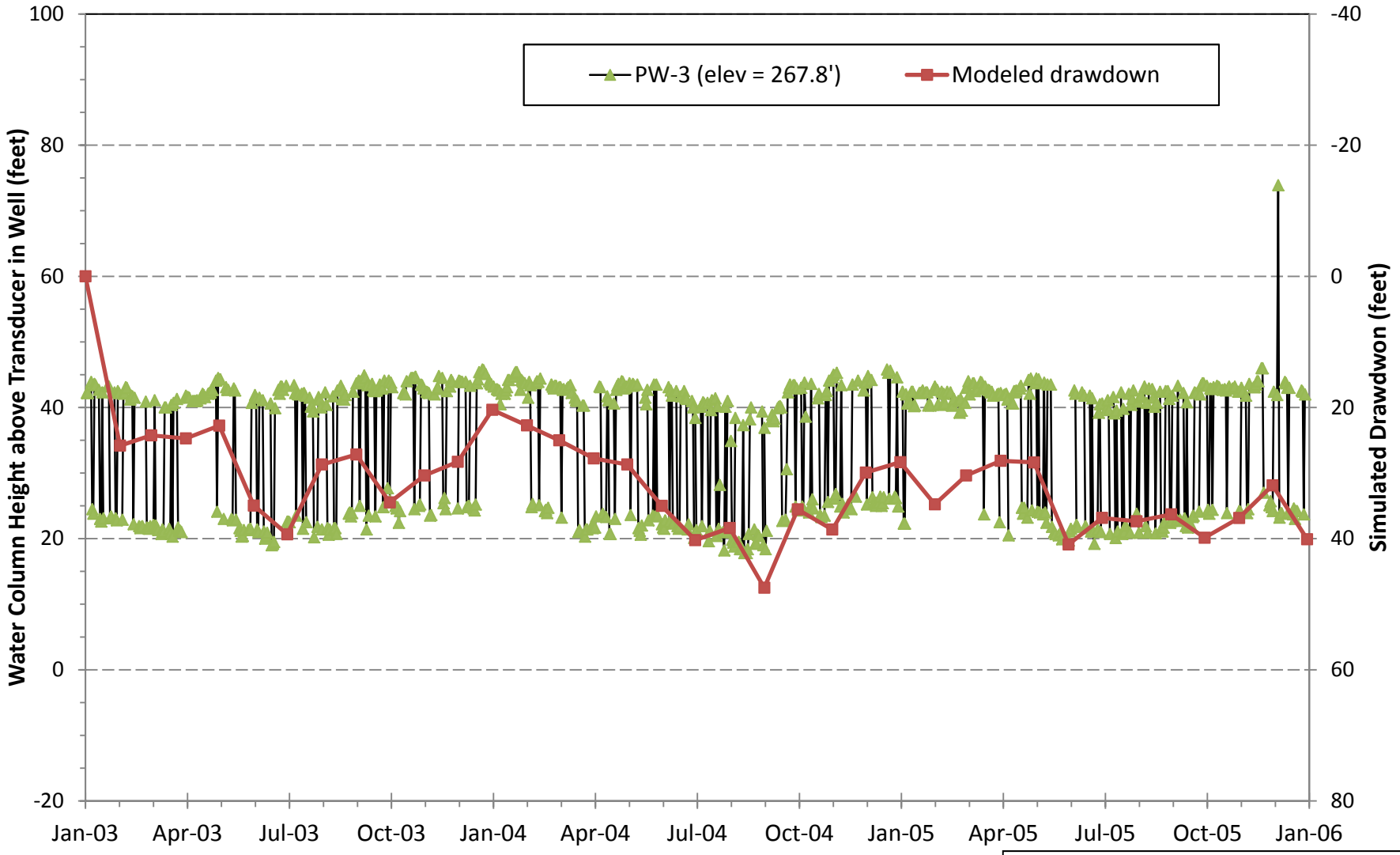
FIG. 23



City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

2003-05 Calibration Well PW-3

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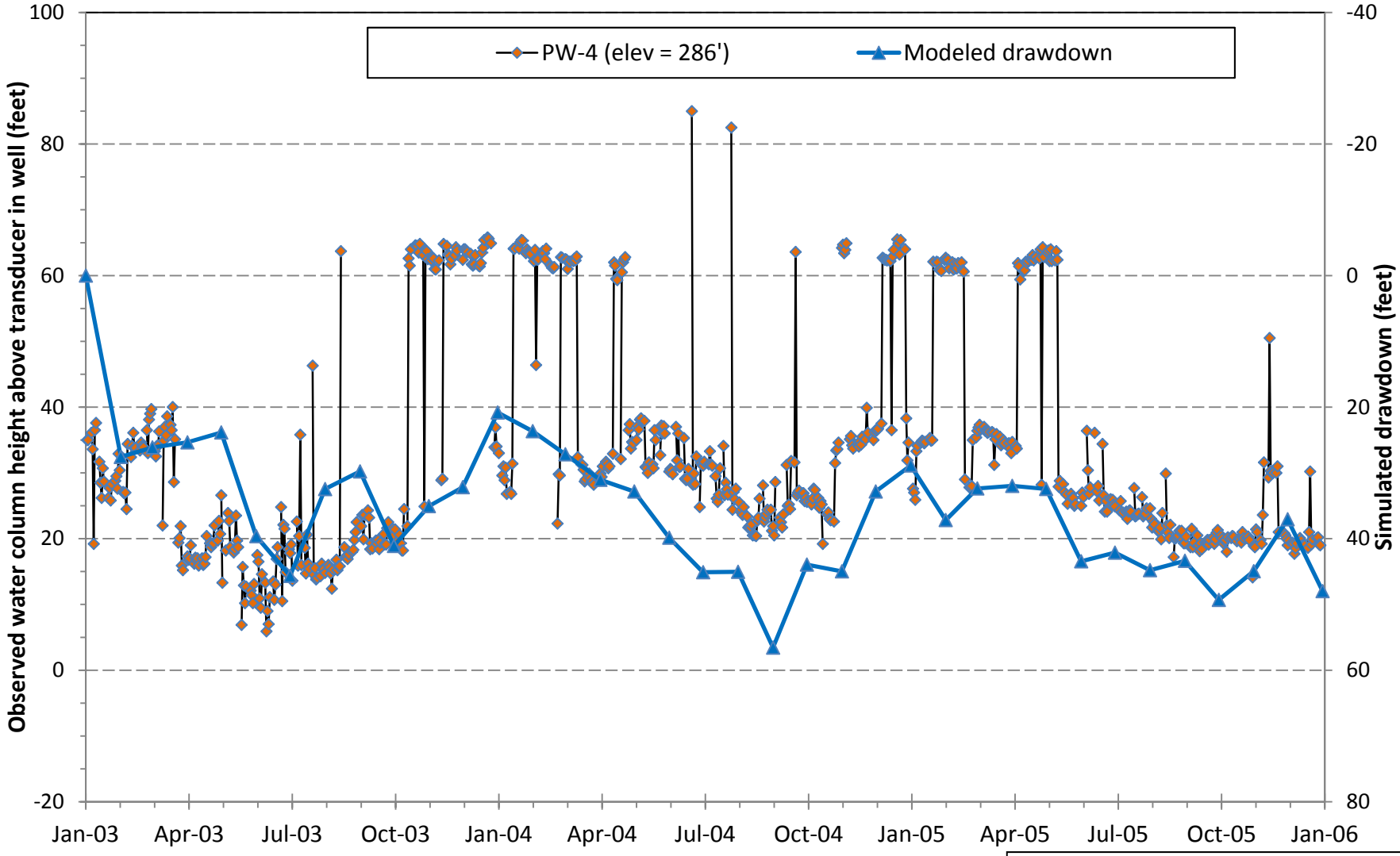
FIG. 24



City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

2003-05 Calibration Well PW-4

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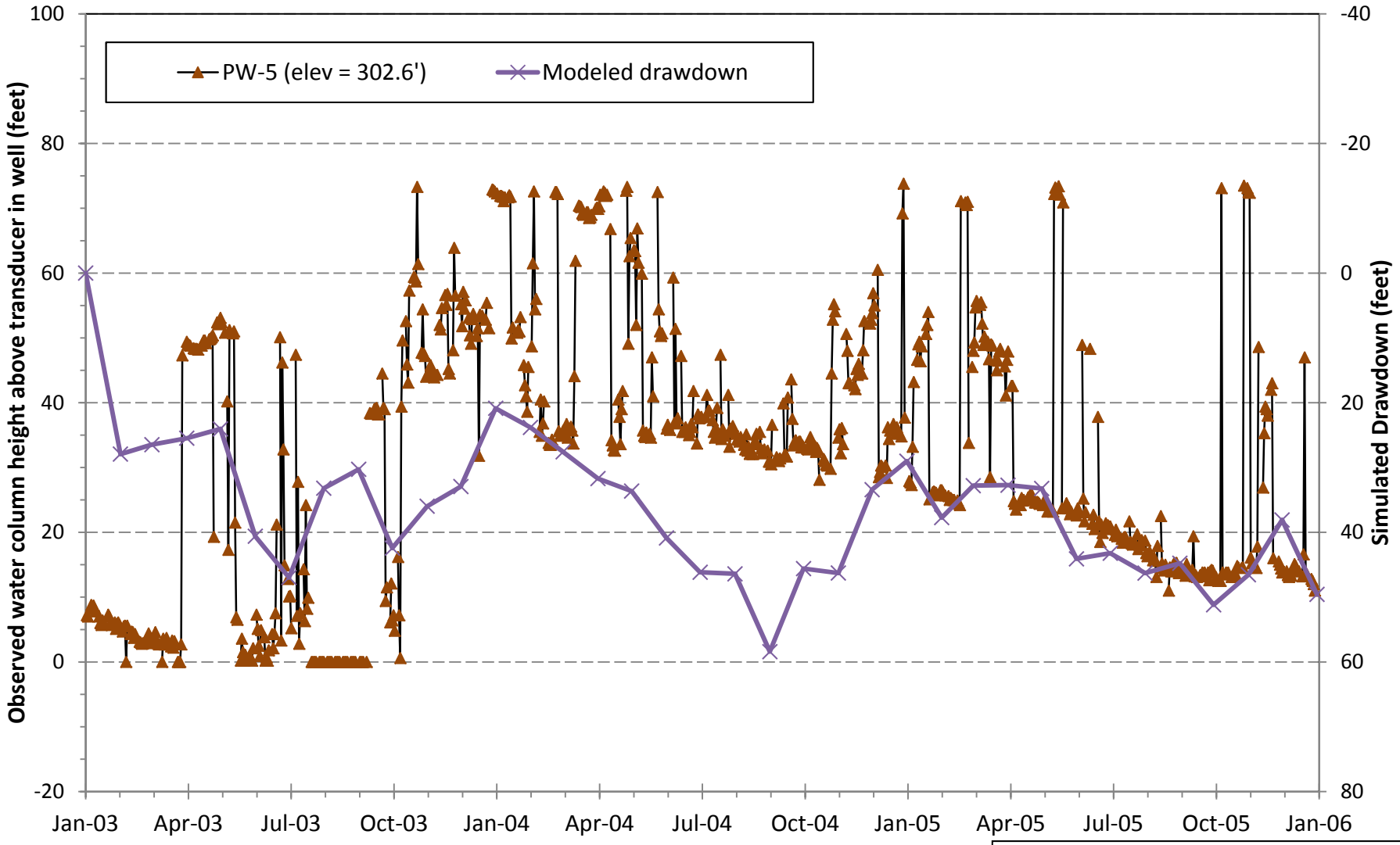
FIG. 24



City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

2003-05 Calibration Well PW-5

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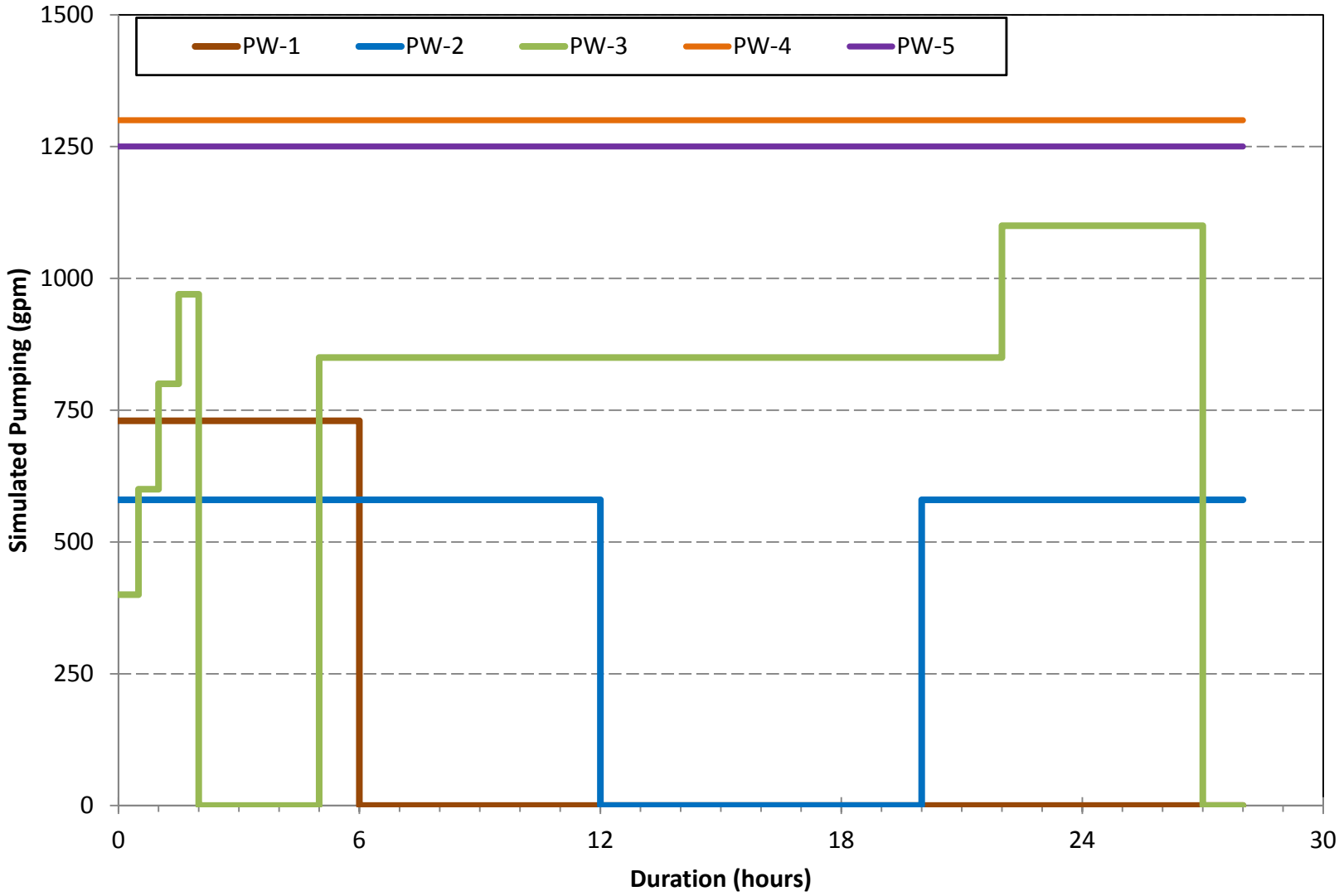
FIG. 25



City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

Simulated Pumping for May 2009 Pumping Test at PW-3

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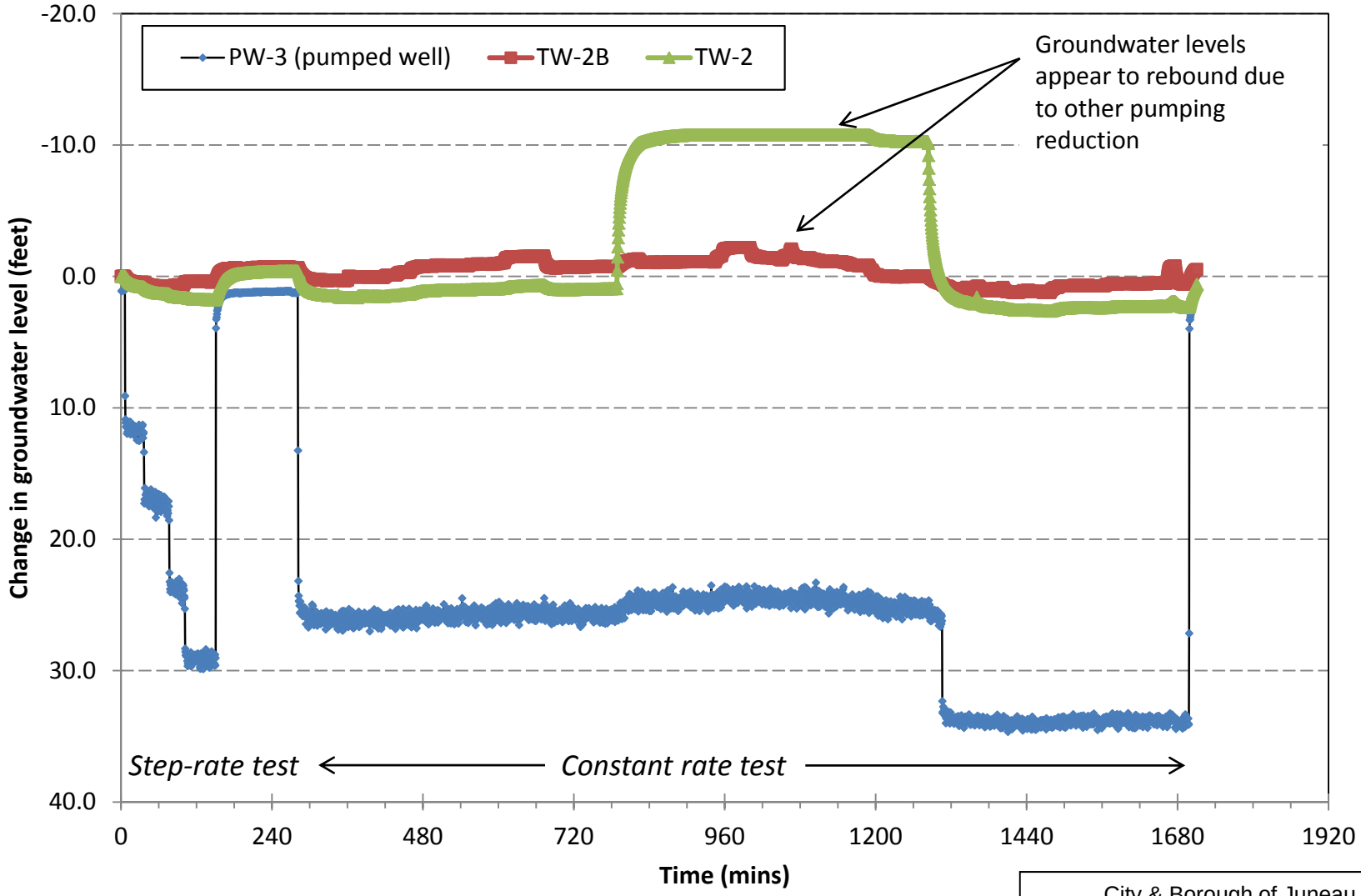
FIG. 26



City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

May 2009 Pumping Test Recorded Groundwater Level Changes

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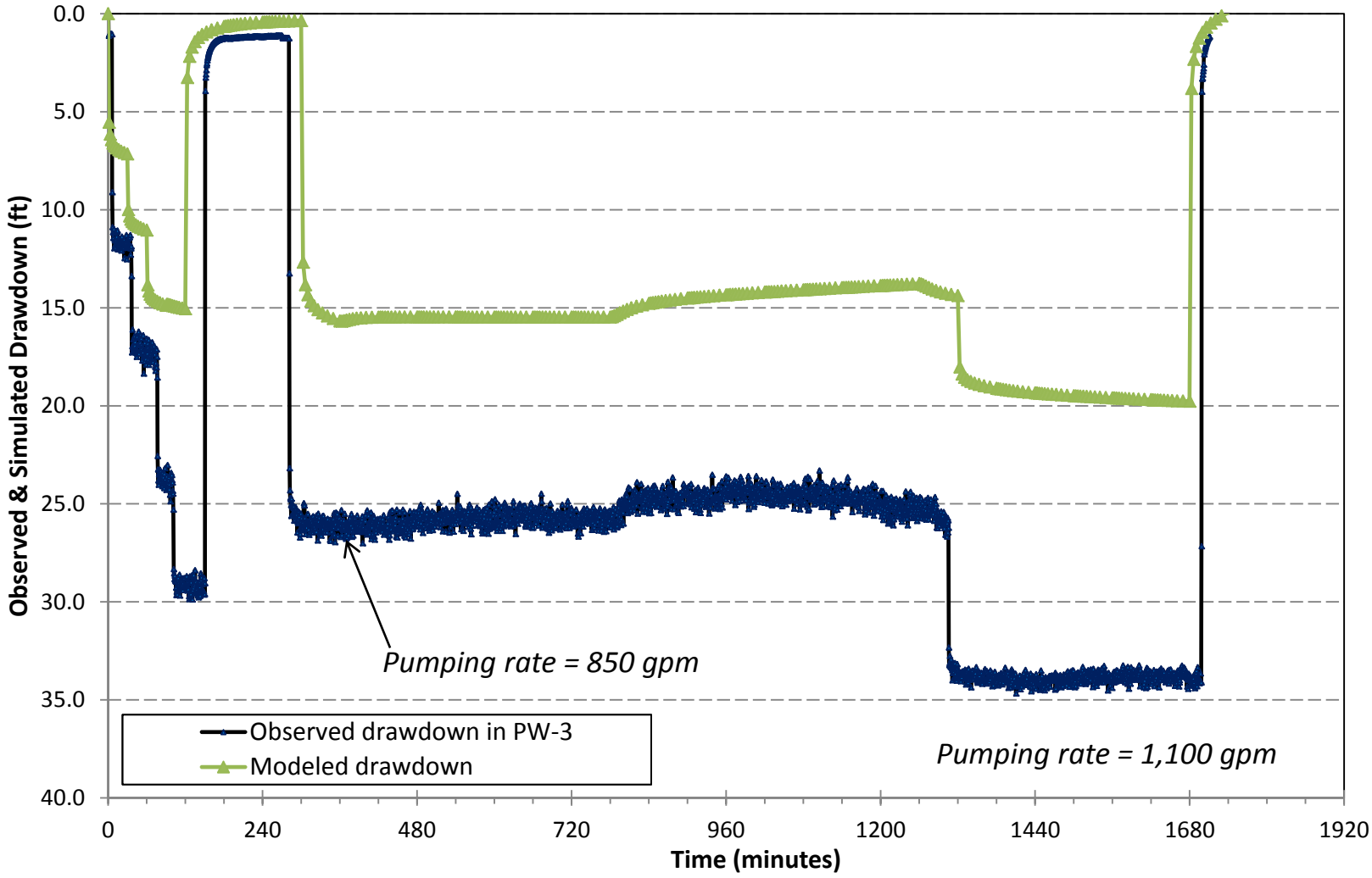
FIG. 27



City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

2009 Pumping Test Calibration - Well PW-3

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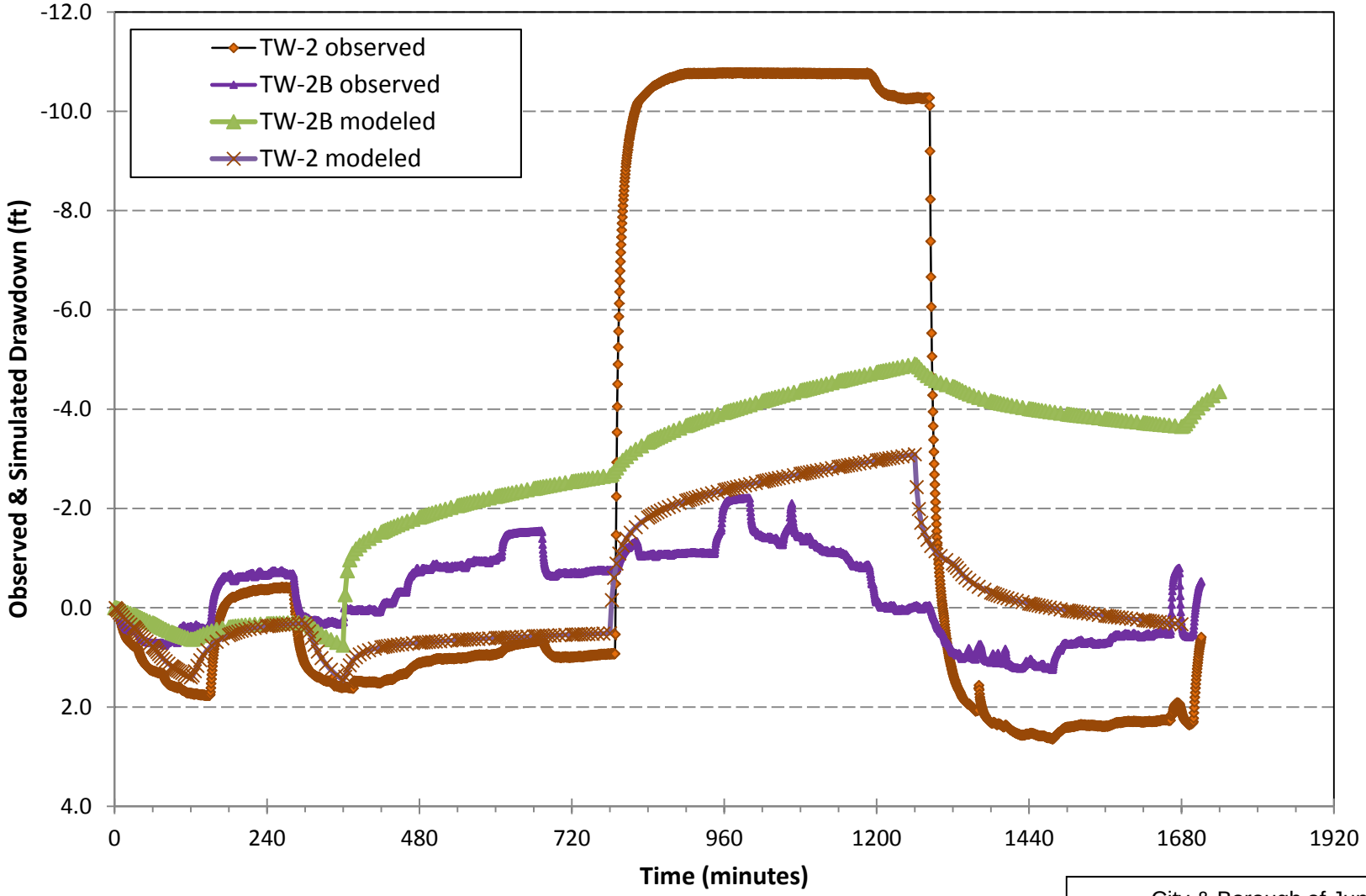
FIG. 28



City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

2009 Pumping Test Calibration - Observation Wells

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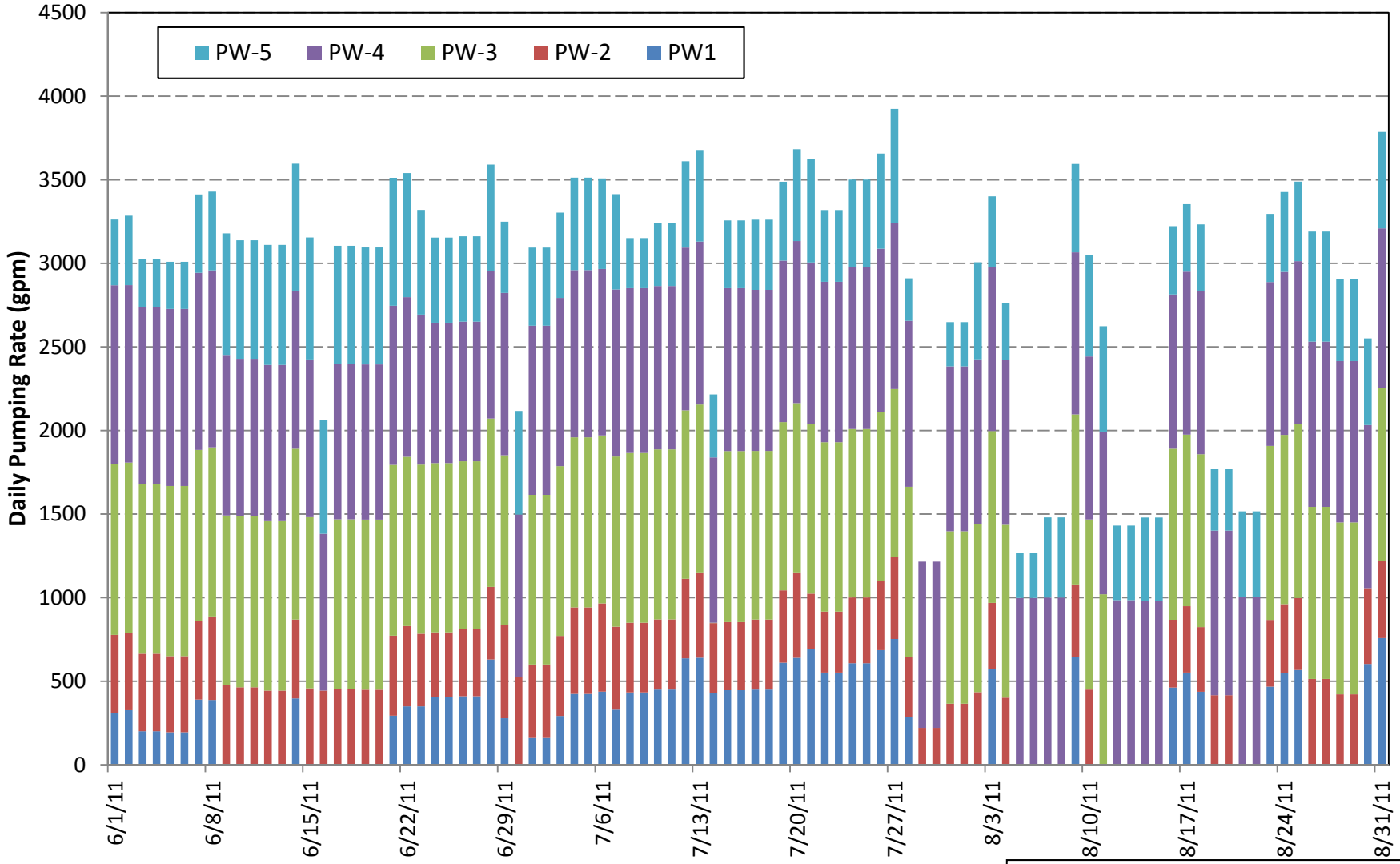
FIG. 29



City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

Summer 2011 Calibration – Simulated Daily Pumping

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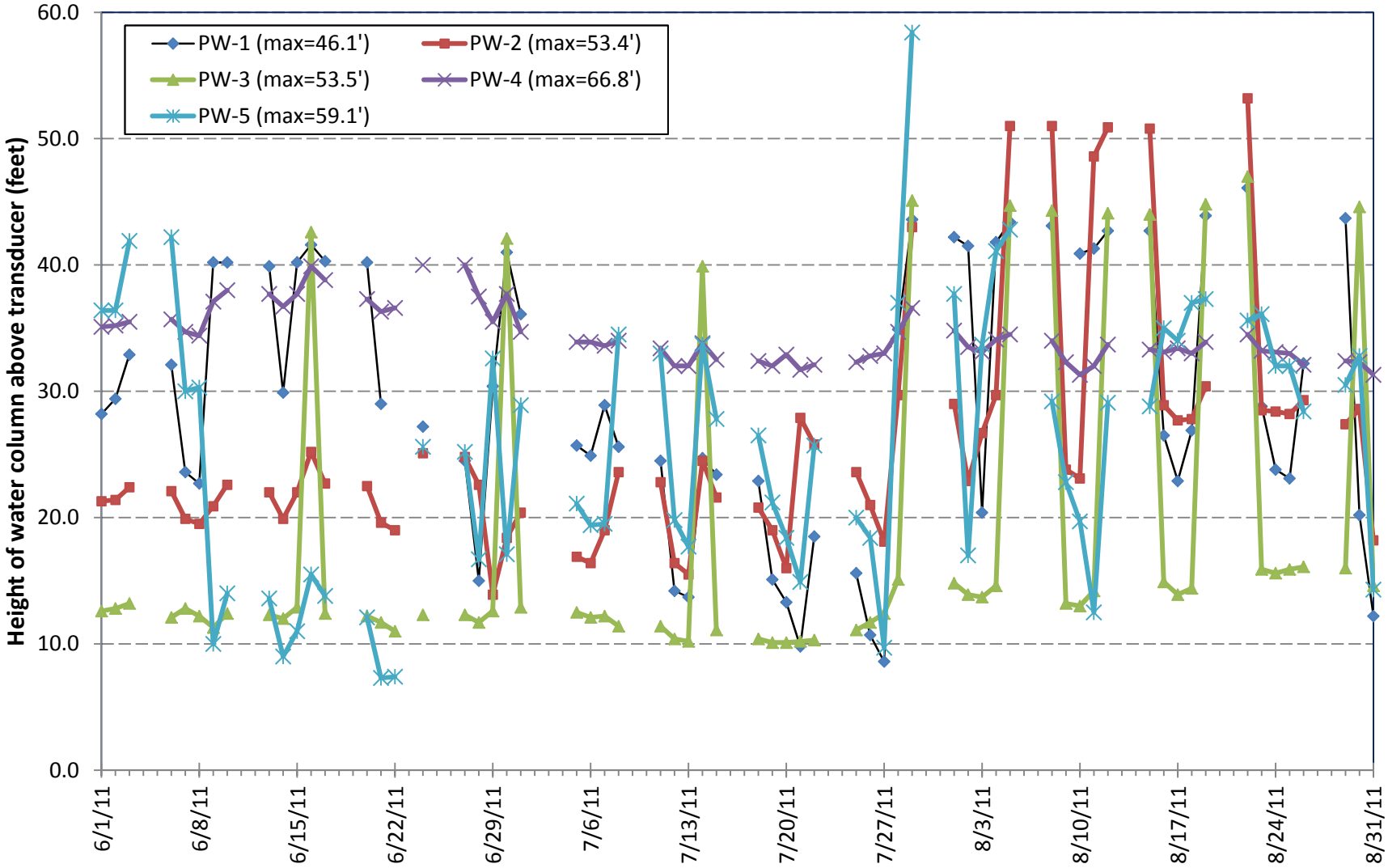
FIG. 30



City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

Observed Groundwater Levels in Pumped Wells – Summer 2011

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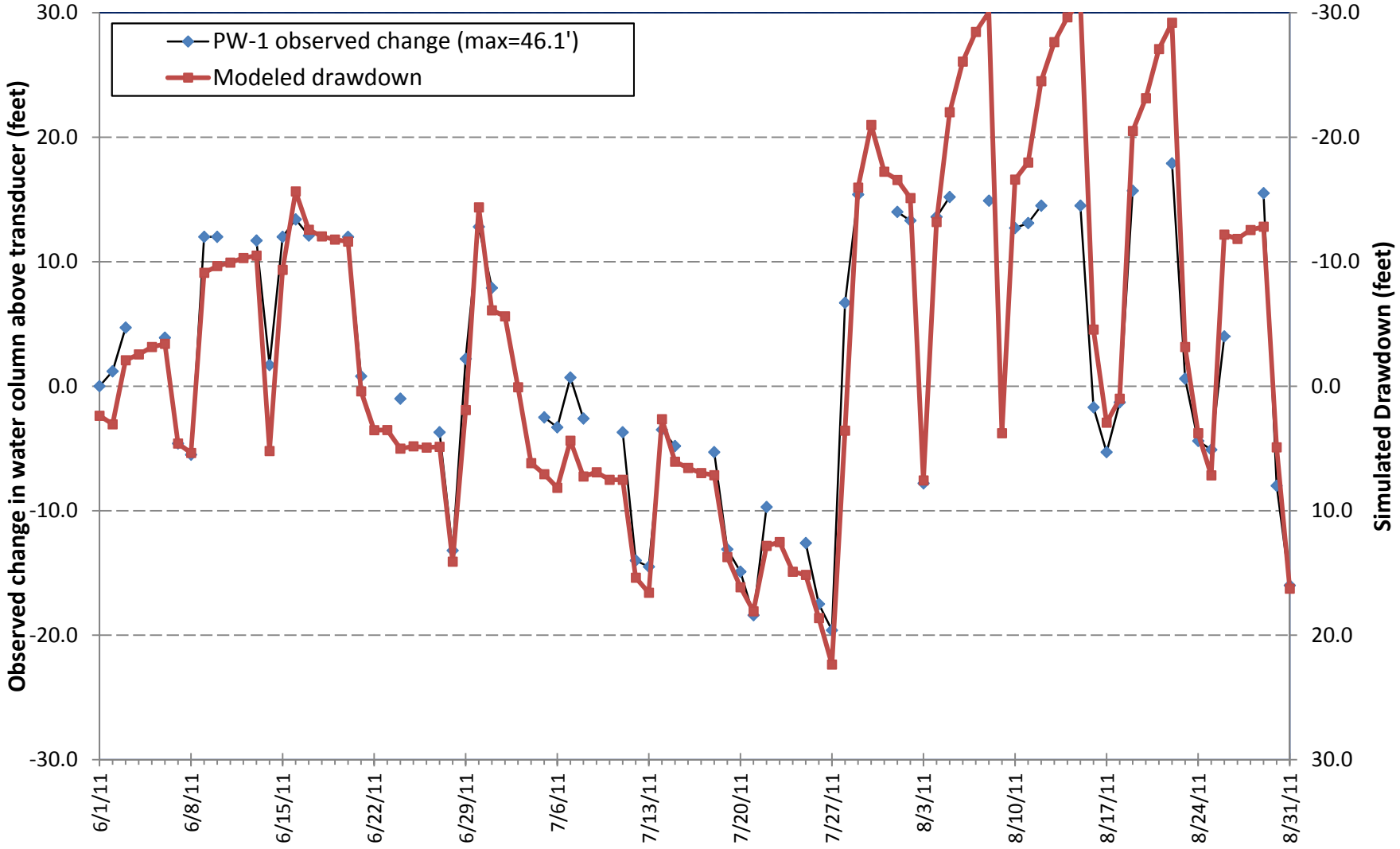
FIG. 31



City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

Summer 2011 Calibration – Well PW-1

September 2013 21-1-12416

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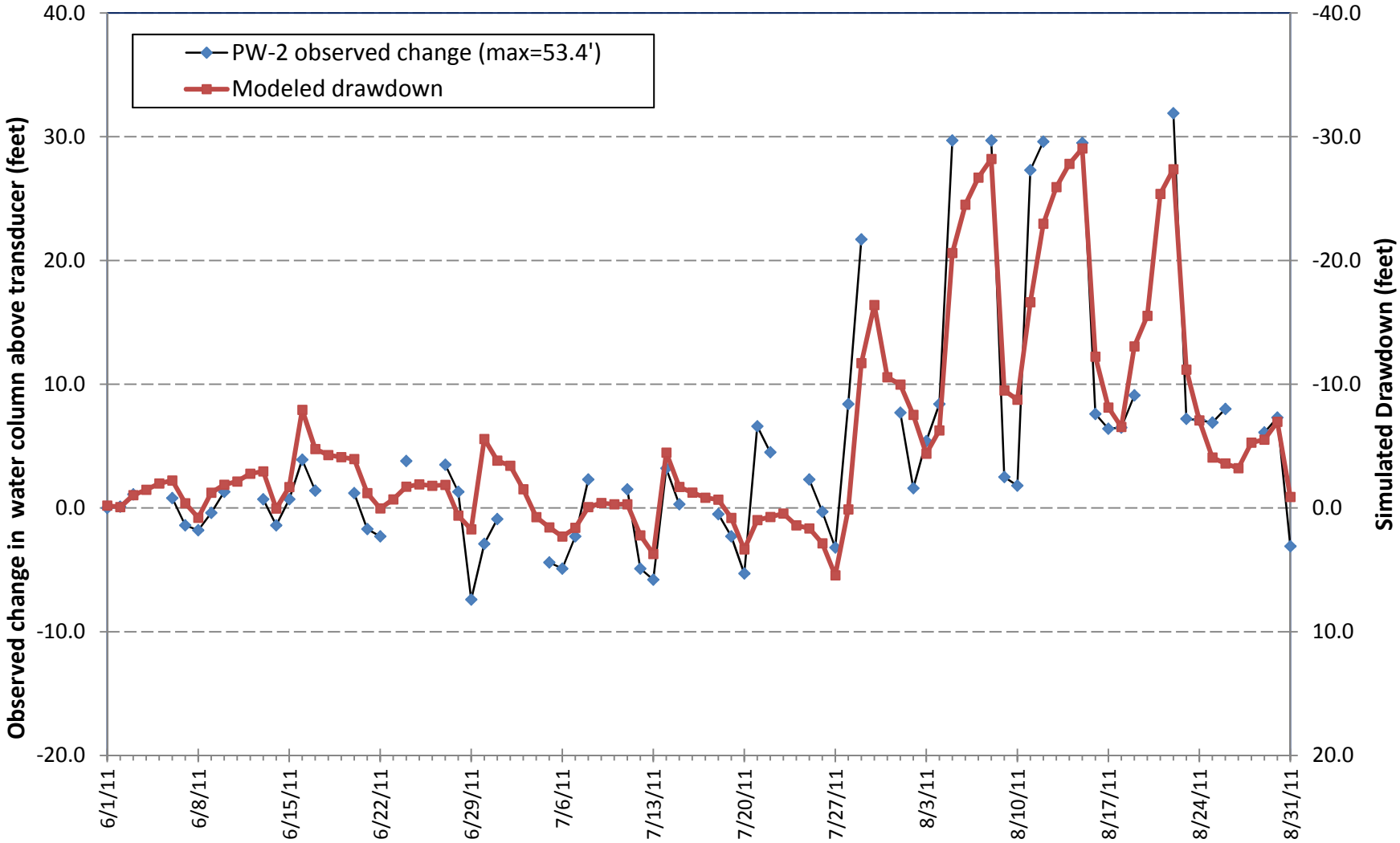
FIG. 32



City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

Summer 2011 Calibration – Well PW-2

September 2013 21-1-12416

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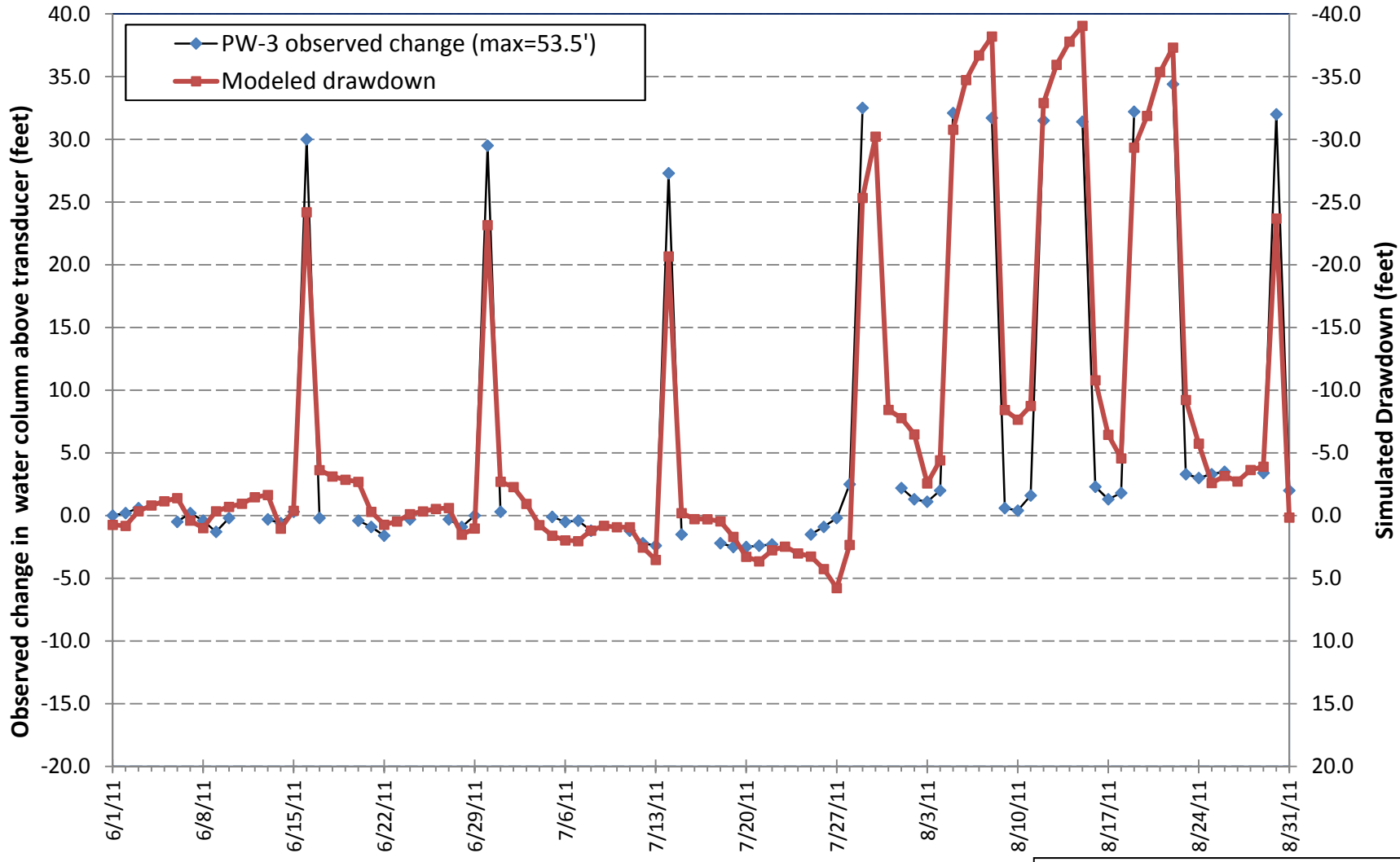
FIG. 33



City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

Summer 2011 Calibration – Well PW-3

September 2013 21-1-12416

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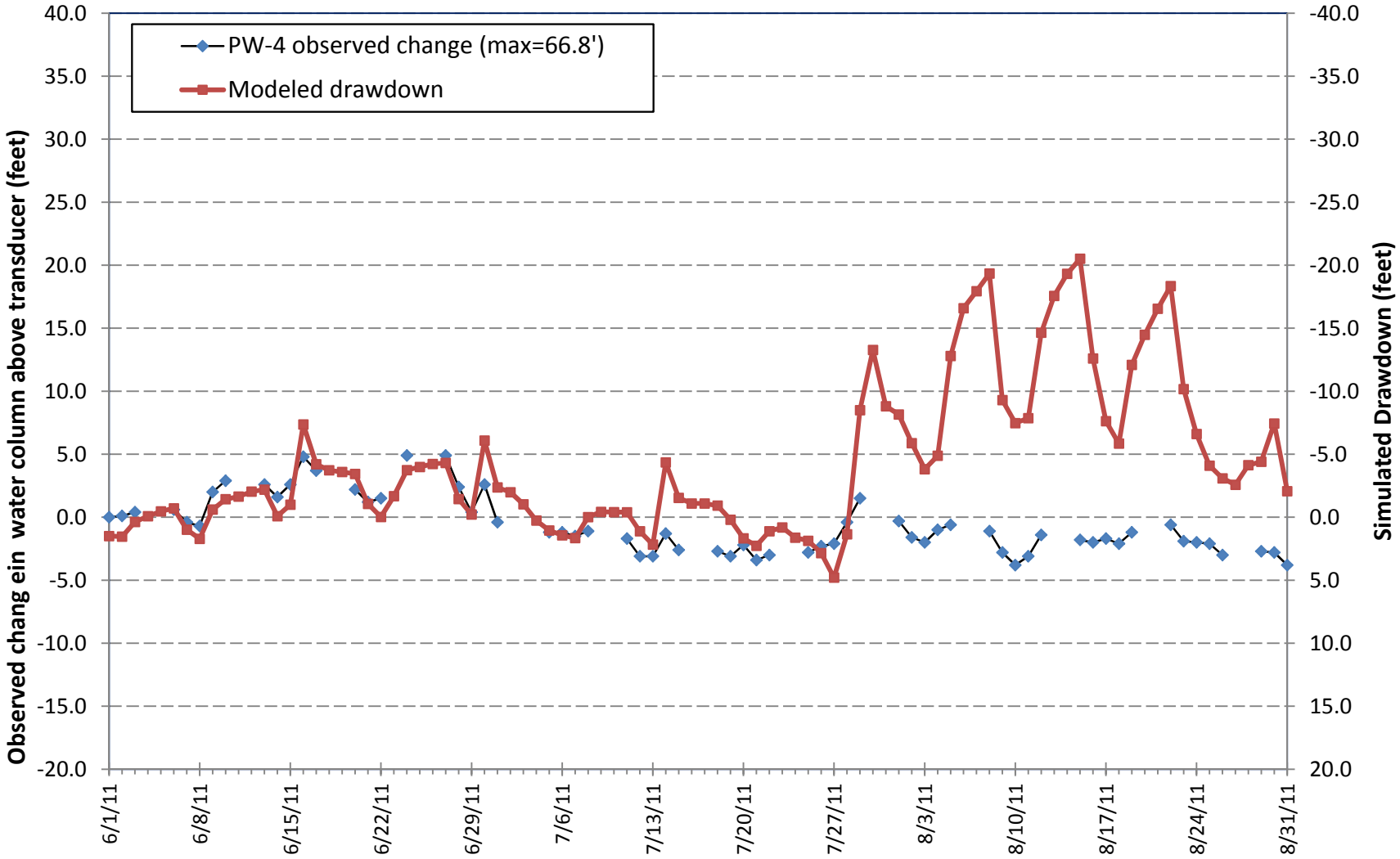
FIG. 34



City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

Summer 2011 Calibration – Well PW-4

September 2013 21-1-12416

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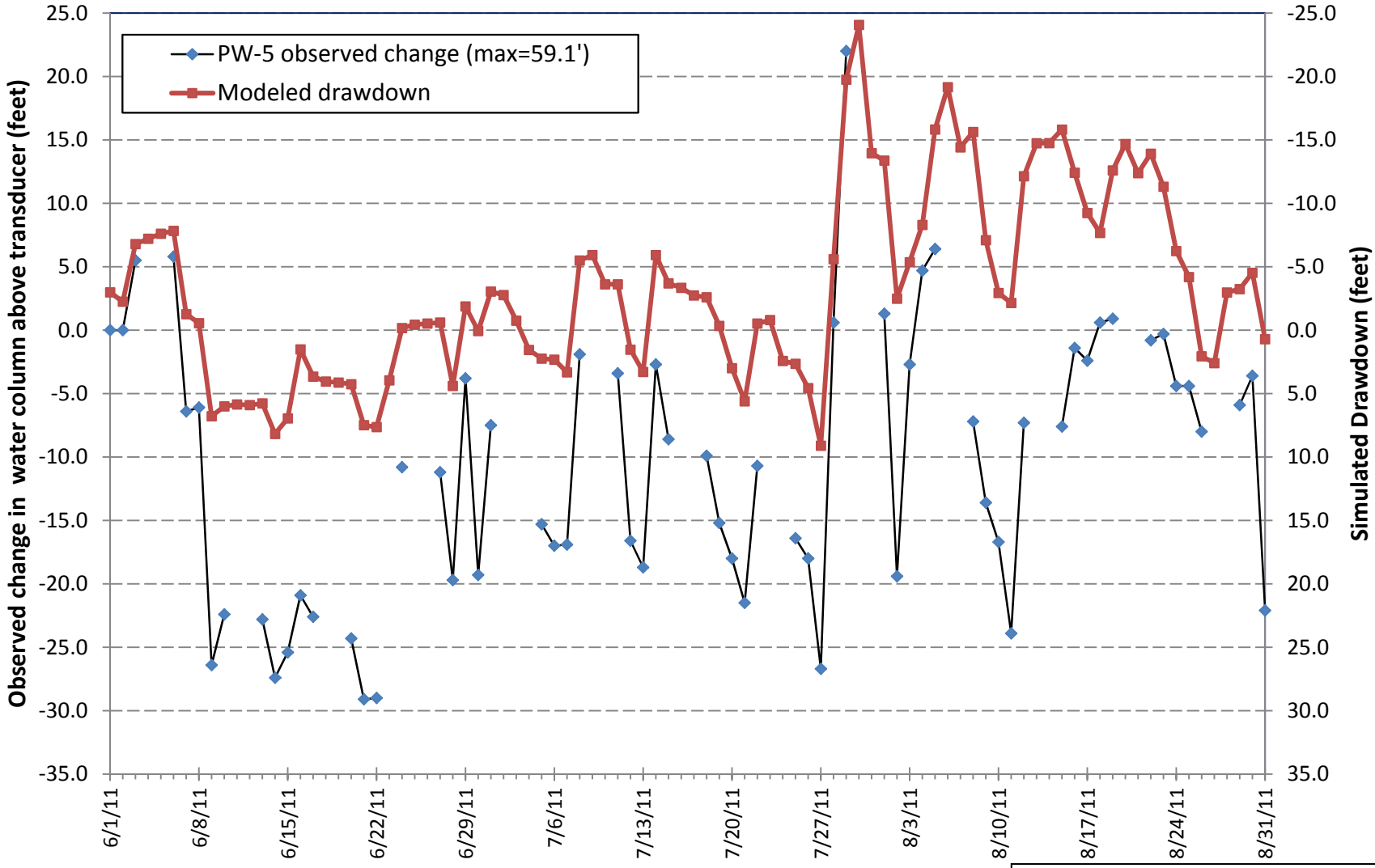
FIG. 35



City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

Summer 2011 Calibration – Well PW-5

September 2013 21-1-12416

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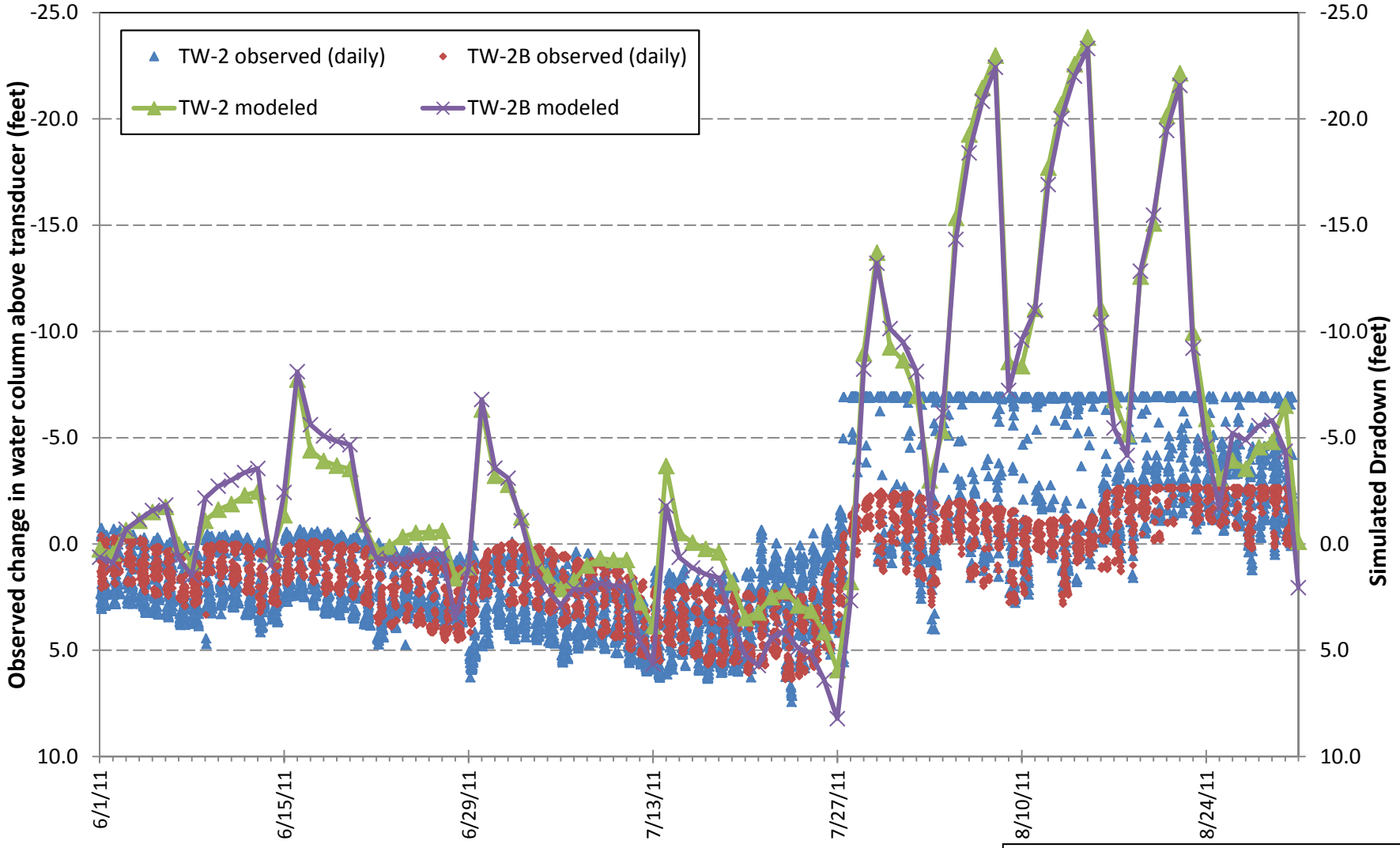
FIG. 36



City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

Summer 2011 Calibration – Observation Wells TW-2 & TW-2B

September 2013 21-1-12416

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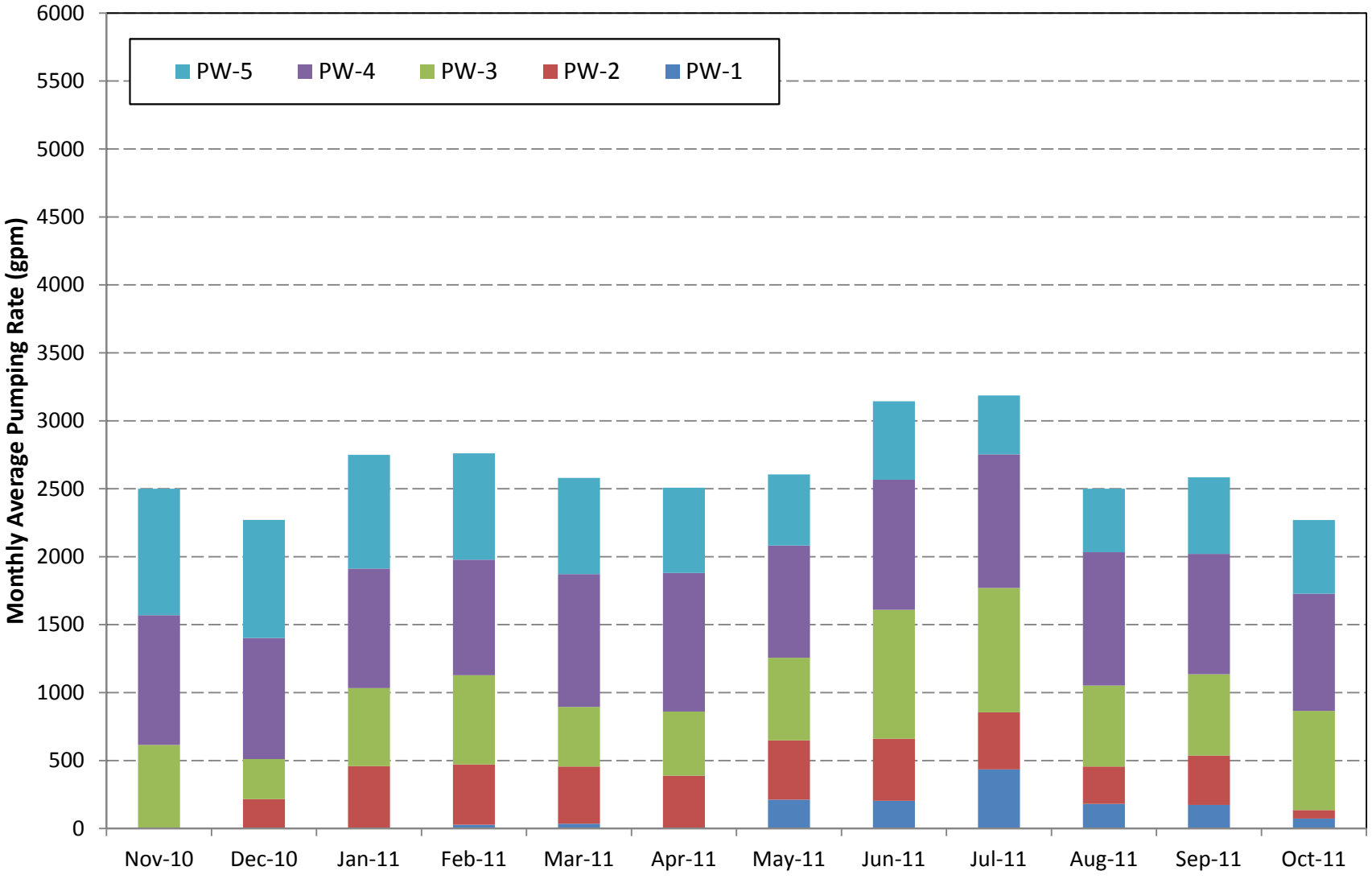
FIG. 37



Based on recorded daily rates for Nov-11 through Oct-12 (provided by CBJ)

City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

Simulated Monthly Pumping for Base Case

September 2013 21-1-12416

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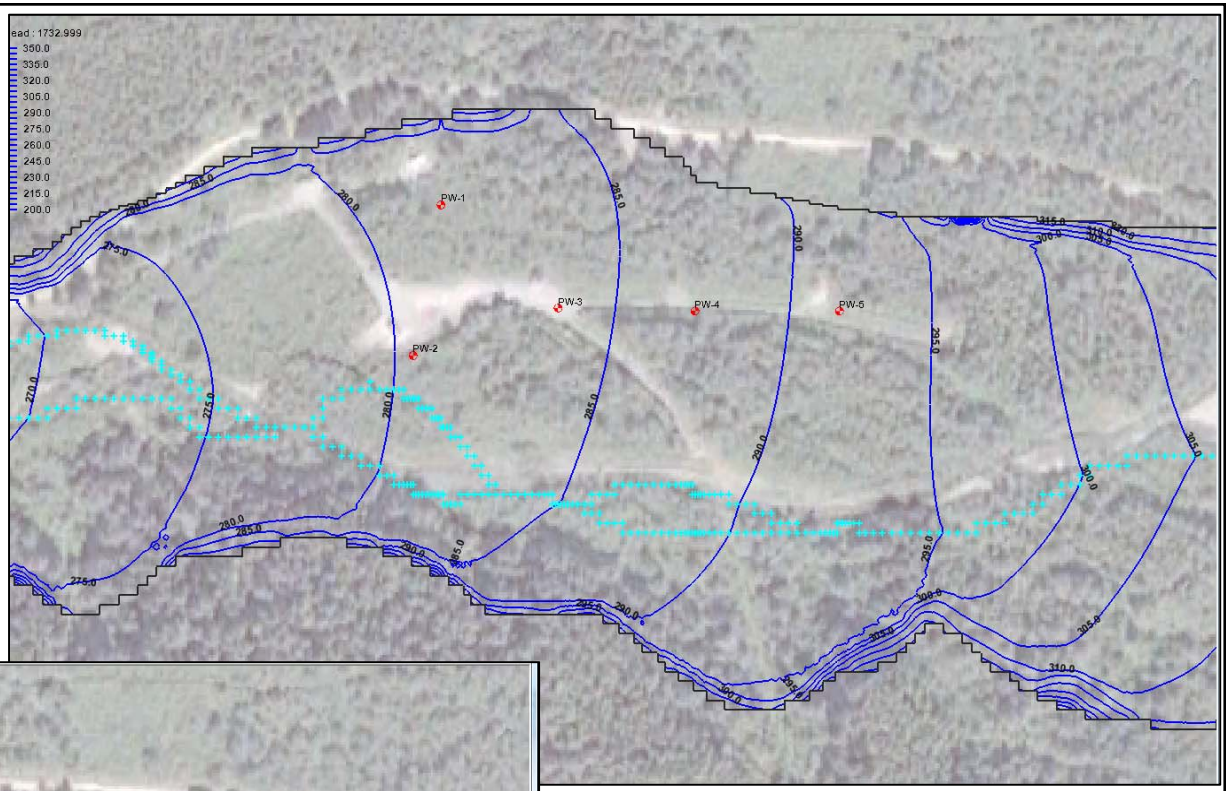
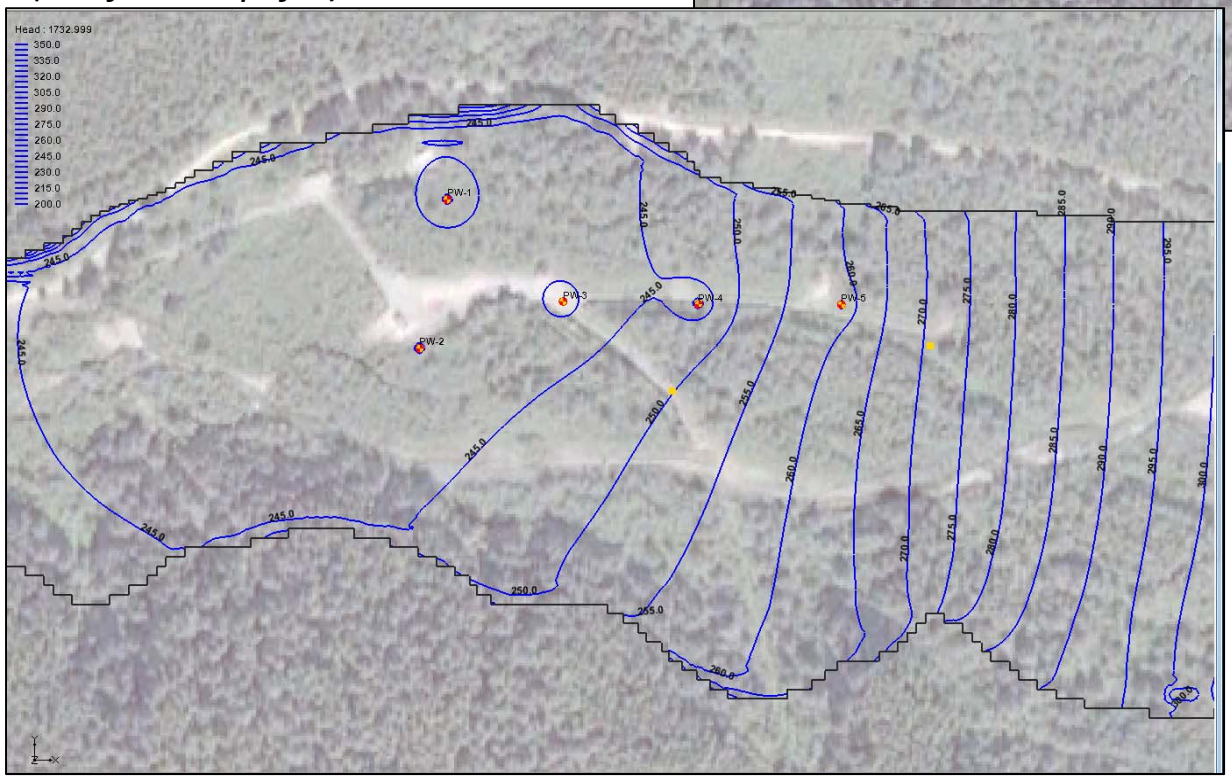
FIG.38

Model layer 1 (Unconfined aquifer)



Model layer 4 (Confined aquifer)



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City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

Baseline Case - Simulated Heads in July

September 2013 21-1-12416

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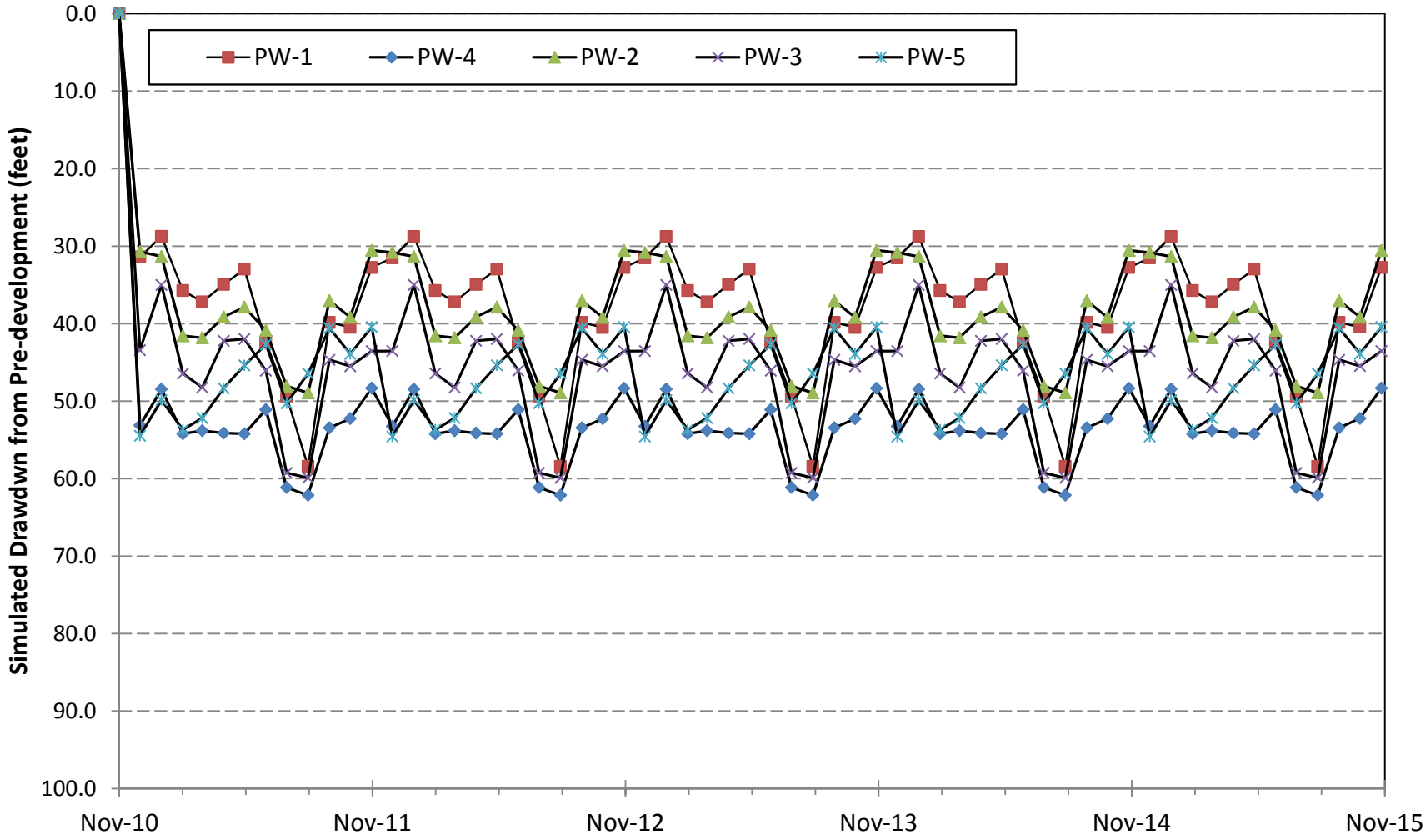
FIG. 39



City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

Baseline Case - Simulated Drawdown Hydrographs

September 2013 21-1-12416

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FIG. 40

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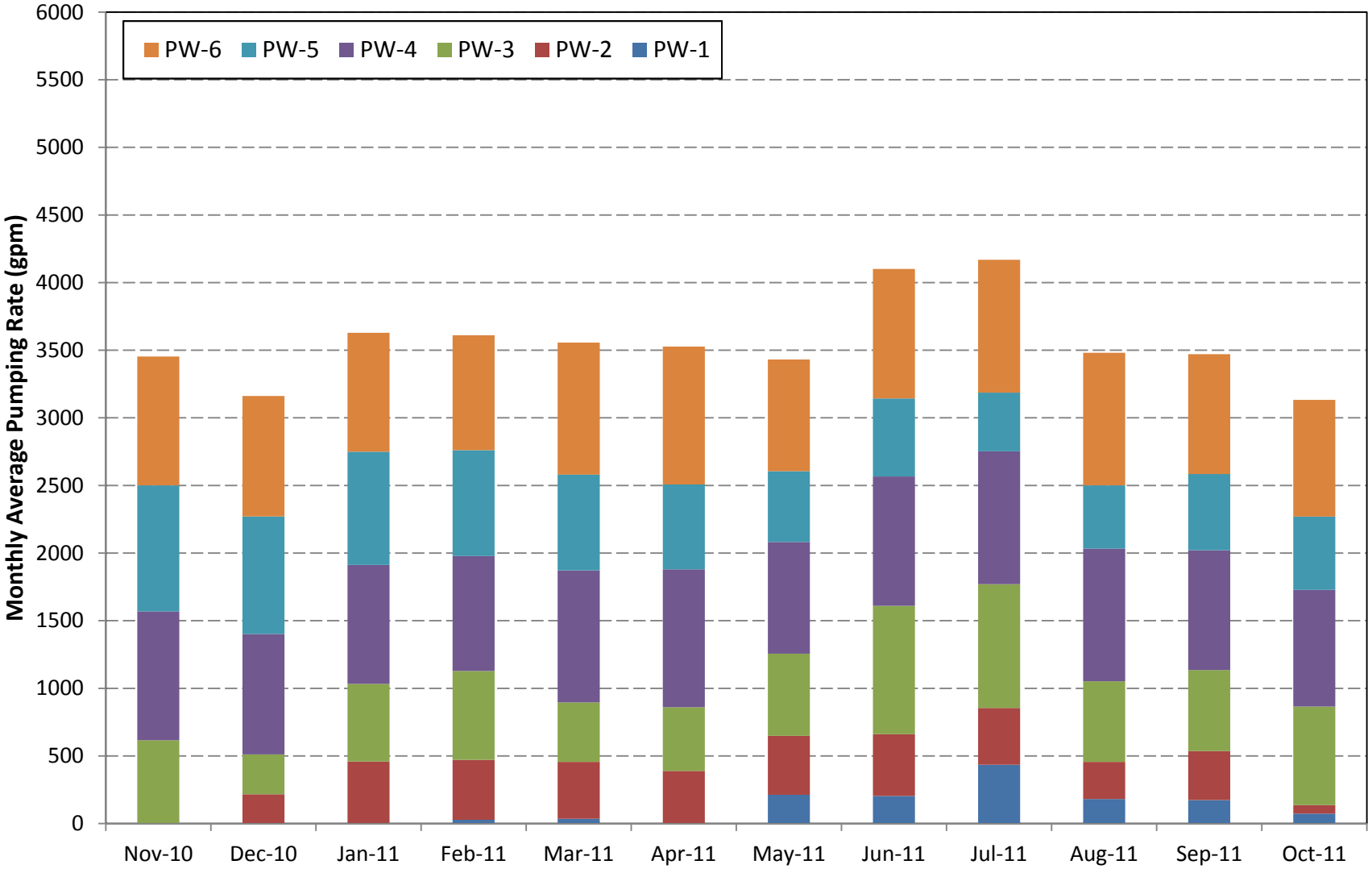

As Base Case, but add PW-6 (same rate at PW-4)

City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

Scenarios 1A & 1B - Simulated Monthly Pumping

September 2013 21-1-12416

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FIG. 41

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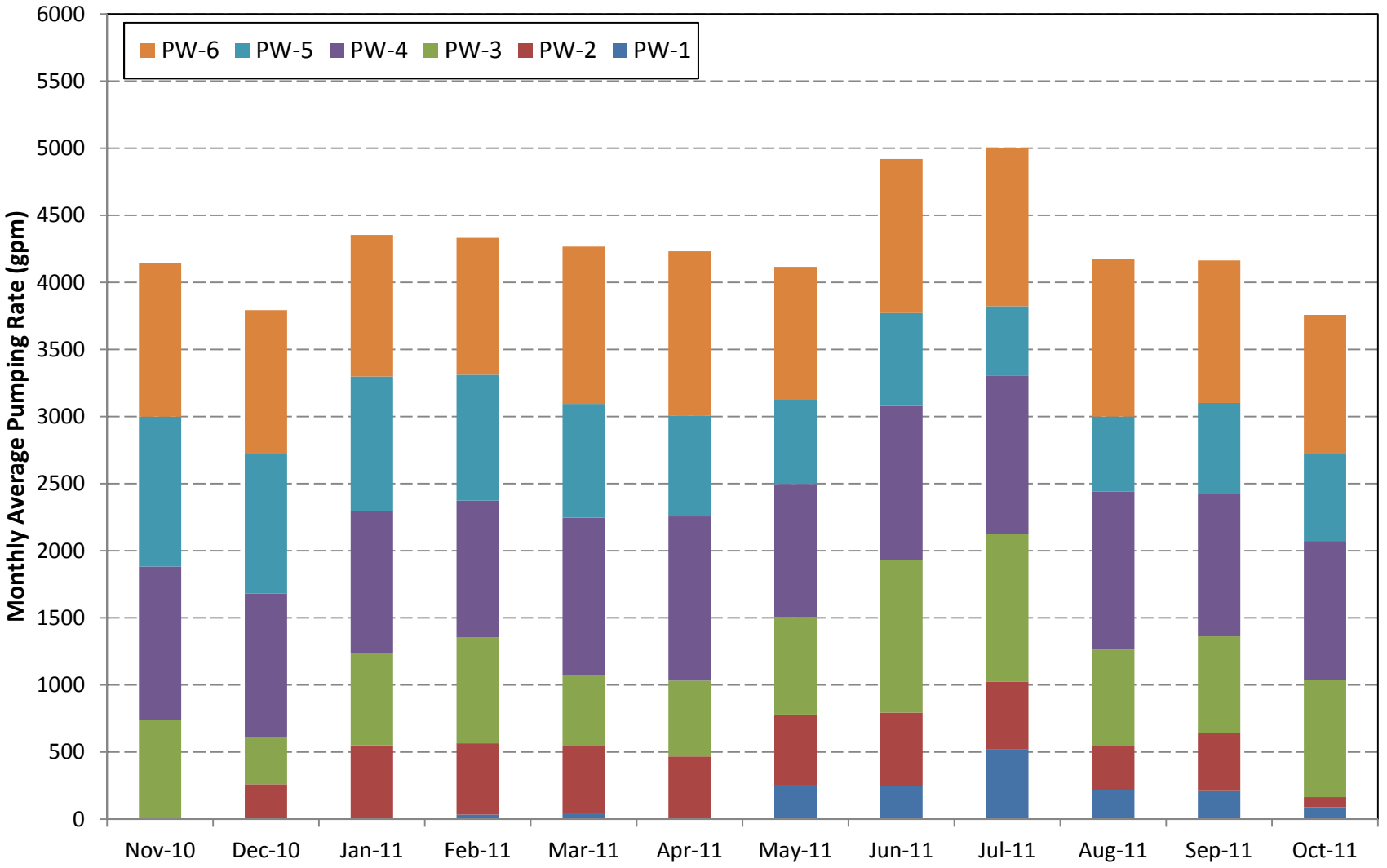

As Cases 1A and 1B, but x1.2 pumping all wells (peak =- 5,000 gpm)

City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

Scenarios 2A & 2B - Simulated Monthly Pumping

September 2013 21-1-12416

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FIG. 42

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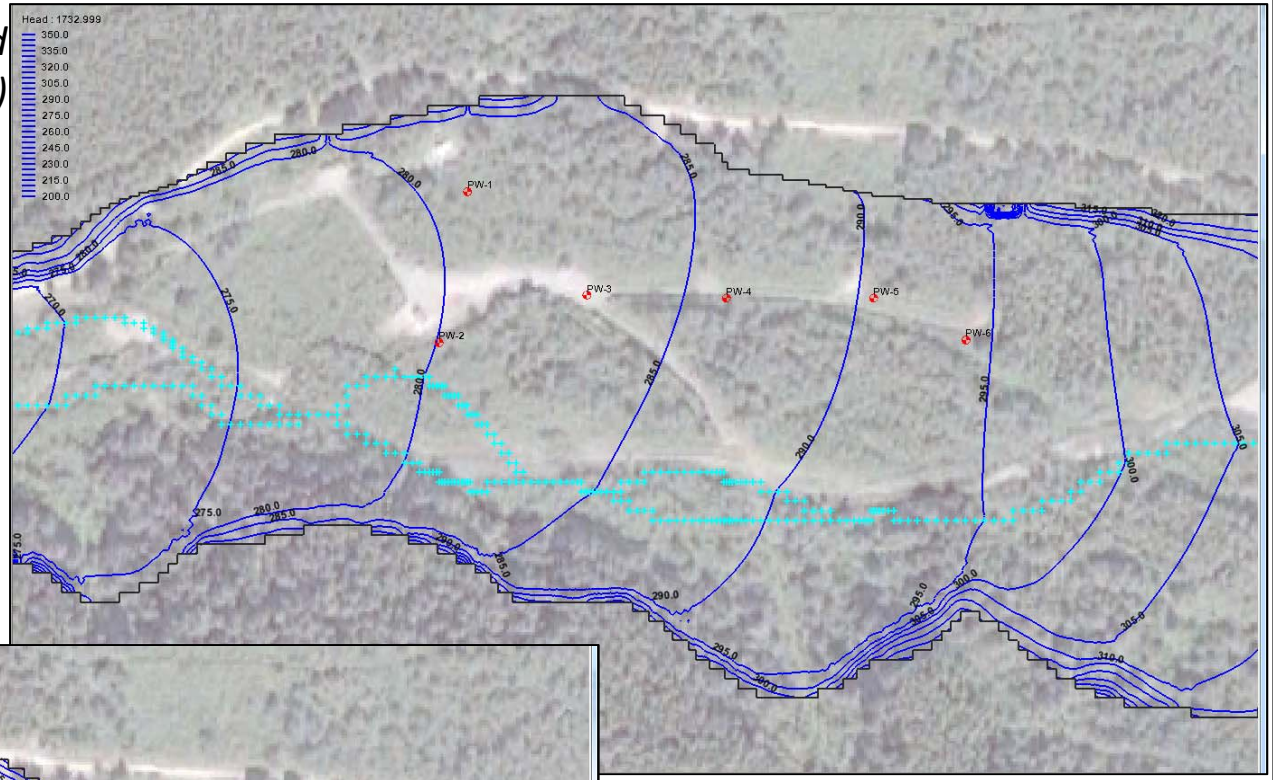
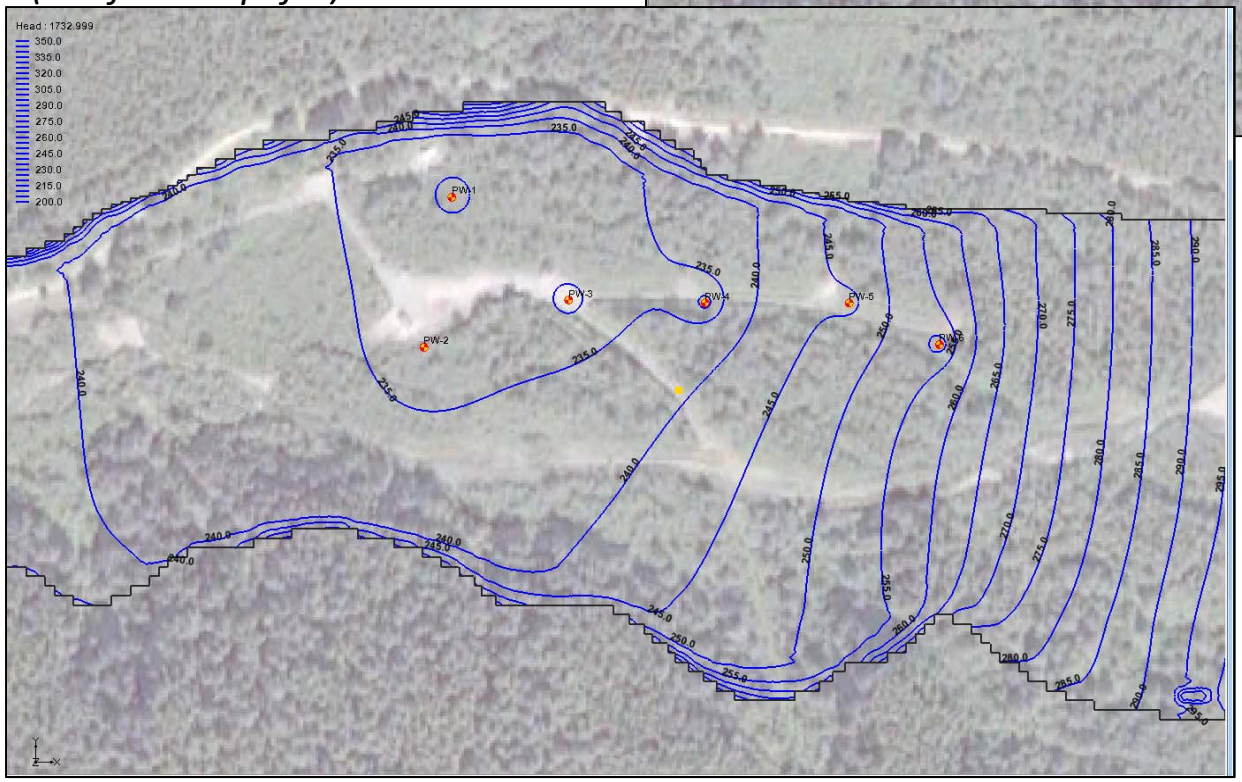
Model layer 1 (Unconfined aquifer)



Model layer 4 (Confined aquifer)



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City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

Scenario 1A - Simulated Heads in July

September 2013 21-1-12416

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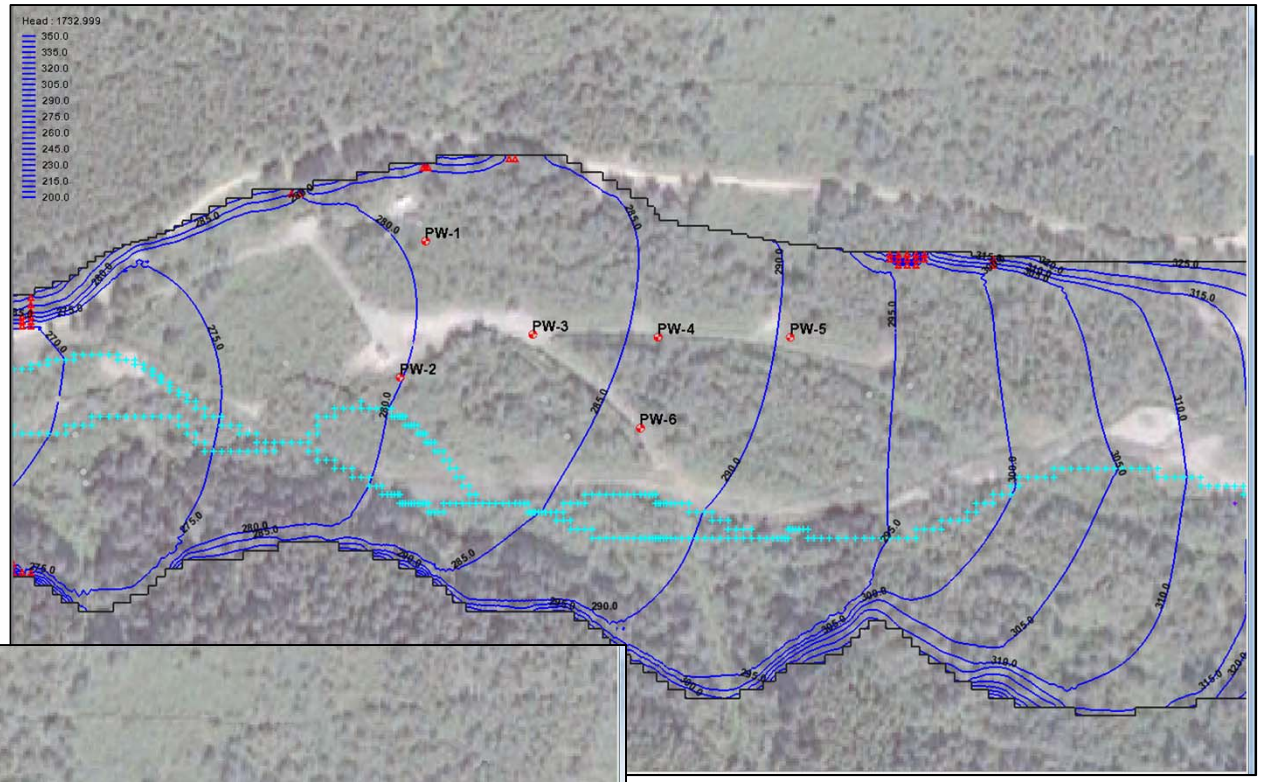
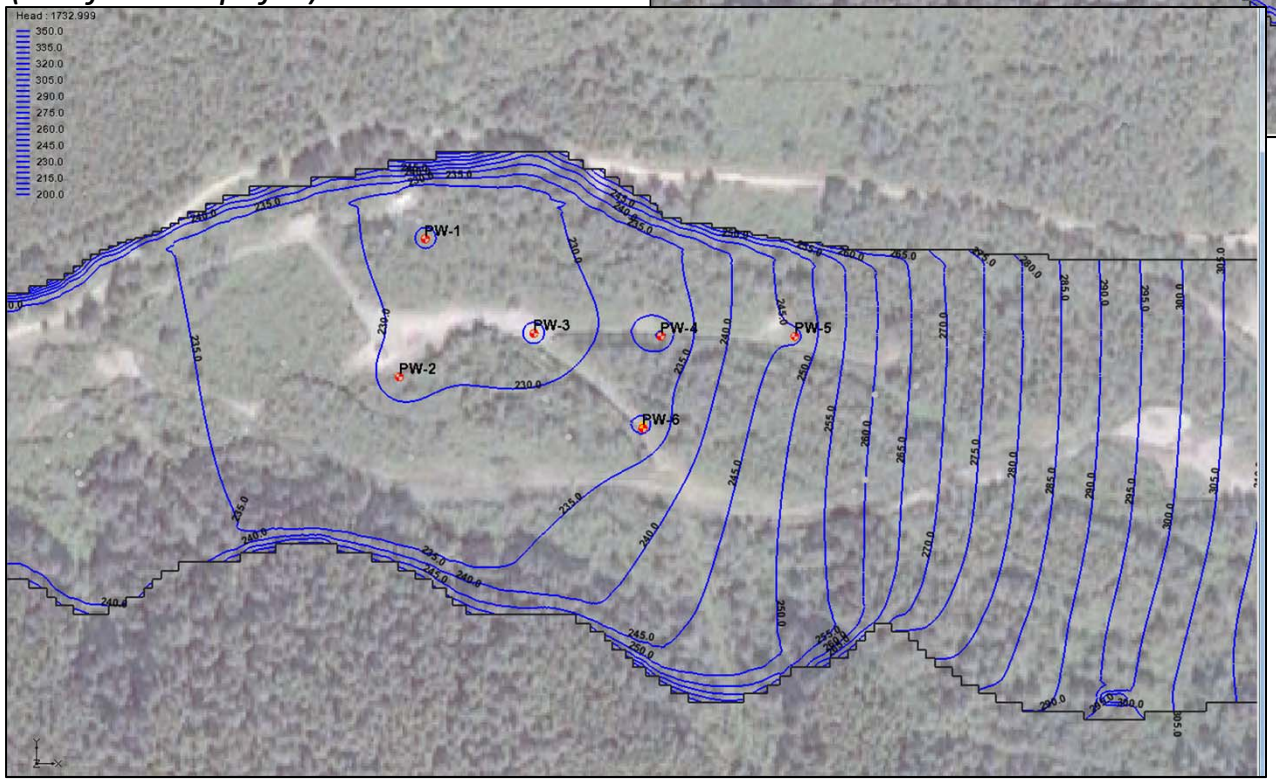
FIG. 43

Model layer 1 (Unconfined aquifer)



Model layer 4 (Confined aquifer)



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City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

Scenario 1B - Simulated Heads in July

September 2013 21-1-12416

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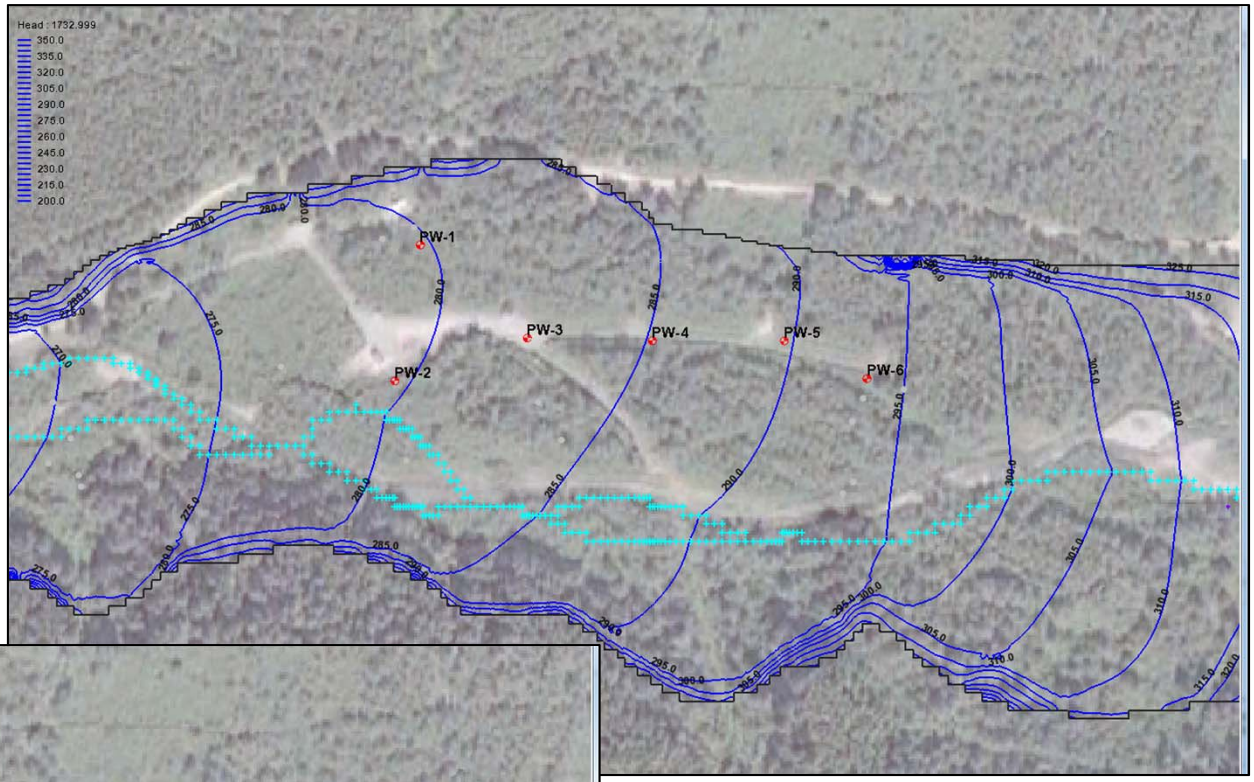
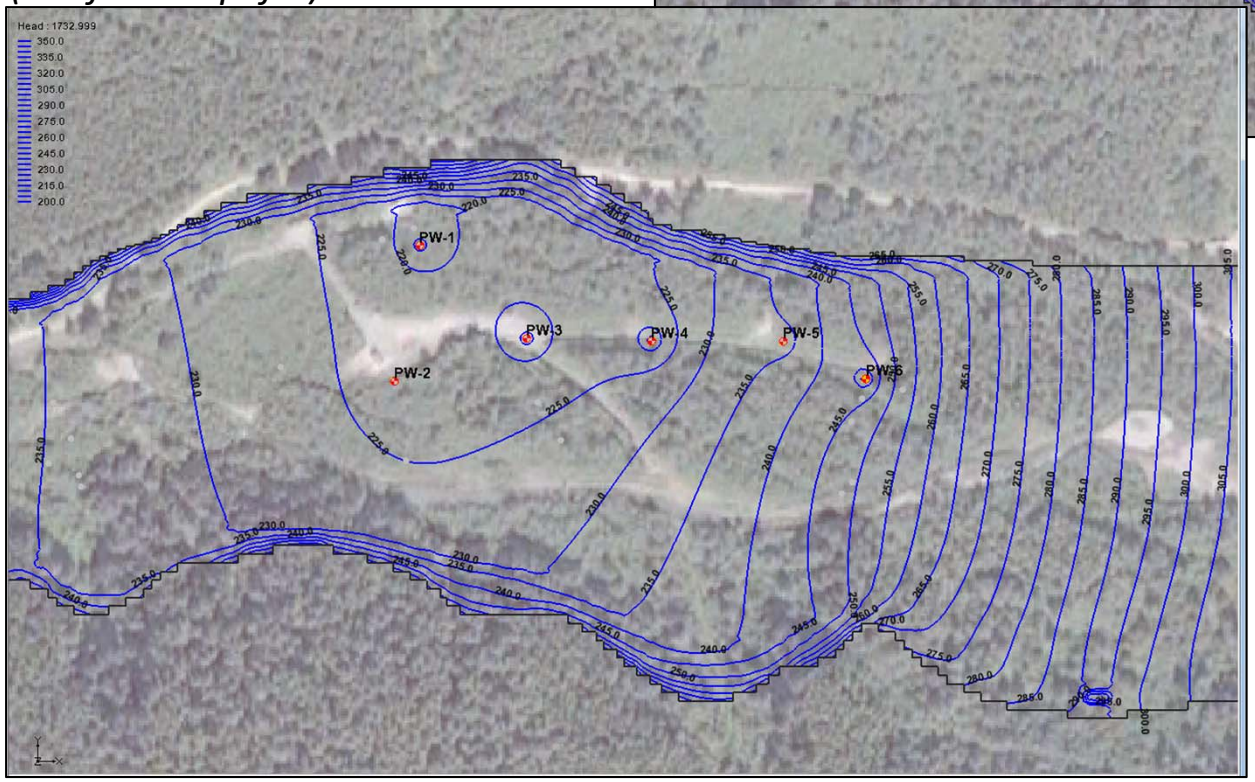
FIG. 44

Model layer 1 (Unconfined aquifer)



Model layer 4 (Confined aquifer)



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City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

Scenario 2A - Simulated Heads in July

September 2013 21-1-12416

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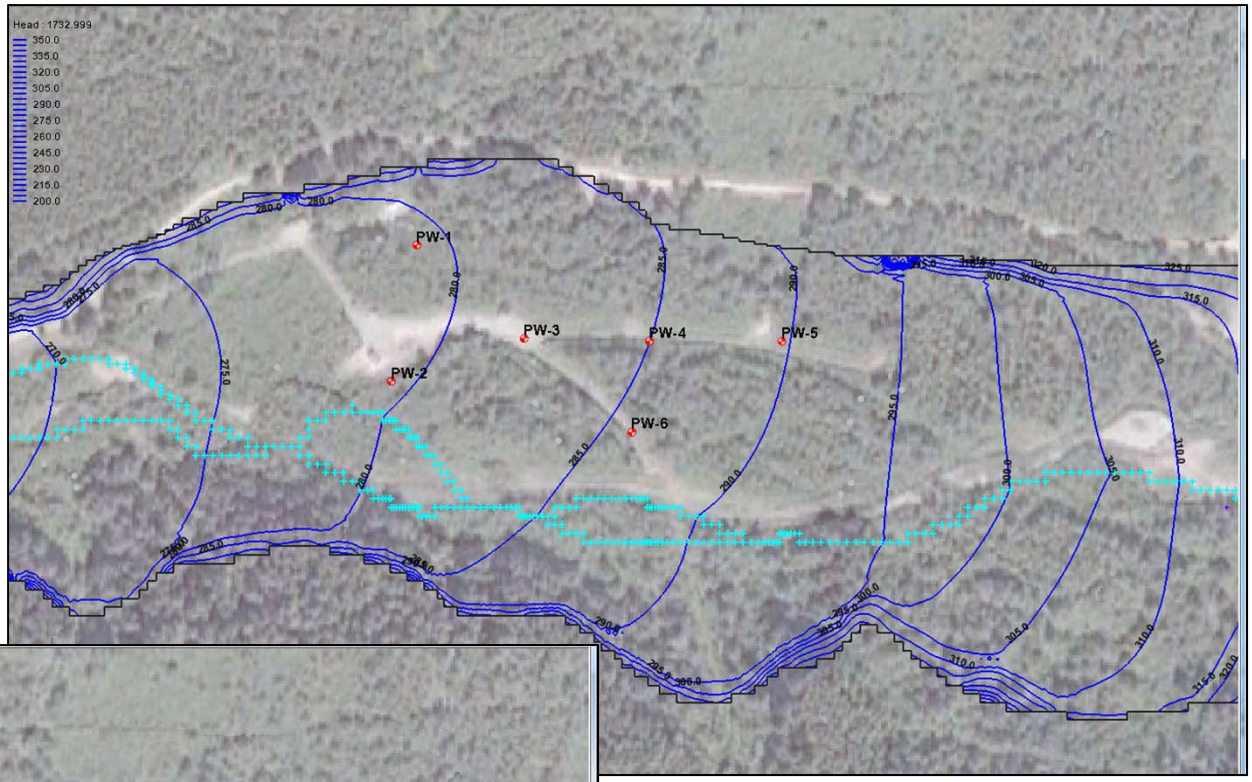
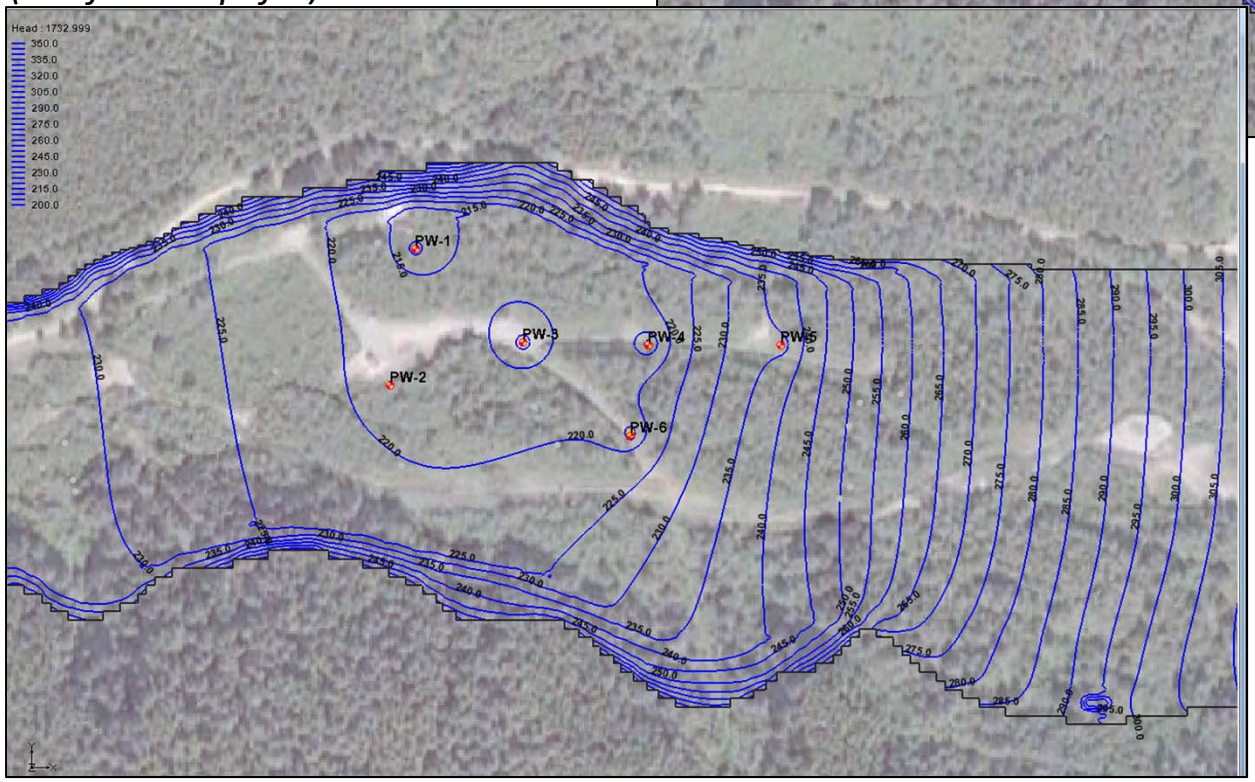
FIG. 45

Model layer 1 (Unconfined aquifer)



Model layer 4 (Confined aquifer)



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City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

Scenario 2B - Simulated Heads in July

September 2013 21-1-12416

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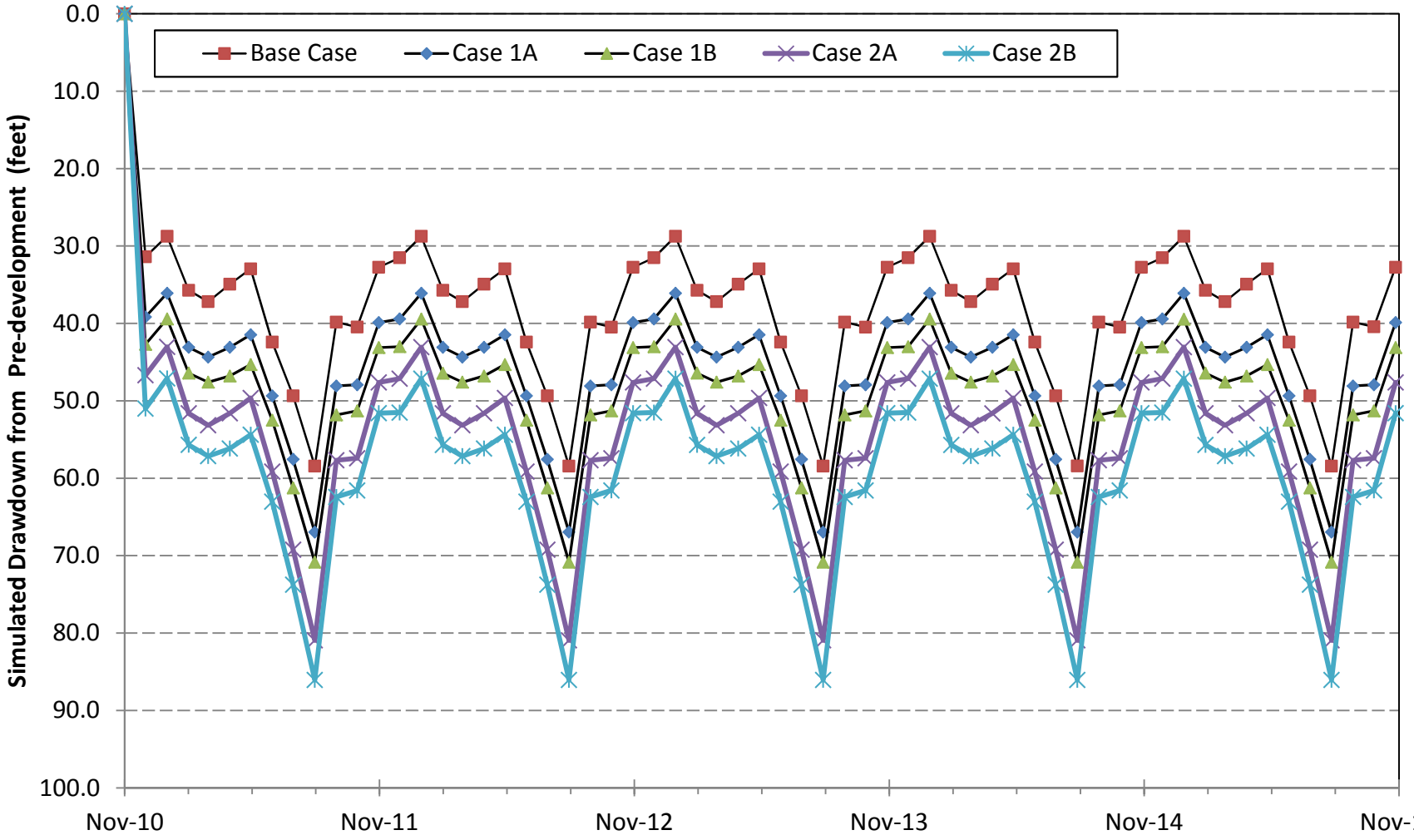
FIG. 46



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City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

Simulated Drawdown Hydrographs – Well PW-1

September 2013 21-1-12416

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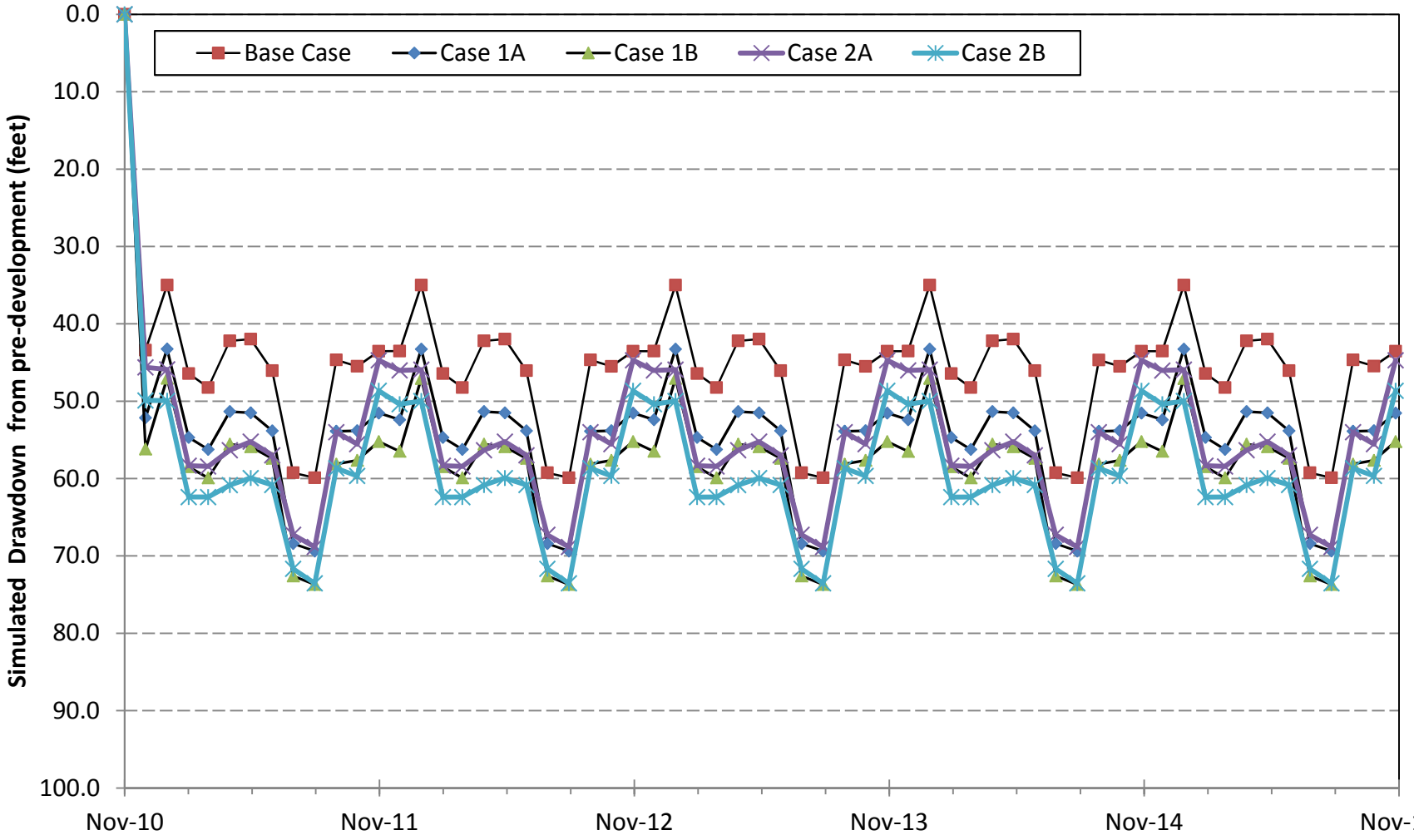
FIG. 47



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City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

Simulated Drawdown Hydrographs – Well PW-2

September 2013 21-1-12416

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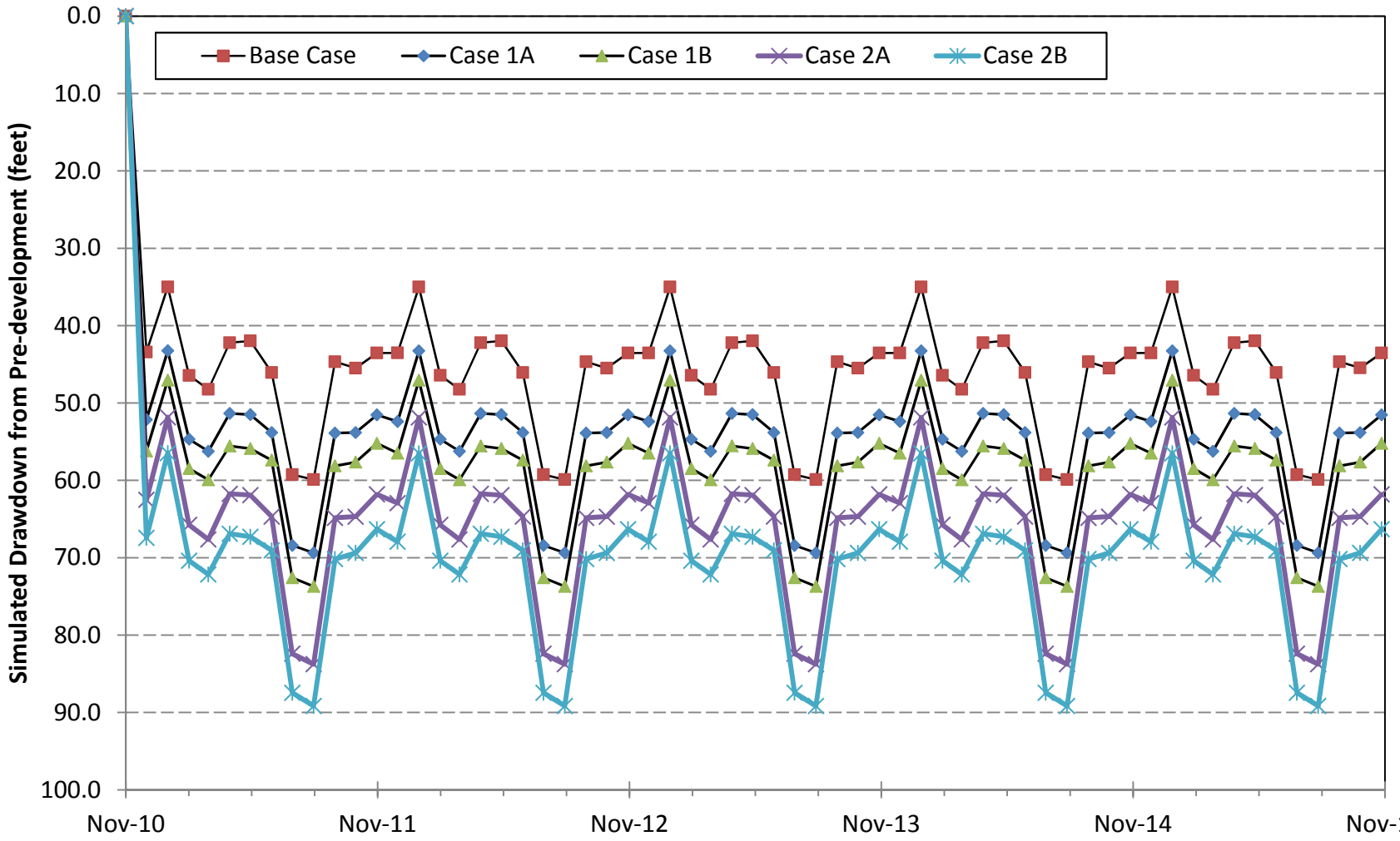
FIG. 48



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City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

Simulated Drawdown Hydrographs – Well PW-3

September 2013 21-1-12416

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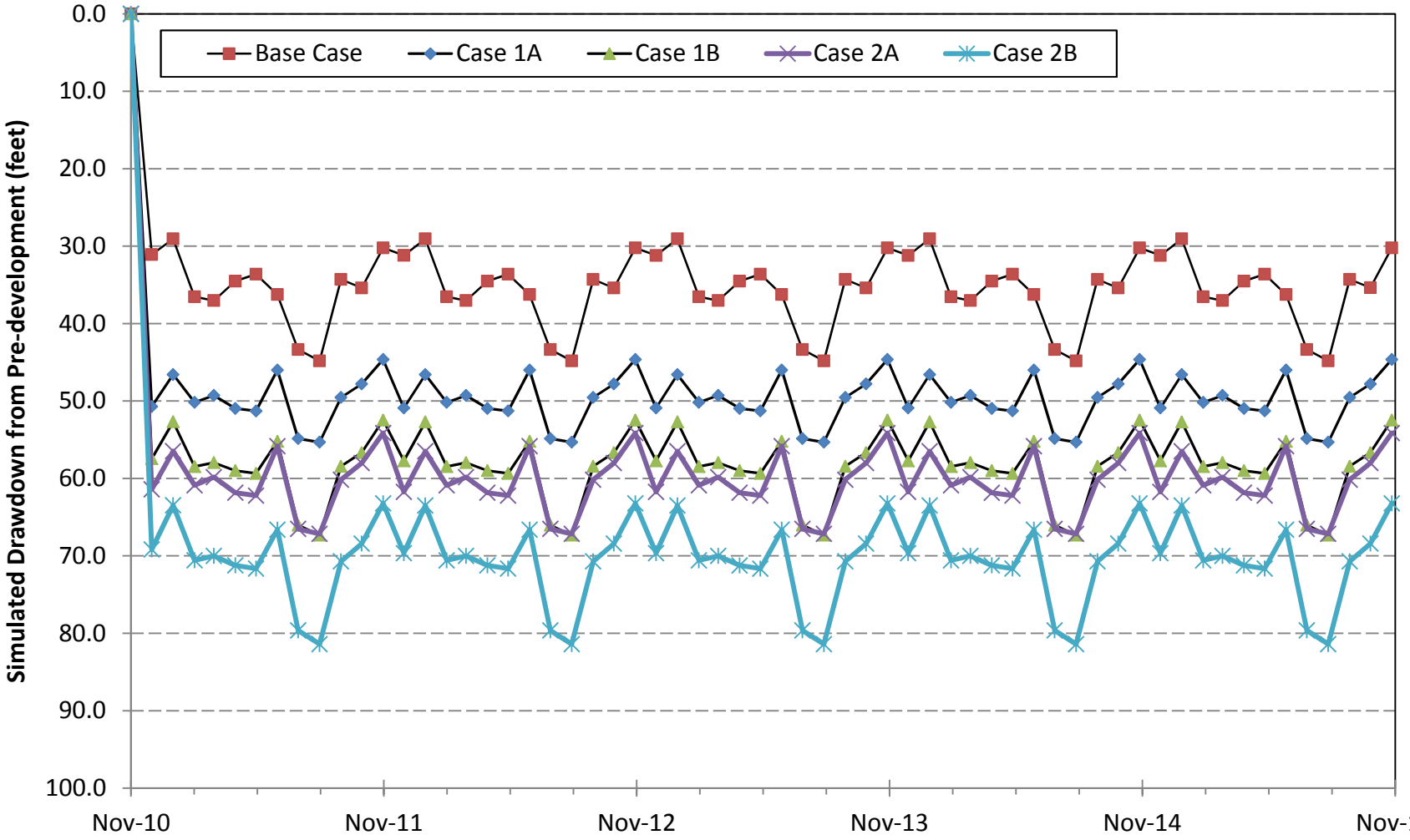
Geotechnical and Environmental Consultants

FIG. 49



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City & Borough of Juneau, Alaska

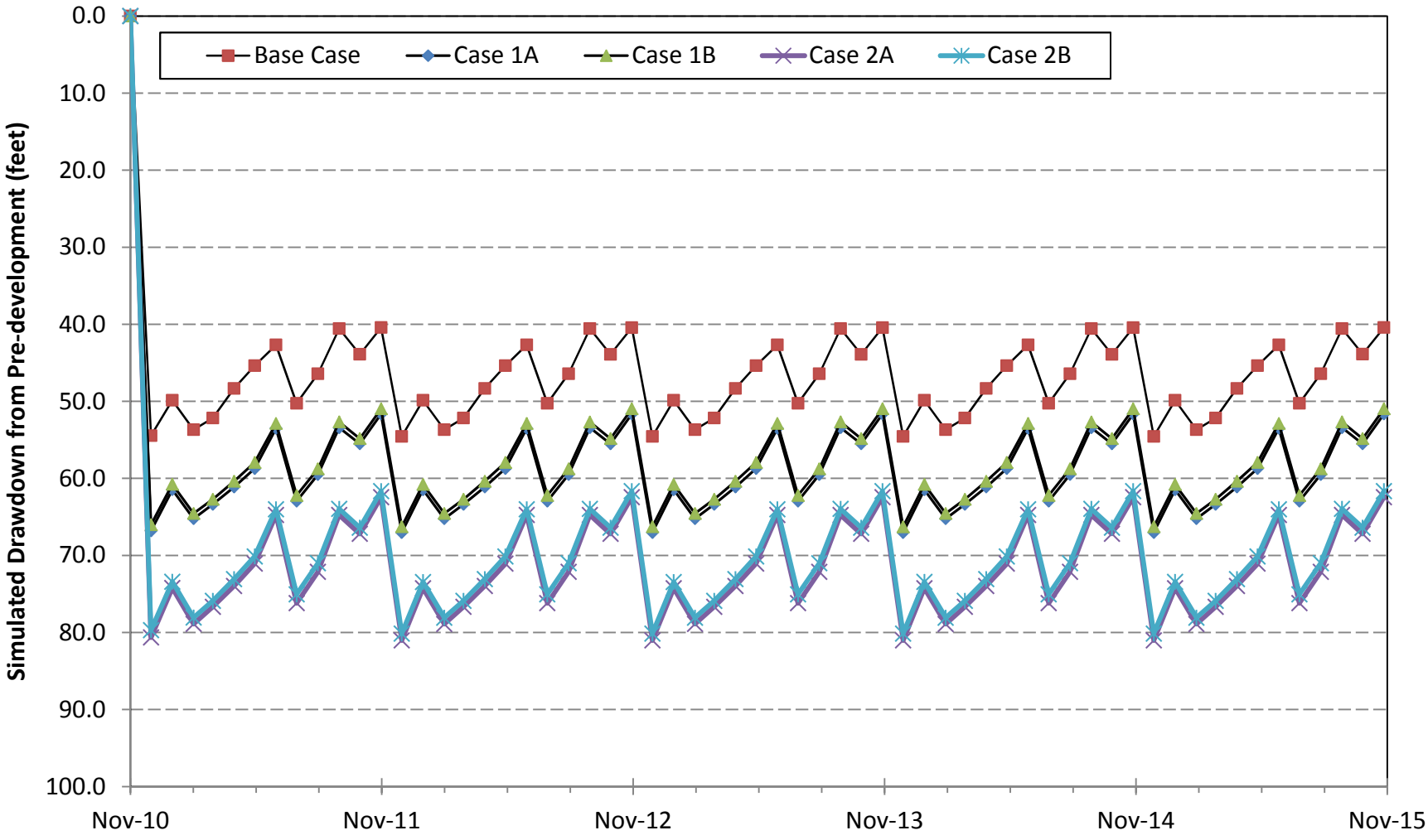
Last Chance Basin Wellfield Assessment

Simulated Drawdown Hydrographs – Well PW-4

September 2013 21-1-12416

SHANNON & WILSON, INC
Geotechnical and Environmental Consultants

FIG. 50



DRAFT

City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

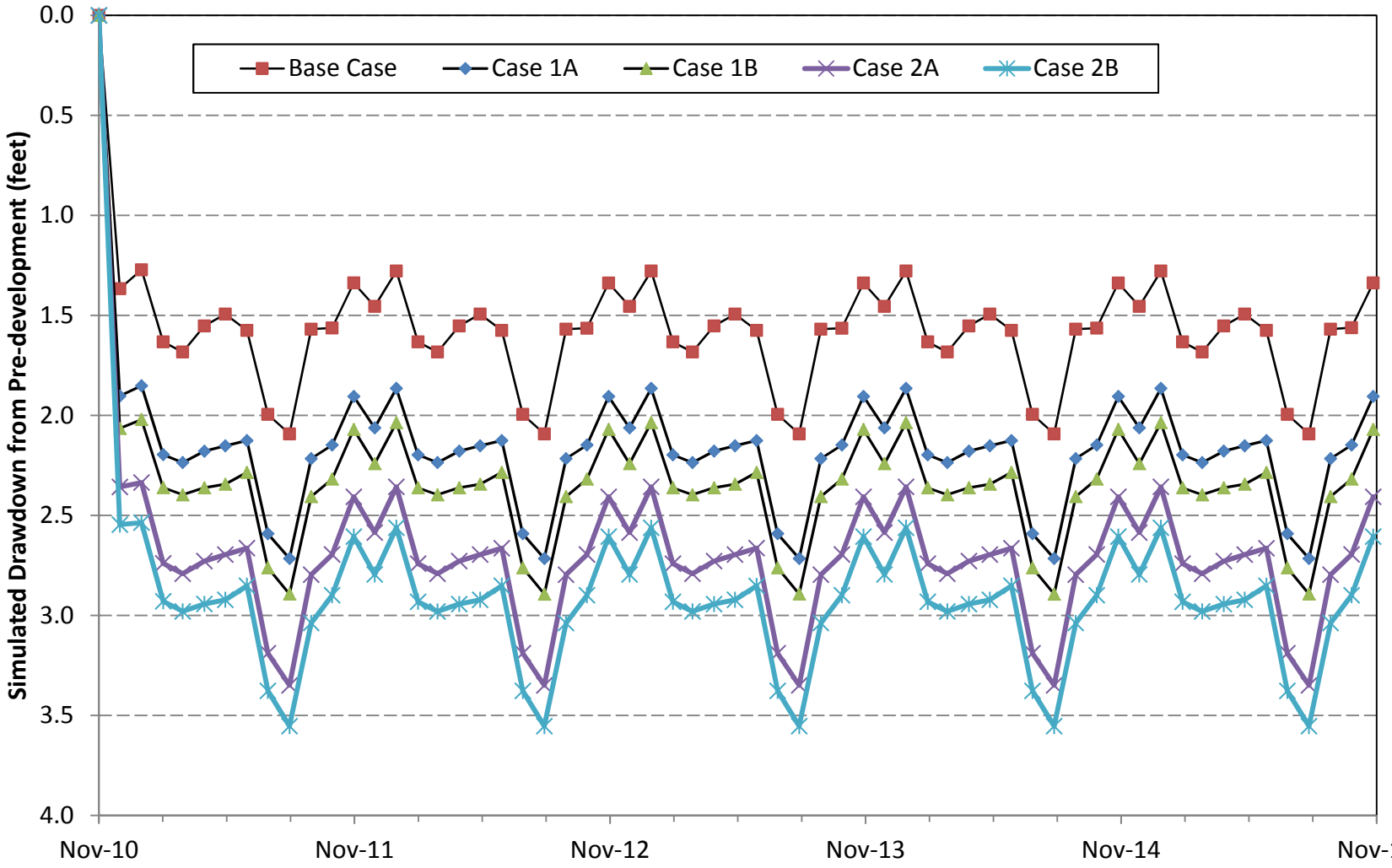
Simulated Drawdown Hydrographs – Well PW-5

September 2013 21-1-12416

SHANNON & WILSON, INC

Geotechnical and Environmental Consultants

FIG. 51



DRAFT

City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

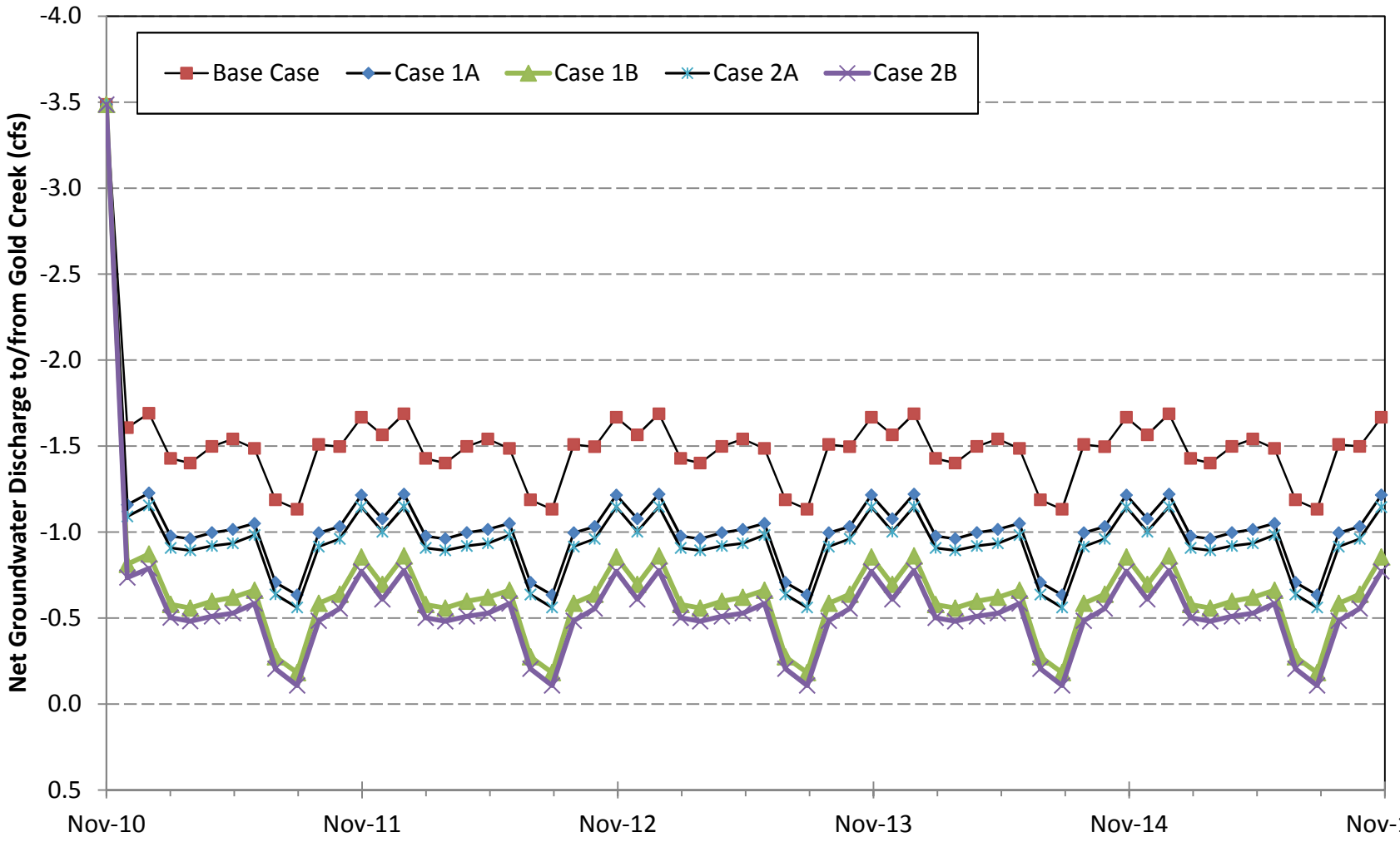
Simulated Drawdown Hydrographs – Well TW-T

September 2013 21-1-12416

SHANNON & WILSON, INC

Geotechnical and Environmental Consultants

FIG. 52



DRAFT

City & Borough of Juneau, Alaska

Last Chance Basin Wellfield Assessment

Simulated Change in Discharge to/from Gold Creek

September 2013 21-1-12416

SHANNON & WILSON, INC

Geotechnical and Environmental Consultants

FIG. 53

Draft

APPENDIX

IMPORTANT INFORMATION ABOUT YOUR GEOTECHNICAL/ENVIRONMENTAL REPORT

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

Attachment to and part of Report 21-1-12416-003

Date: September 5, 2013
To: Mr. Ken Huddlestun
City and Borough of Juneau

IMPORTANT INFORMATION ABOUT YOUR GEOTECHNICAL/ENVIRONMENTAL REPORT

CONSULTING SERVICES ARE PERFORMED FOR SPECIFIC PURPOSES AND FOR SPECIFIC CLIENTS.

Consultants prepare reports to meet the specific needs of specific individuals. A report prepared for a civil engineer may not be adequate for a construction contractor or even another civil engineer. Unless indicated otherwise, your consultant prepared your report expressly for you and expressly for the purposes you indicated. No one other than you should apply this report for its intended purpose without first conferring with the consultant. No party should apply this report for any purpose other than that originally contemplated without first conferring with the consultant.

THE CONSULTANT'S REPORT IS BASED ON PROJECT-SPECIFIC FACTORS.

A geotechnical/environmental report is based on a subsurface exploration plan designed to consider a unique set of project-specific factors. Depending on the project, these may include: the general nature of the structure and property involved; its size and configuration; its historical use and practice; the location of the structure on the site and its orientation; other improvements such as access roads, parking lots, and underground utilities; and the additional risk created by scope-of-service limitations imposed by the client. To help avoid costly problems, ask the consultant to evaluate how any factors that change subsequent to the date of the report may affect the recommendations. Unless your consultant indicates otherwise, your report should not be used: (1) when the nature of the proposed project is changed (for example, if an office building will be erected instead of a parking garage, or if a refrigerated warehouse will be built instead of an unrefrigerated one, or chemicals are discovered on or near the site); (2) when the size, elevation, or configuration of the proposed project is altered; (3) when the location or orientation of the proposed project is modified; (4) when there is a change of ownership; or (5) for application to an adjacent site. Consultants cannot accept responsibility for problems that may occur if they are not consulted after factors which were considered in the development of the report have changed.

SUBSURFACE CONDITIONS CAN CHANGE.

Subsurface conditions may be affected as a result of natural processes or human activity. Because a geotechnical/environmental report is based on conditions that existed at the time of subsurface exploration, construction decisions should not be based on a report whose adequacy may have been affected by time. Ask the consultant to advise if additional tests are desirable before construction starts; for example, groundwater conditions commonly vary seasonally.

Construction operations at or adjacent to the site and natural events such as floods, earthquakes, or groundwater fluctuations may also affect subsurface conditions and, thus, the continuing adequacy of a geotechnical/environmental report. The consultant should be kept apprised of any such events, and should be consulted to determine if additional tests are necessary.

MOST RECOMMENDATIONS ARE PROFESSIONAL JUDGMENTS.

Site exploration and testing identifies actual surface and subsurface conditions only at those points where samples are taken. The data were extrapolated by your consultant, who then applied judgment to render an opinion about overall subsurface conditions. The actual interface between materials may be far more gradual or abrupt than your report indicates. Actual conditions in areas not sampled may differ from those predicted in your report. While nothing can be done to prevent such situations, you and your consultant can work together to help reduce their impacts. Retaining your consultant to observe subsurface construction operations can be particularly beneficial in this respect.

A REPORT'S CONCLUSIONS ARE PRELIMINARY.

The conclusions contained in your consultant's report are preliminary because they must be based on the assumption that conditions revealed through selective exploratory sampling are indicative of actual conditions throughout a site. Actual subsurface conditions can be discerned only during earthwork; therefore, you should retain your consultant to observe actual conditions and to provide conclusions. Only the consultant who prepared the report is fully familiar with the background information needed to determine whether or not the report's recommendations based on those conclusions are valid and whether or not the contractor is abiding by applicable recommendations. The consultant who developed your report cannot assume responsibility or liability for the adequacy of the report's recommendations if another party is retained to observe construction.

THE CONSULTANT'S REPORT IS SUBJECT TO MISINTERPRETATION.

Costly problems can occur when other design professionals develop their plans based on misinterpretation of a geotechnical/environmental report. To help avoid these problems, the consultant should be retained to work with other project design professionals to explain relevant geotechnical, geological, hydrogeological, and environmental findings, and to review the adequacy of their plans and specifications relative to these issues.

BORING LOGS AND/OR MONITORING WELL DATA SHOULD NOT BE SEPARATED FROM THE REPORT.

Final boring logs developed by the consultant are based upon interpretation of field logs (assembled by site personnel), field test results, and laboratory and/or office evaluation of field samples and data. Only final boring logs and data are customarily included in geotechnical/environmental reports. These final logs should not, under any circumstances, be redrawn for inclusion in architectural or other design drawings, because drafters may commit errors or omissions in the transfer process.

To reduce the likelihood of boring log or monitoring well misinterpretation, contractors should be given ready access to the complete geotechnical engineering/environmental report prepared or authorized for their use. If access is provided only to the report prepared for you, you should advise contractors of the report's limitations, assuming that a contractor was not one of the specific persons for whom the report was prepared, and that developing construction cost estimates was not one of the specific purposes for which it was prepared. While a contractor may gain important knowledge from a report prepared for another party, the contractor should discuss the report with your consultant and perform the additional or alternative work believed necessary to obtain the data specifically appropriate for construction cost estimating purposes. Some clients hold the mistaken impression that simply disclaiming responsibility for the accuracy of subsurface information always insulates them from attendant liability. Providing the best available information to contractors helps prevent costly construction problems and the adversarial attitudes that aggravate them to a disproportionate scale.

READ RESPONSIBILITY CLAUSES CLOSELY.

Because geotechnical/environmental engineering is based extensively on judgment and opinion, it is far less exact than other design disciplines. This situation has resulted in wholly unwarranted claims being lodged against consultants. To help prevent this problem, consultants have developed a number of clauses for use in their contracts, reports and other documents. These responsibility clauses are not exculpatory clauses designed to transfer the consultant's liabilities to other parties; rather, they are definitive clauses that identify where the consultant's responsibilities begin and end. Their use helps all parties involved recognize their individual responsibilities and take appropriate action. Some of these definitive clauses are likely to appear in your report, and you are encouraged to read them closely. Your consultant will be pleased to give full and frank answers to your questions.

The preceding paragraphs are based on information provided by the
ASFE/Association of Engineering Firms Practicing in the Geosciences, Silver Spring, Maryland