

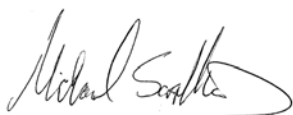
MEMORANDUM

Project No.: 140369-01

December 21, 2015

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From:



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Re: Task 1—Hydrogeological Assessment of Groundwater Quantity, Quality, and Production

This memo provides a summary of the data collected and assessed for the City of Bainbridge Island (COBI) to understand the current conditions of COBI's groundwater resources. COBI's monitoring well network consists of 70 public and exempt (private) wells (see Figure 1). The public wells are managed by both COBI and Kitsap Public Utility District (KPUD). Aspect Consulting, LLC (Aspect) gathered additional Group A and B public well and exempt well data from the Kitsap Public Health District (KPHD). The collected data were compiled and assessed for potential impacts to COBI aquifers.

Summary of Findings

Wells in the COBI monitoring well network (which includes KPUD wells) generally provide good coverage in both geographic and aquifer distribution on Bainbridge Island (Figure 1). The current monitoring network strikes a balance between the costs of monitoring more often and with more wells versus the benefit that such data would bring. The sharing of well data with KPUD allows COBI to expand their effective monitoring network without the direct cost of monitoring in those wells.

Based on the data reviewed, the production from these wells over the last 10 years has remained fairly steady at approximately 350 million gallons a year. Increased pumping in 2000–2004 corresponds with a period of below-average precipitation.

Water levels in the aquifers did not indicate any aquifer-wide trends over the last 10 years that would trigger the Early Warning Level (EWL) for safe yield, and only two individual wells were noted for further review (discussed in water level data section below).

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Water quality results did not exceed the EWL of 100 milligrams per liter (mg/L) nor exhibit an increasing trend for chloride nor did they exceed the U.S. Environmental Protection Agency's (EPA) Maximum Contaminant Level (MCL) of 10 mg/L for nitrate.

The following sections summarize the island's aquifer system and the data reviewed, evaluate COBI's monitoring well network data, and provide recommendations for possible next steps.

Bainbridge Island Aquifers

Bainbridge Island has six principal aquifers (Kato & Warren and Robinson & Noble, 2000), the extents of which were refined in the *Conceptual Model and Numerical Simulation of the Groundwater-Flow System of Bainbridge Island, Washington* (USGS, 2011). The six aquifers delineated below reflect updated understanding based on the United States Geological Survey (USGS) model, and provide a framework to assess potential local impacts in a single water supply well or more general impacts to an aquifer. Additional details about the aquifers, including detailed maps and discussion regarding the extent, thickness, and other characteristics, can be found in the USGS report.

COBI's monitoring well network is distributed across the six Bainbridge Island aquifers as follows: 16 in the Perched Aquifer, 7 in the Semi-Perched Aquifer, 32 in the Sea Level Aquifer, 5 in the Glaciomarine Aquifer, 9 in the Fletcher Bay Aquifer, and 1 in the Bedrock Aquifer. Aspect has updated the USGS groundwater model to include one new public supply well (KPU D North Bainbridge Well #10), for a total of 1,470 Group A and B public wells and exempt wells estimated to be active on Bainbridge Island.

1. **Perched Aquifer System (PA)**—This aquifer is comprised predominantly of Vashon Advance glacial outwash (Qva). The top of the aquifer ranges from sea level to more than 300 feet above mean sea level [ft MSL], with a thickness of 20 to 200 feet, and is utilized predominantly by domestic wells. About 4 percent of wells are reported to be completed in this unit.
2. **Semi-Perched Aquifer System (SPA)**—This semi-perched aquifer exists within permeable interbeds (QClpi) of the upper confining unit (QC1). The top of the aquifer ranges from sea level to more than 200 ft MSL, with a thickness of 10 to 50 feet. About 25 percent of wells are reported to be completed in this unit.
3. **Sea Level Aquifer (SLA)**—The Sea Level aquifer (QA1) is extensive, widely used, and mostly confined by QC1. The top of the aquifer ranges from -200 to 200 ft MSL, with a typical thickness of 25 to 200 feet. Fifty-three percent (53%) of wells are completed in the SLA.
4. **Glaciomarine Aquifer System (GMA)**—This aquifer consists of water-bearing units within a thick sequence of fine-grained glaciomarine drift (QA2). The top of the aquifer ranges between more than -500 to -300 ft MSL, with a typical thickness of 20 to 300 feet. Several of the Bainbridge Island's production wells and at least 4 domestic wells are completed in this aquifer, representing about 2 percent of wells.
5. **Fletcher Bay Aquifer System (FBA)**—The FBA (QA3) is the deepest identified aquifer on Bainbridge Island. Several large production wells are completed in this aquifer including the Fletcher Bay Well. The top of the aquifer ranges between more than -900 to slightly less than 600 ft MSL, with a typical thickness of 50 to 300 feet. While representing only about 1 percent

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of wells on Bainbridge Island, the metered KPUD and COBI FBA wells provide approximately 30 percent of the estimated total Island groundwater production.

- 6. Bedrock Aquifer System**—Less than 1 percent of the wells are completed in the sedimentary Blakely Harbor and Blakeley formations on the south end of Bainbridge Island.

Other wells on Bainbridge Island are either completed in water bearing zones within confining units or have an indeterminate aquifer completion zone. In assigning wells in the monitoring network to a given aquifer, the determination of the aquifer was made by comparing screen elevation with aquifer elevation and by comparing well location with lateral extent of an aquifer as shown in the 2000 Level II Basin Assessment (Kato & Warren and Robinson & Noble, 2000).

Data Compilation and Assessment

Groundwater data were compiled for assessment of safe yield and seawater intrusion.

Data Compilation

Primary data sources for this study were COBI's groundwater database, COBI Public Works production well records, KPUD's production well records, and KPHD's exempt and Group A and B well data. In addition to groundwater data, COBI provided on-island precipitation data which were reviewed for trends relative to groundwater levels.

Data Assessment

The compiled data were compared with EWLs¹ for safe yield and seawater intrusion in accordance with the COBI's Groundwater Management Program's Groundwater Monitoring Program (COBI, 2009). As described in the monitoring program update and COBI's most recent Groundwater Level Summary (COBI, 2013a) and Seawater Intrusion Assessment (COBI, 2013b), through the use of monitoring and EWLs, COBI is able to identify potential groundwater resources impacts for further investigation. In this study, as an additional measure of water quality, nitrate data were also compared to EPA's MCL (discussed in the water quality data section below).

Safe Yield

Safe yield is the amount of water that can be withdrawn from an aquifer without causing adverse effects. The EWL for safe yield is defined as a declining rate of ½ foot or more per year over a 10-year period that cannot be explained by the seasonal precipitation variations. Our assessment of safe yield trends for the COBI monitoring well network are discussed in the water level data section below.

Seawater Intrusion

The EWL for chloride concentration is at or above 100 mg/L (based on Ecology's draft Seawater Intrusion Policy; Ecology, 1990) or any increasing trend in chloride concentration. Confirmation of an increasing trend in chloride concentration requires at least four consecutive samples with increasing concentrations or samples taken over at least a 1-year period with seasonality taken in to

¹ According to COBI's 2009 *Groundwater Monitoring Program Update* (COBI, 2009), an EWL is a monitoring criteria that, if exceeded, would result in appropriate Management Responses, of which there are two types: (1) additional investigations in order to determine if a potential problem is developing, and (2) protective or remedial actions where appropriate.

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account. Our assessment of trends for chloride are discussed in the water quality data section below.

Specific determination of seawater intrusion requires additional focused monitoring and study in any suspect areas.

Summary of Assessments

Production

Most of the major public water supply wells on Bainbridge Island are operated by either COBI or KPUD, both of which record pumping volumes and water levels. Public water supply wells on Bainbridge Island have typically utilized the Fletcher Bay Aquifer (~65 percent) or the Sea-Level Aquifer (33 percent), with minimal pumping from the Glaciomarine, Perched, and Semi-Perched aquifers.

Production from these wells over the last 10 years has remained fairly steady at approximately 350 million gallons a year. Increased pumping in 2000–2004 corresponds with a period of below-average precipitation.

Updated well production data were merged with historic production data to provide a long-term production history of public supply wells from 1986 through 2014. Wells were grouped by aquifer, and overall production was reviewed for trends. COBI precipitation data were used to compare production with concurrent trends in rainfall through the use of the Cumulative Departure Precipitation (CDP).

Groundwater levels are influenced by the balance between inputs (recharge) and withdrawals (production). The influence of recharge is approximated by trends in precipitation over time, as measured by CDP. Due to the delay between rain falling and recharge reaching the deeper aquifers, the more immediate impact from dry periods is typically seen as increased demand for water (production). CDP measures the running total of differences between mean (average) precipitation and annual totals. Periods of below-average precipitation are seen as downward trending CDP, while periods of above-average precipitation are seen as upward trending CDP.

CDP was calculated from January 1995 through December 2014 and compared with production records over the same period. Historical pumping records are shown in Figure 2 in conjunction with the calculated CDP from 1995 to current.

Water Level

Water level data were compiled and grouped by aquifer for analysis (Figure 3).

Water levels in the aquifers did not indicate any aquifer-wide trends, and only two individual wells were noted for further review as described below. Individual well levels were reviewed for trends and compared against the EWL for safe yield. All wells were found to be below the EWL.

An exempt well (25N/02E-21P03) in the Sea Level Aquifer showed an apparent average decline of approximately 0.56 feet/year over the 8-year period of record. However, further review of the water level measurement method history showed that it changed twice over the period of record from a steel tape to a sonic water level meter and, then, back to steel tape. The results collected via sonic

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water level meter appeared to be inconsistent compared to the results before and after using the steel tape, a more rudimentary but more reliable measurement method. Therefore, the sonic level readings were removed from the analysis.

Once removed, the remaining data were below the EWL. Water-use data were not available for the well. However, the well owner indicated to COBI that no known change in water use occurred over the period of record. Continued long-term monitoring of this well using the steel tape method, as planned by COBI, will determine if there is a significant trend in water level decline over time.

Group A system well 'Island Utility Well #1' (25N/02E-34F07) in the Fletcher Bay Aquifer has shown an average decline of approximately 0.49 feet/year from 2004-2014. Although this does not yet exceed the EWL, it is very close to approaching it. Therefore, further monitoring and assessment are warranted.

The well is situated next to two other Fletcher Bay Aquifer production wells (Island Utility Well #2, Island Utility Well #4) within the same water system. Production data have not been available for these wells, which makes it unclear if declines are related to changes in water use over the period. This system has just transitioned to operation by KPUD in mid-2015, and they are now reviewing available information to understand the current conditions within that water system. Additional data review will continue as the system infrastructure is updated to see if additional water use, system loss, or some other factor contributed to the historical decline.

No other Fletcher Bay Aquifer wells monitored exhibited a similar declining trend, so it appears that this issue is specific to this well and not an aquifer-wide concern.

Water Quality

Water quality data were collected from COBI, KPUD, and KPHD and reviewed for potential exceedances of the EWLs for seawater intrusion. Nitrate was also compared against the EPA's MCL to verify that no concern is warranted at this time.

Data collected by COBI and KPUD represent long-term monitoring at individual wells and are useful for evaluating baseline water quality and potential water quality trends. Data submitted to KPHD include many exempt wells that have only a single result. Though useful for a current status assessment, these are not sufficient for evaluating trends in water quality.

Chloride

Chloride data from COBI and KPUD were reviewed as an indicator of seawater intrusion. No wells exceeded the EWL of 100 mg/L or an increasing trend in chloride concentration (increasing trends confirmation requires four consecutive increasing concentrations taking seasonality into account).

Chloride concentrations typically varied between 2 mg/L and 15 mg/L. Results in 2013 and 2014 in the Fletcher Bay Aquifer indicate slightly elevated chloride above historic baseline concentration, but not upward trending results. However, these should be monitored for continued changes. No trends in chloride results were noted. Summarized chloride results for the Fletcher Bay and Sea Level aquifers show historic concentrations since 1982 (Figure 4).

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Nitrate

Nitrate data were reviewed and were not found to exceed EPA's MCL of 10 mg/L. Nitrate data for Group A and B public wells and exempt wells do not indicate any trends. Data submitted to KPHD for exempt wells are typically single results and are insufficient to calculate any trends. The maximum result during the last 15 years (2000–2014) was 5.17 mg/L in 2007. There are no apparent trends over time or geographically across the island.

Recommendations

Based on our review of the monitoring data, we make the following recommendations:

- Wells in the Fletcher Bay Aquifer are typically collocated, so geographic distribution is somewhat limited. If additional wells in the aquifer become available to monitor, or are monitored by KPUD, these data will help expand the understanding of aquifer conditions.
- The transition of smaller water purveyor systems to either COBI or KPUD management will allow easier collection of monitoring data and review of the wells in those systems. The transition of Island Utility water system to KPUD management will assist in this regard.
- If there is ongoing concern for nitrate concentrations in COBI aquifers, then nitrate should be added as an additional parameter during the existing annual sampling currently performed for chloride. This would allow for more comprehensive trend analysis.
- As stipulated by the COBI's Groundwater Management Program Groundwater Monitoring Program plan, when an EWL is exceeded, additional focused monitoring and study is recommended. In particular, to further characterize the source of a chloride exceedance (in other words, rule out seawater intrusion), analysis of cations and anions or specific conductance can be used to determine the source (Culhane, 1993). These additional analyses can provide clarity on seawater intrusion versus natural conditions such as hard groundwater.
- If exempt well owners are encouraged to periodically test their water quality and self-report to KPHD, it will enhance the reviewable record.

References

City of Bainbridge Island (COBI, 2009), Groundwater Monitoring Program – Program Update, December 2008, revised March 2009,

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COBI, 2013b Seawater Intrusion Assessment

<http://www.ci.bainbridge-isl.wa.us/DocumentCenter/View/2812>

Culhane, 1993, High Chloride Concentrations in Ground Water Withdrawn from Above Sea Level Aquifers, December 3, 1993

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United States Geological Survey (USGS) 2011, Conceptual Model and Numerical Simulation of the Groundwater-Flow System of Bainbridge Island, Washington, 2011.

Washington Department of Ecology (Ecology), 1990, Draft Seawater Intrusion Policy, November 30, 1990.

Limitations

Work for this project was performed for the City of Bainbridge Island (Client), and this memorandum was prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. This memorandum does not represent a legal opinion. No other warranty, expressed or implied, is made.

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Attachments

Figure 1—Groundwater Monitoring Well Network

Figure 2—Well Production History

Figure 3—Hydrographs by Aquifer

Figure 4—Chloride Concentrations Over Time

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Groundwater Monitoring Wells	
●	Perched Aquifer
●	Semi-Perched Aquifer
●	Sea Level Aquifer
●	Glaciomarine Aquifer
●	Fletcher Bay Aquifer
●	Bedrock Aquifer

Aspect CONSULTING		Groundwater Monitoring Well Network Task 1 - Hydrogeological Assessment of Groundwater Quantity, Quality, and Production City of Bainbridge Island, Washington	
		AUG-2015 PROJECT NO. 140369	BY: MS / EAC REVISED BY: ---
		FIGURE NO. 1	

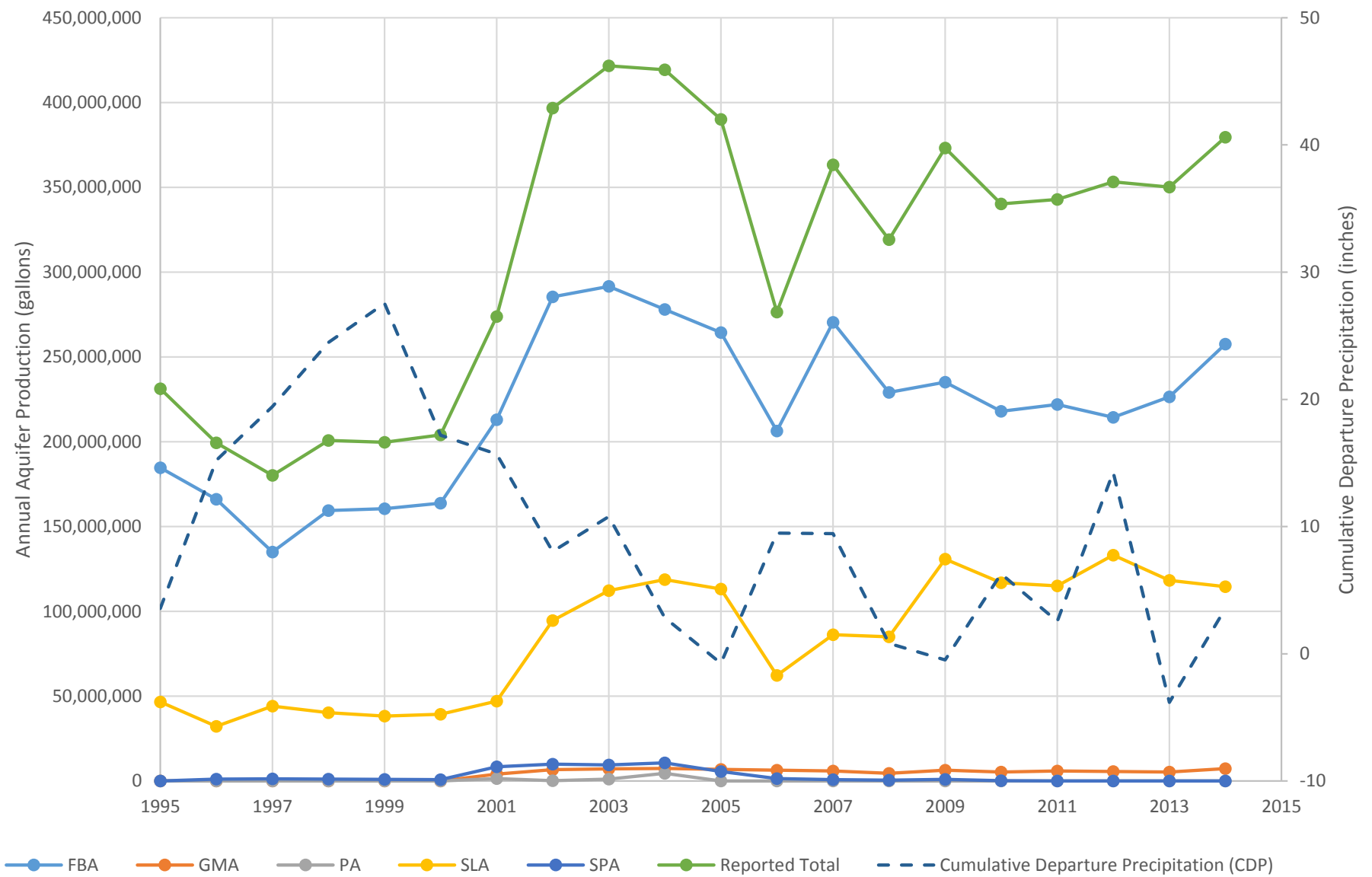


Figure 2
Well Production History
 Task 1 - Hydrogeological Assessment of Groundwater Quantity, Quality, and Production
 City of Bainbridge Island

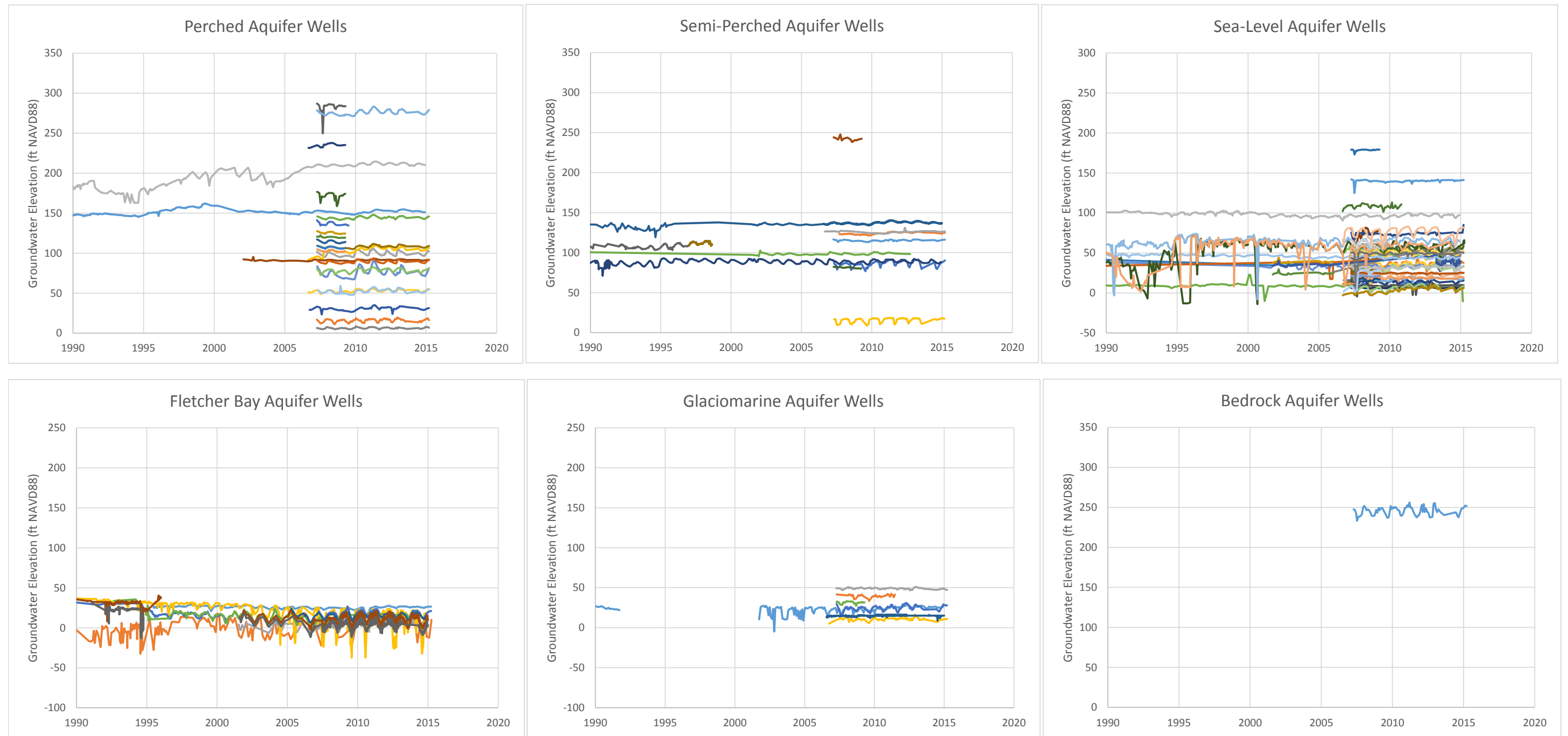


Figure 3

Hydrographs by Aquifer

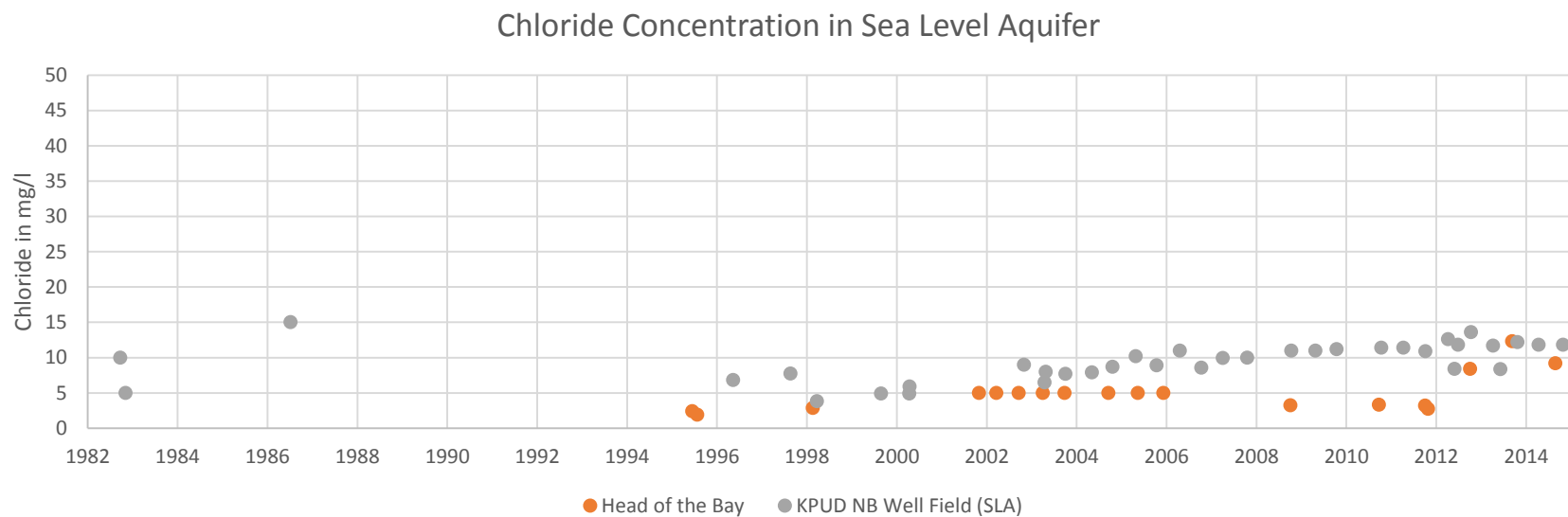
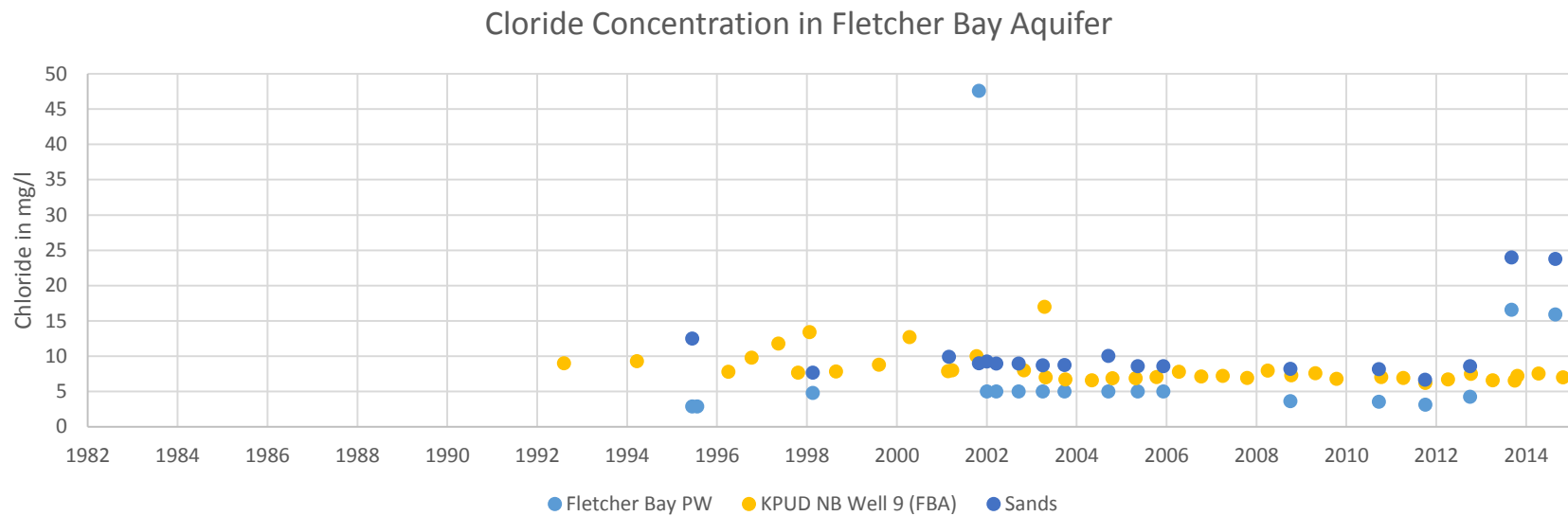


Figure 4

Chloride Concentration Over Time

Aspect Consulting LLC

12/21/2015

Task 1 - Hydrogeological Assessment of Groundwater Quantity, Quality, and Production

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City of Bainbridge Island, WA