CITY OF
BAINBRIDGE ISLAND

ENVIRONMENTAL TECHNICAL ADVISORY COMMITTEE
SPECIAL MEETING
FRIDAY, JUNE 1, 2018
8:00 AM – 10:00 AM
COUNCIL CONFERENCE ROOM
280 MADISON AVENUE NORTH
BAINBRIDGE ISLAND, WA 98110

AGENDA

1. **CALL TO ORDER / ROLL CALL / ACCEPT OR MODIFY AGENDA / CONFLICT OF INTEREST DISCLOSURE**
   8:00 AM

   CHAIR: FRANK GREMSE

   MEMBERS: JASON FLOWERS, CHARLIE KRATZER, DYLAN FRAZER, KARL SHEARER

   COUNCIL LIAISON: RASHAM NASSAR

2. **APPROVAL OF MINUTES** – MAY 18, 2018

3. **COUNCIL LIAISON REPORT** – RASHAM NASSAR

4. **DISCUSSION OF GROUND WATER MANAGEMENT PLAN REPORT**– ALL

5. **PUBLIC COMMENT**

6. **ADJOURNMENT**
   10:00 AM

For special accommodations, please contact Roz Lassoff,
206-780-8624 or at rlassoff@bainbridgewa.gov

CITY OF
BAINBRIDGE ISLAND

ENVIRONMENTAL TECHNICAL ADVISORY COMMITTEE
REGULAR MEETING
THURSDAY, MAY 17, 2018

AGENDA

1. **CALL TO ORDER / ROLL CALL / ACCEPT OR MODIFY AGENDA / CONFLICT OF INTEREST DISCLOSURE**
   3:10 PM

CHAIR:	FRANK GREMSE	
MEMBERS:	JASON FLOWERS DYLAN FRAZER	CHARLIE KRATZER KARL SHEARER
COUNCIL LIAISON:	RASHAM NASSAR	
PUBLIC:	DAVE GRAFF MELANIE KEENAN	CASEY SCHMIDT MALCOLM GANDER

2. **APPROVAL OF MINUTES** – APRIL 20, 2018.

3. **COUNCIL LIAISON REPORT –** RASHAM NASSAR

4. **DISCUSSION OF GROUND WATER MANAGEMENT PLAN REPORT–** ALL
   TOPICS DISCUSSED FOCUSED ON THE REPORT CONCLUSIONS AND RECOMMENDATIONS.

5. **PUBLIC COMMENTS:**

   A. ABILITY TO DOCUMENT AND REPORT ON PROBLEMS ASSOCIATED WITH PRIVATE WELLS OR AQUIFERS SHOULD BE DEVELOPED.
   B. AQUIFER CONSERVATION ZONES SHOULD BE IDENTIFIED.
   C. WELL MONITORING PROGRAM SHOULD BE EXPANDED.
   D. EARLY WARNING LEVEL CRITERIA SHOULD BE REVISED.

6. **ADJOURNMENT**
   5:15 PM

FRANK GREMSE, CHAIR 6/1/18

Ground Water Management Plan Discussion Paper

30 May 2018

By

Environmental Technical Advisory Committee

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1. **Introduction:** Groundwater is the sole source of drinking water on Bainbridge Island. The increased demands for groundwater resulting from population growth and the anticipated effects of climate change have created concern about the sustainability of the island's aquifers as well as the potential for saltwater intrusion. ETAC has been asked by the City Council to analyze the possible need for the development of a Groundwater Management Plan. To complete that assessment we have reviewed the available information on the aquifers, aquifer modeling efforts, well hydrographs and groundwater quality information. We have summarized that information in this report. For details underlying the information presented here, the original reports should be accessed. This paper is written with the idea that its primary readership is the non-technical island resident. The final section of this report presents our recommendations.

2. Bainbridge Island Aquifer Descriptions:

a. Table 1 presents the names for all six Bainbridge Island aquifers which should be thought of as not a group of six but rather a group of five plus one. The first five aquifers listed in Table 1 exist approximately north and west of the IslandWood area (Mac's Pond Fault) (Figure 1) but are not, in general, present to the south. The southernmost area of the island has been uplifted by a series of earthquakes along the still-active Seattle Fault Zone. The geologic layers containing the five primary aquifers were eroded away in this uplifted area during that time, leaving only older rocks exposed at the surface (Figure 2).

Table 1 Bainbridge Island Withdrawal by Aquifer

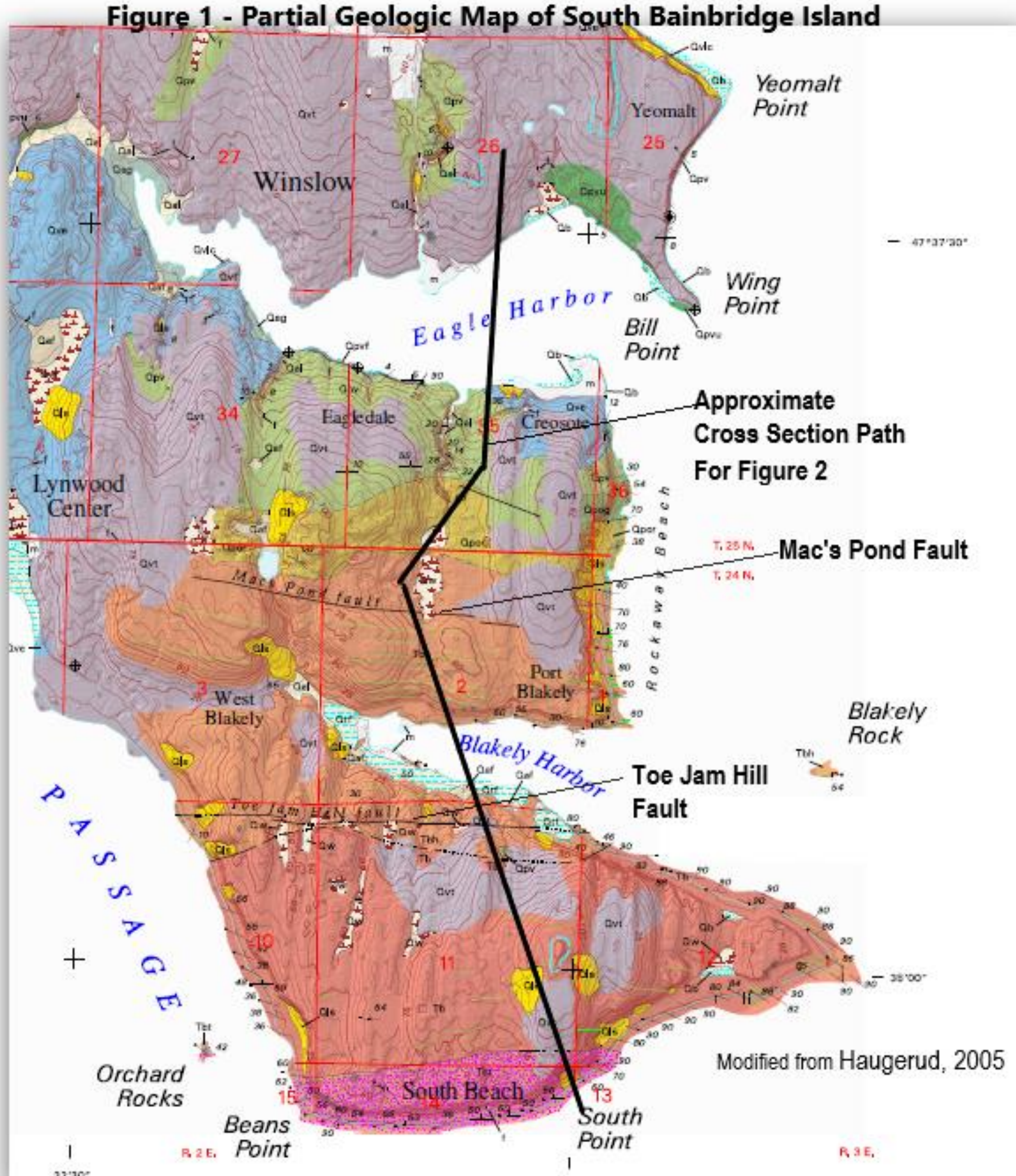
Aquifers	% of Wells (1)	No. of Monitoring Wells (1)	Aquifer Withdrawal, mgy (2)	Withdrawal Percentage
Perched Aquifer	4%	16	160	19%
Semi-Perched	25%	8	7	1%
Sea Level	53%	43	387	46%
Glaciomarine	2%	6	16	2%
Fletcher Bay	1%	12	264	32%
Bedrock	1%	1	not modeled	not modeled
Confining Units – low permeability layers	15%	0	Included in aquifer modeling	Included in aquifer modeling
Total		86	834	

1) Apfelbeck and Berg, July 2017; 2) Aspect, 2016

b. Table 1 shows that the three most significant aquifers on the island, based on water usage, are the Perched Aquifer, the Sea Level Aquifer and the Fletcher Bay Aquifer. These three aquifers provide 97% of the water supply. Table 1 has been developed from information presented in Aspect 2016 and Apfelbeck and Berg 2017.

c. The older uplifted formations (tan to pink in Figure 1) are considered bedrock, and thin porous intervals within these units collectively constitute the 'bedrock aquifer'. The bedrock is so geologically complex that mapping and modeling of aquifer units and predicting performance are not practical and come with large uncertainties. That is why they were not included in modeling studies. The thin bedrock aquifer layers are unlikely to support significant production. It is estimated that approximately 10 to 20 bedrock aquifer wells exist in this area.

Figure 1 - Partial Geologic Map of South Bainbridge Island



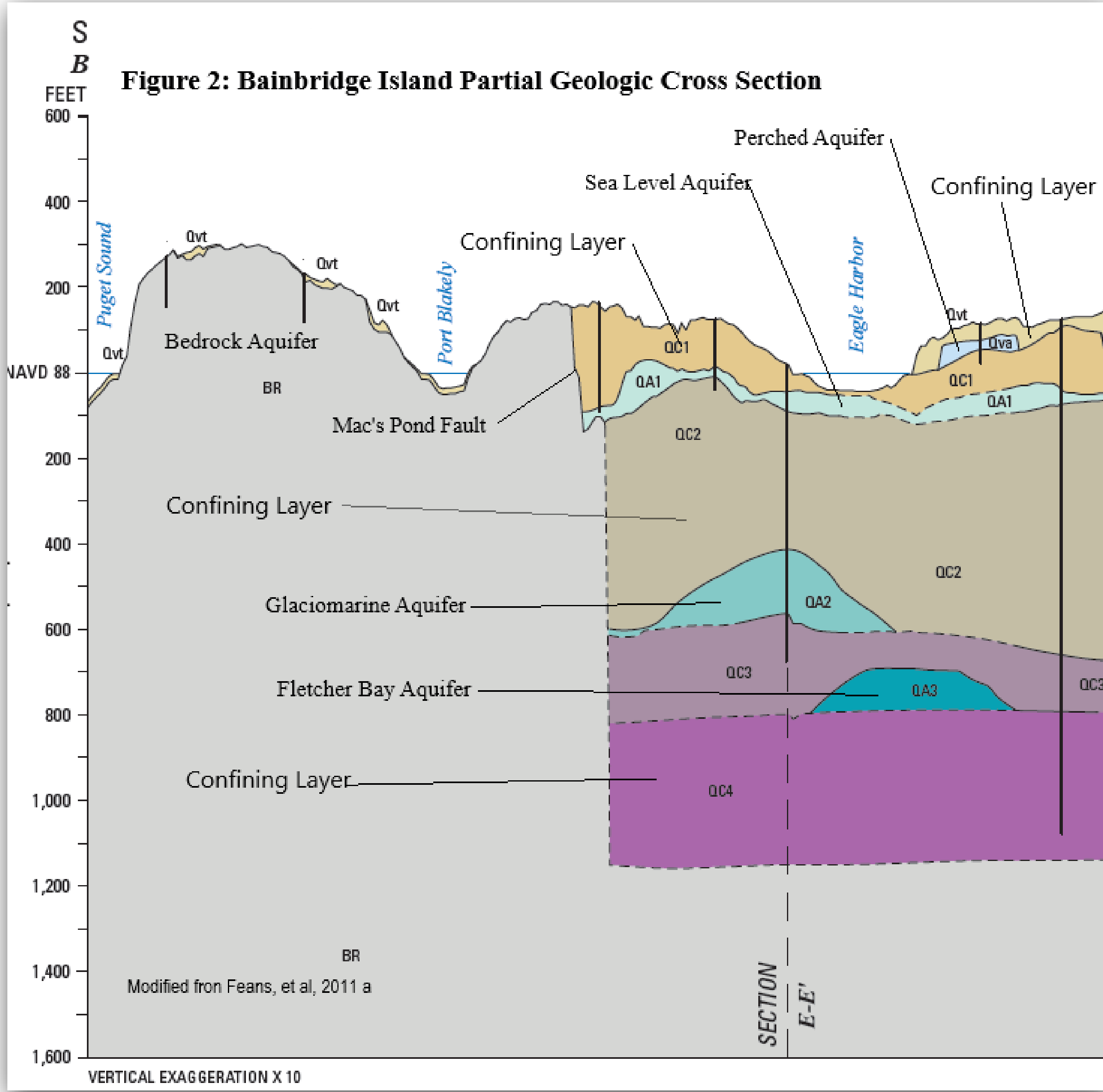


Figure 2: Bainbridge Island Partial Geologic Cross Section

3. <u>Aquifer Water Balance and Budget Issues:</u>

a. The water balance of an aquifer is the summation of the inflows minus the outflows. The inflows are primarily from surface water infiltration, septic system returns and to a minor extent, seepage from on island water features (ponds, streams, etc.) and off island aquifer water flow to the island for some of the aquifers. The outflows are from pumping, evapotranspiration, seepage to island water features and aquifer water flow out of the aquifer (i.e. to Puget Sound). If the outflows exceed the inflows then the difference must be made up from the excess water stored in the aquifer system termed *aquifer storage*. Similarly if the inflows exceed the outflows then the surplus will be added to the aquifer storage. Both of these scenarios have secondary effects on hydraulically influenced outflows.

b. In the 2011 USGS study of the Bainbridge Island aquifers (Frans, et al, 2011b) the USGS used data from over 400 wells to develop a groundwater model, and used synoptic measurements from over 100 wells and 20 stream flow measurement stations to calibrate the model. Water balance conditions were developed for 2008 using the USGS model and are presented in Table 2. The rates presented in Table 2 have been converted from acre-feet per year to million gallons per year to facilitate comparison with the Aspect study. Also the out flow from “pumping from wells” has been increased as suggested by Frans, 2018.

Table 2 Water Budget Bainbridge Island 2008 (Frans, et al, 2011b) Million Gallons per Year				
In	Rate		Out	Rate
groundwater inflow	325		groundwater outflow	3,259
recharge from precipitation and septic returns	5,865		discharge to surface-water features	5,214
recharge from lakes	0		pumping from wells	756
From storage	3,910		out to storage	652

b.i. Groundwater flow to the island was approximately 325 million gallons per year (mgy) or approximately 5% of the recharge amount. Thus, the primary source of recharge for all aquifers is precipitation and septic systems volume which account for approximately 95%.

b.ii. These data indicate aquifer pumping volumes were approximately 13% of the recharge (precipitation and septic systems) returns. However, pumping withdrawals are not the only aquifer withdrawals occurring. Groundwater also flows out to island surface water features such as streams, ponds, wetlands, etc. and underground into Puget Sound. When balancing all outflows against all inflows the outflows were approximately 57% greater than the recharge. It should be noted that the precipitation for 2008 was approximately 65% of normal based on a review of 30 years of data (Frans, et al, 2011b, pages 2, 68), meaning recharge was significantly less than normal in 2008.

b.iii. The deficit between outflow and recharge is made up from the stored groundwater (termed *aquifer storage*). This indicates that a plan should be developed to address the occurrence of extended periods of low rainfall and for extended periods of severe drought.

c. In 2015 Aspect reviewed and revised the USGS modeling effort reported in FRANS, ET AL, 2011b (Aspect 2015b and Aspect 2016). In Aspect's modeling effort they made changes in three areas to the USGS approach:

c.i. Revised the Precipitation Recharge Rate: Aspect used the precipitation recharge rate from USGS 2014 Kitsap Peninsula Report (USGS 2014) which is approximately 79% lower then what USGS 2011 used for the pre-development period (prior to 1995) and 2.4 times less for 1995 - 2008. Aspect also removed the septic systems return flows from their modeling as it represented less than 5% of overall recharge.

c.ii. Updated Well Pumping Rates: Aspect used the same well pumping data as the USGS for 2004 – 2008. In addition, Aspect used actual measured well pumping rates from COBI and KPUD wells for the years 2009 through 2014. Pumping rates for all other wells (Group A, B, and domestic water supply wells) were assigned the same monthly averages used by the USGS.

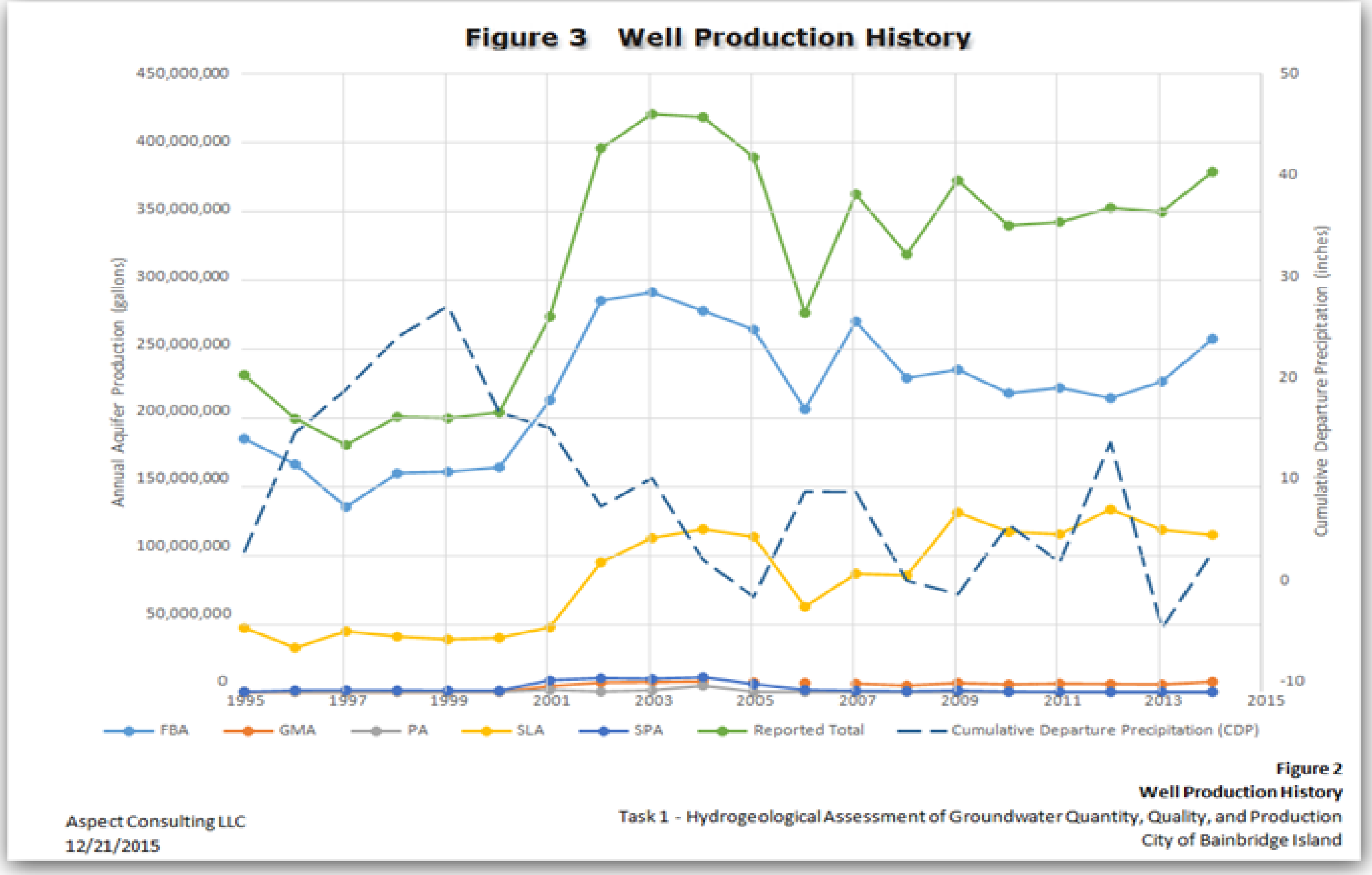
c.iii. Revised Modeling Approach: Aspect implemented several modifications to the modeling approach to better simulate groundwater flow (e.g. corrected sea level, set a no-flow boundary condition between the island and Puget Sound, removed 'double-count' precipitation recharge from lakes, revised precipitation infiltration rate, revised the groundwater flow algorithm and corrected topography using 2015 LiDAR data Aspect also ran the model out 100 years from present as opposed to just year 2035, to allow a more critical approach to evaluating potential seawater intrusion, which may geologically take a longer timeframe in which to occur.

c.iv. Table 3 presents the water balance results of Aspect's modeling for 2014.

Table 3 Water Balance Components 2014 (Aspect 2016)

Component	Million Gallons per Year (mgy)
Precipitation Recharge	4,456
Net Aquifer Storage	0
Well Pumping	-834
Surface Water Features	-1,261
Net Groundwater flow	-2,362

d. Comparing the USGS and Aspect modeling numbers yields observations based on differences attributable to different modeling techniques (such as Aspect not modeling aquifer storage and changing the interface with surface water features) and due to differences in changed data inputs between 2008 and 2014. Another notable comparison is the difference in pumping/withdrawal volumes from 2008 to 2014 which is 756 mgy versus 834 mgy, respectively. It would not be appropriate to interpret the difference between these two numbers as indicating a trend. The pumping/withdrawal volume number is a combination of measurements and estimation. Water volumes pumped from water purveyors are measured and reported. However, about half the wells on the island are exempt from reporting pumping volumes because they are rather small (less than 15 connections). The pumping volumes associated with these wells are estimated based upon per individual usage estimates, individual to connection estimates, and population estimates for the Island. In addition, it should be noted that groundwater withdrawal rates can vary significantly from season to season and year to year. An indication of this variability is what is being shown by the difference in the 2008 and 2014 pumping/withdrawal rates. Another even better example of the year to year well production rate variation is presented in Figure 3. These withdrawal rates present a considerable degree of variability with time (over 100%). The variability in withdrawal rates and the variability in the environmental factors influencing the withdrawal rates should be included in long term planning.



4. Water Level Measurements for Some Bainbridge Island Wells

a. Table 4 (Apfelbeck, 2018) presents information on wells of historic and/or current concern. The table shows that four of these five island wells are withdrawing water from Fletcher Bay Aquifer. This is important because Fletcher Bay Aquifer supplies approximately 32% of the island's groundwater. If those wells fail in any way, it would be a significant burden on the island. In 2017 Aspect in conjunction with COBI and KPUD conducted a field test from January through April 2017 where production was temporarily transferred from the Fletcher Bay Aquifer to the Sea Level Aquifer. This field test was successful. The water levels in the wells recovered to a normal level. This field test points to the possibility that a plan could be developed for the use of the aquifers in an interrelated fashion to address possible deficiencies in any one aquifer.

Table 4. Wells of Historic and/or Current Concern[3]			
Well	**Aquifer**	**Historic Well Water Levels through 2008[1]**	**2007-2016 Well Water Levels[2]**
North Bainbridge Well 7	Sea Level	Exhibited long-term decline 1995 through 2005 not consistent with rainfall patterns and attributed to production; at that time pumping from this well was reduced; as static water levels showed a relatively rapid recovery to pre-pumping levels when pumping reduced and water levels observed in nearby wells 3 and 6 did not show the same pattern of decline, the decline in 7 was determined to be localized to the well and not an aquifer condition.	Not of concern at this time; 0.39 feet water level rise per year; production remains fairly steady
North Bainbridge Well 9	Fletcher Bay	Decline 1994 - 2000 suggests production may have exceeded recharge; 2000-2005 levels consistent with rainfall patterns; stable since 2005	Not of concern at this time; questionable data indicated 0.4 feet of water level decline per year; however, KPUD hydrogeologist reported continuous data that was not vetted in time for the assessment indicates no decline; the continuous data will be included in this year's assessment
Sands Road 1	Fletcher Bay	Decline 1994 - 2000 suggests production may have exceeded recharge; 2000-2005 levels consistent with rainfall patterns; stable since 2005	Not of concern at this time; negligible decline of 0.08 feet per year
Sands Road 2	Fletcher Bay	Decline 1994 - 2000 suggests production may have exceeded recharge; 2000-2005 levels consistent with rainfall patterns; stable since 2005	Not of concern at this time; 0.37 feet water level rise per year
Island Utilities Well 1	Fletcher Bay	Declined about 15 feet since 1988; exceeds Early Warning Level	Continues to exceed Early Warning Level and of immediate concern; 0.69 feet water level decline per year; KPUD hydrogeologist reports decline localized to this well and increased monitoring in wells 1, 2 and 3 to build better water level and production data to discern cause and design appropriate action

[1]Groundwater Monitoring Program-Program Update, Aspect Consulting, LLC, March 2009
[2]Groundwater Monitoring Program Early Warning Level Assessment (2016), COBI, July 2017
[3] Apfelbeck, 2018

b. COBI conducted early warning level (EWL) assessments of hydrographs from 71 wells in the monitoring network for which they monitored water level. Their results are summarized in Table 5 (Apfelbeck and Berg, 2017). Note that the one well monitoring the Bedrock Aquifer is not included due to complexities in assessments of this aquifer (see 2e above). Fifty-three of the well hydrographs reviewed showed positive trends over the 10-year period, while only 14 showed a negative trend, and the negative trends mostly exhibited a gradual downward slope. Three wells did not have sufficient years of data to calculate trends at this time. For a detailed explanation of these results, the report should be reviewed. In general, the report presents a condition which attests to an overall state of the five aquifers as being operationally functional to satisfy present island needs. However, it does not present a basis to determine long-term sustainability of the aquifer system.

Table 5 Water Level Trends for Some Bainbridge Island Wells (2007-2016)

Aquifers	No. of Monitoring Wells	Positive Trend	Negative Trend	Neutral
Perched Aquifer	16	15	1	0
Semi-Perched	8	7	1	0
Sea Level	32	22	7	3
Glaciomarine	5	4	1	0
Fletcher Bay	9	5	4	0
Total	70	53	14	3

c. Some members of ETAC reviewed available water utility hydrographs for Kitsap Public Utility District and a selection of COBI water utility hydrographs for a total of 26 Bainbridge Island wells (Appendix A). We did not find any basis for not accepting the results presented in Apfelbeck and Berg, 2017. The wells were not selected according to any predetermined scheme but also a rigorous randomization scheme was not used.

5. Water Quality

a. The two main concerns for Bainbridge Island's water quality are chloride and nitrate. Increased chloride levels are indicators of potential seawater intrusion into the aquifers. Increased nitrate levels in the groundwater are frequently associated with septic systems. In addition, discrete hazardous chemical releases can often impact local groundwater quality. The following sections discuss the data collected to date.

b. Aspect's 2015 assessment of water quality data reported that 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.

c. Chloride measurements were also reviewed for data collected between 2007 and 2016 (Apfelbeck and Berg, 2017). No chloride concentrations measured for this assessment period exceeded the EWL of 100 mg/L. Chloride concentrations in all aquifers were low (usually less than 21 mg/L). This, there is no evidence to indicate that sea water intrusion is occurring.

d. As shown in Table 6 from the WA Dept. of Ecology, there are a number of contaminated cleanup sites on Bainbridge Island. Thus, there exists a potential for contamination to seep into the aquifers and/or into the wellheads. However, the actual probability of this is unknown.

Table 6: DOE Hazardous Sites List - 21 Feb 2018

https://fortress.wa.gov/ecy/publications/documents/1809042a.pdf
https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Site-Register-lists-and-data

	FSID	SITE NAME	CITY	RANK	STATUS	RU
1	64365396	BI Intermodal Transfer	Bainbridge	5	Cleanup Started	NW
2	2602	BI Landfill	Bainbridge	5	Cleanup Started	NW
3	96325489	Chevron	Bainbridge	2	Cleanup Started	NW
4	23096	Clean Center	Bainbridge	2	Awaiting Cleanup	NW
5	2611	Day Road Industrial Park	Bainbridge	2	Awaiting Cleanup	NW
6	151	Eagle Harbor **Superfund Site** State	Bainbridge		Cleanup Started	HQ
7	153	Eagle Harbor E **Superfund Site** State	Bainbridge		Performance Monitoring	HQ
8	154	Eagle Harbor W **Superfund Site** -Federal	Bainbridge		Cleanup Started	EP
9	152	Eagle Harbor Wyckoff **Superfund Site** State	Bainbridge		Cleanup Started	HQ
10	3804318	Lynwood Center Corner	Bainbridge	2	Cleanup Started	NW
11	44882172	Madison Ave S & Parfitt Way SW	Bainbridge	5	Awaiting Cleanup	NW
12	61317581	Norge Equipped Cleaning Village Store	Bainbridge	2	Cleanup Started	NW
13	15438	Strawberry Plant	Bainbridge	2	Cleanup Started	NW
14	26595127	TOSCO Bainbridge Island Bulk Plant 1784	Bainbridge	2	Awaiting Cleanup	NW
15	46126151	Unocal 4388	Bainbridge	2	Cleanup Started	NW
16	28682498	Winslow Way W & Madison Ave N	Bainbridge	5	Awaiting Cleanup	NW

e. **Washington Ranking Method (WARM):** The results of the Site Hazard Assessment step are used in the Washington Ranking Method (WARM) to yield a WARM score (a number between 1 and 5). A score of 1 represents the highest level of risk and 5 the lowest. Generally, Federal Superfund sites and sites ranked 1 or 2 are higher priority for cleanup. Factors that enter into site hazard ranking include: the amount and type of contaminants present, how easily contaminants could come into contact with people and the environment, and the level of public concern.

f. It is important that groundwater quality parameters continue to be monitored to ensure the potability of the island's ground water.

6. Modeling Forecasts

a. In section 3 "Aquifer Water Balance and Budget" there is a description of the USGS model developed and calibrated for Bainbridge Island (FRANS, ET AL, 2011b). For the three primary aquifers, the USGS used the model to simulate the possible effects of increased groundwater pumping and changes to recharge due to changes in land use and climactic conditions between 2008 and 2035 under minimal, expected, and maximum impact conditions. They found maximum drawdown levels to be 0-10 ft (0 – 0.37 ft/yr) for most of the Island for the minimal and expected impact scenarios (Table 7). The maximum impact scenario applied exaggerated population growth, full island and Kitsap Peninsula build out, and the most severe climate change conditions (sea level rise and rainfall runoff). For this scenario drawdowns levels for most areas in all three aquifers were still less than 10 feet (or 0.37 ft/yr). However, isolated areas in the Perched and Sea Level Aquifers had steeper declines of between 15 – 20 feet, and isolated areas in the Fletcher Bay Aquifer showed declines of up to 40 feet.

b. For the maximum scenario for 2035, the model projected that direction of flow in the deep Fletcher Bay Aquifer would reverse and flow from east to west.

c. Although the model did not predict seawater intrusion by 2035 under any of the scenarios, USGS reported that continued exposure to the maximum conditions would likely result in seawater intrusion in the Fletcher Bay Aquifer along the northern and eastern coastlines at some undefined future date. .

d. The water budget developed by USGS showed that about 50% of groundwater discharge is to surface waters (streams, lakes, springs) on the island, about 33% is to Puget Sound, and about 7% is to groundwater pumping (Frans et al, 2011b).

Table 7: USGS Projected Groundwater Level Fluctuation by 2035

Aquifer	Minimum	Expected	Maximum[1]
Perched Aquifer	For most of the aquifer, increases of as much as 5 ft or decreases less than 5 ft; slightly more than 10 ft decrease near Lynwood Center (Figure 39A, page 82).	0-5 ft decrease for most of the aquifer; one isolated pocket of up to 25 ft decrease in southwest near Lynwood Center (Figure 37A, page 78).	Some areas increase as much as 5 ft; decreases < 10 ft for most of the aquifer with isolated pockets of declines that exceed 15-20 ft (Figure 40A, page 86).

Sea-level Aquifer	Much of the aquifer will have increases of as much as 5 ft. Decreases of less than 5 ft in areas north of Eagle Harbor, south of Fletcher Bay, and from Manzanita Bay to Port Madison; decreases from 15-20 feet near Lynwood Center (Figure 39B, page 83).	0-5 ft decrease for most of the central and northern areas with isolated pockets of declines between 10-20 ft near Lynwood Center and south of Port Madison; isolated increases up to 5 ft northwest of Murden Cove, south of Eagle Harbor, and along the western coastline (Figure 37B, page 79).	Decreases < 10 ft for most of the aquifer. Some level decrease between 10-20ft with isolated pockets in excess of 20 ft near Port Madison and Lynwood Center (Figure 40B, page 87).
Fletcher Bay Aquifer	Decreases of up to 5 ft mostly in the southwestern part of the unit around Eagle Harbor, Fletcher Bay, and south Manzanita Bay (Figure 39C, page 84).	Decreases range from < 4 ft in the northeast to 10 ft on the western side of the Island (Figure 37C, page 80).	Declines range from a minimum of 10 ft in the northeast corner of the Island to more than 40 ft on the western edge of the Island (Figure 40C, page 88).

1. The maximum impact scenario represents purposely exaggerated population growth, full Island build out, and the most severe reduction in recharge, but does not reflect anticipated conditions.

e. Aspect also modeled Bainbridge Island aquifers with certain refinements with respect to the USGS 2011 modeling effort (Aspect 2016). The model was run for a 100-year time frame and found the following results:

- The Perched Aquifer system showed an average 0.10 foot per year of water level decrease at 25 locations simulated across the Island;
- The Semi-Perched Aquifer system showed an average 0.13 foot per year of water level decrease at 12 locations simulated across the Island;
- The Sea Level Aquifer system showed an average 0.09 foot per year of water level decrease at 49 locations simulated across the Island;
- The Glaciomarine Aquifer showed an average 0.02 foot per year of water level decrease at 6 locations simulated across the Island; and
- The Fletcher Bay Aquifer showed an average 0.15 foot per year of water level decrease at 9 locations simulated across the Island.
- Water decreases above reflect aquifer storage reduced by approximately 11,000 million gallons between current and future conditions.

- The predictive model results did not demonstrate a flow reversal in the Fletcher Bay Aquifer, and indicated that groundwater from the Bainbridge Island aquifer system continued to flow to the shoreline, keeping the freshwater/seawater interface at a distance from the Bainbridge Island shoreline (no seawater intrusion).
- Aspect found that with increased groundwater withdrawal the total discharge of groundwater to surface waters features would decrease by up to 40%. It is important to note that this is a very gross estimate, because the limited grid resolution may not be sufficient to accurately simulate groundwater discharge to surface water and the model has not been calibrated to observed flows. However, potential reduced stream flow and lake and wetland volumes are important factors which should be included in future planning.
- It is important to note that there are a number of assumptions underlying Aspects development of their predictions (both positive and negative). A plan should be developed to help insure that the adverse effects realized under the conditions are not realized.

7. Conclusions

a. The three aquifers: Perched, Sea Level and Fletcher Bay produce approximately 97% of the pumped well water.

b. The Bedrock Aquifer (area south of the “Mac’s Pond Fault/IslandWood”) is not included in current Bainbridge Island groundwater model assessments, and is not expected to be considered for significant water production. Pumping wells in this area should not be promoted. Residences in this southern most area of the island should be encouraged to obtain a connection with a water purveyor.

c. The primary source of aquifer recharge, for all aquifers, is precipitation with return flows from septic systems and off island aquifer flow to the island, being of significantly less importance.

d. Well hydrographs from the existing monitoring well network and modeling efforts indicate that the Bainbridge Island aquifers are functioning at a level which is capable of meeting the present withdrawal demands.

e. The groundwater withdrawal rates show a considerable degree of variability with time (over 100%) which shows that a number of environmental factors influence the withdrawal rates.

f. The deficit between groundwater outflow and inflow is made up from the stored groundwater (termed *aquifer storage*). This means that a plan should be developed for those conditions of extended periods of low rainfall and for extended periods of severe drought where large volumes of groundwater will be required to be withdrawn from aquifer storage. And it is essential to have a good estimate of groundwater storage.

g. It is evident from available climate change information that our precipitation patterns are changing and will continue to change into our future. The present prediction for the Pacific Northwest is that the frequency of increased rainfall intensity will increase (Mauger et al 2015) with a concomitant increase in runoff (Aspect 2016).

h. Climate change is also predicted to increase our normal temperatures which during the dry summer months will result in increased water usage both indoors and outdoors. The current DOE pilot test of the seasonal groundwater usage can inform any effort to develop a plan to deal with groundwater usage during periods of aquifer stress.

i. Climate change could lead to more severe droughts. There is also the possibility of multi-year droughts, although the probability of this for the Pacific Northwest is presently deemed to be low.

j. The Aspect predictive model (Aspect 2016) did not show a flow reversal in the Fletcher Bay Aquifer, also it indicated that groundwater from the Bainbridge Island aquifer system continued to flow to the shoreline, keeping the freshwater/seawater interface at a distance from the Bainbridge Island shoreline (no seawater intrusion). USGS model results showed the same for expected conditions. Only the USGS model results for extreme conditions (worst climate change, full island and Kitsap Peninsula build out, and purposefully exaggerated population growth) projected a flow reversal in the Fletcher Bay Aquifer which USGS scientists reported could cause seawater intrusion to develop *in time* along the eastern and northern shorelines.

k. An outline of Groundwater Management Plans is included in Appendix B. Experience of a few counties with the development and implementation of Ground Water Management Plans is presented in Appendix C.

8. Recommendations

a. Because of the critical nature of the island's sole source aquifer the development of a groundwater management plan would be of great benefit to the island community. The development of the plan could follow a couple of different paths:

- a.i. Apply to the Department of Ecology (DOE) for assistance in the development of a Groundwater Management Plan. DOE has indicated to us that given their present work load and without a new funding source they do not have the resources to address this in the near term (approximately two years to initiate). Previous plans begun in the late 1980's and 1990's took up to 10 years to complete.
- a.ii. COBI could initiate and lead the process with the assistance of a consultant. It is likely the COBI could obtain DOE's assistance in bring all the stakeholders to the table for development process.
- a.iii. Contact Kitsap PUD to determine their interest in leading an Island wide GWMP.

b. Areas which such a plan could address are:

- b.i. Community wide education program concerning the state of the island's aquifers.
- b.ii. A feasibility analysis of the potential inter-operability of the island's aquifers.
- b.iii. Ensure that the well monitoring network is maintained (water extraction and seawater intrusion monitoring) and examined to see if it should be expanded, with the possibility of including private (exempt), Group A, and Group B water systems.
- b.iv. Encourage the expansion of existing water systems.

b.v. Assess the impacts of proposed activities, development, and population growth on the streams and wetlands that are either sustained by groundwater discharge or contribute recharge to groundwater.

b.vi. Consider creation and application of one or more aquifer conservation zones

b.vii. Encourage water re-use and reclamation

b.viii. Develop a water conservation program

b.ix. Develop a program that incentivizes and facilitates innovative methods for homeowners and business owners to use storm water and grey water.

b.x. Develop a refined water budget for each aquifer (and therefore the system) with the incorporation of more robust modeling of groundwater/surface water interaction.

b.xi. Potential methods for funding initiatives and programs developed by the GWMP.

References:

1) Kato & Warren, Inc., and Robinson & Noble, Inc., 2000, City of Bainbridge Island Level II Assessment, an element of water resources study, December 2000.

2) Haugerud, Ralph A., Preliminary Geologic Map Of Bainbridge Island, Washington, *Http://Pubs.Usgs.Gov/Of/2005/1387*, USGS 2005.

3) Frans, L.M., Bachmann, M.P., Sumioka, S.S., and Olsen, T.D., 2011a, Geologic Map and Cross Sections Showing Hydrogeologic Units on Bainbridge Island, Kitsap County, Washington, SCIENTIFIC INVESTIGATIONS REPORT 2011–5021, 1 p.

4) Frans, L.M., Bachmann, M.P., Sumioka, S.S., and Olsen, T.D., 2011b, Conceptual model and numerical simulation of the groundwater-flow system of Bainbridge Island, Washington: U.S. Geological Survey Scientific Investigations Report 2011-5021, 96 p.

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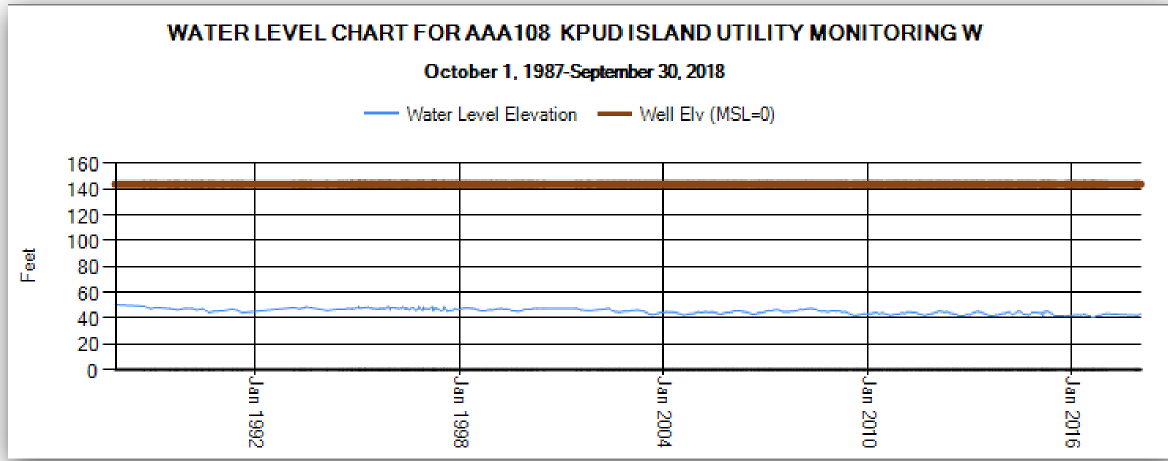
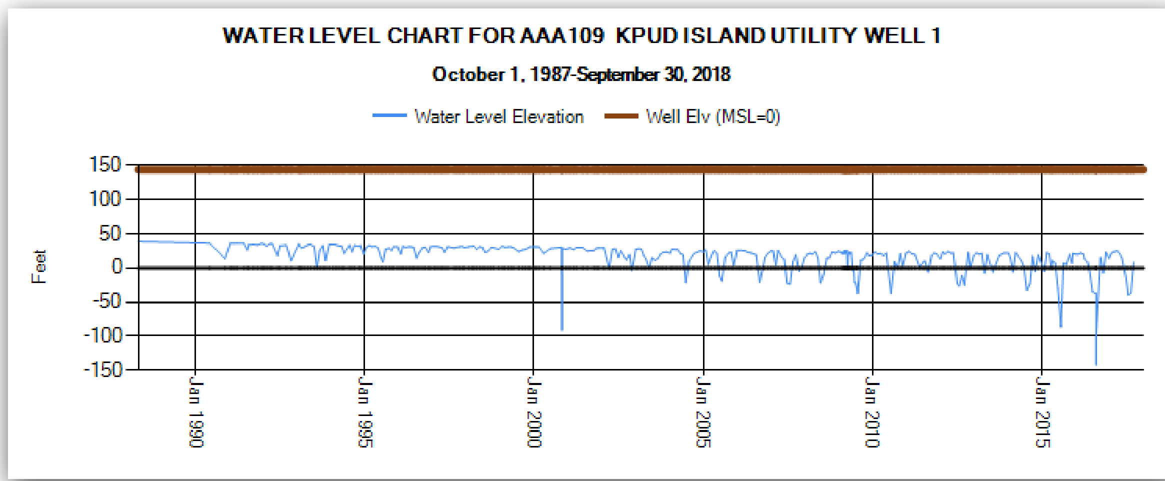
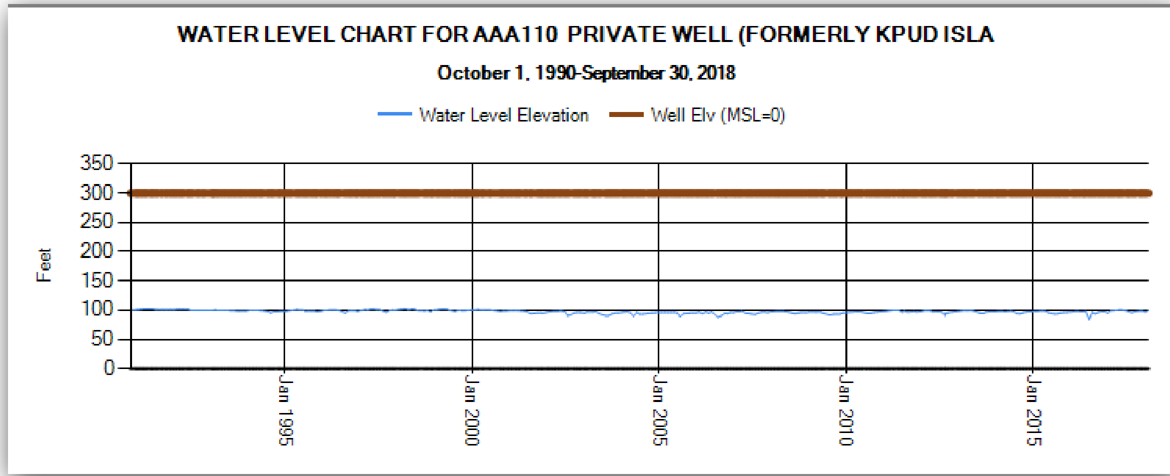
Appendix A: Bainbridge Island Some COBI & KPUD Wells

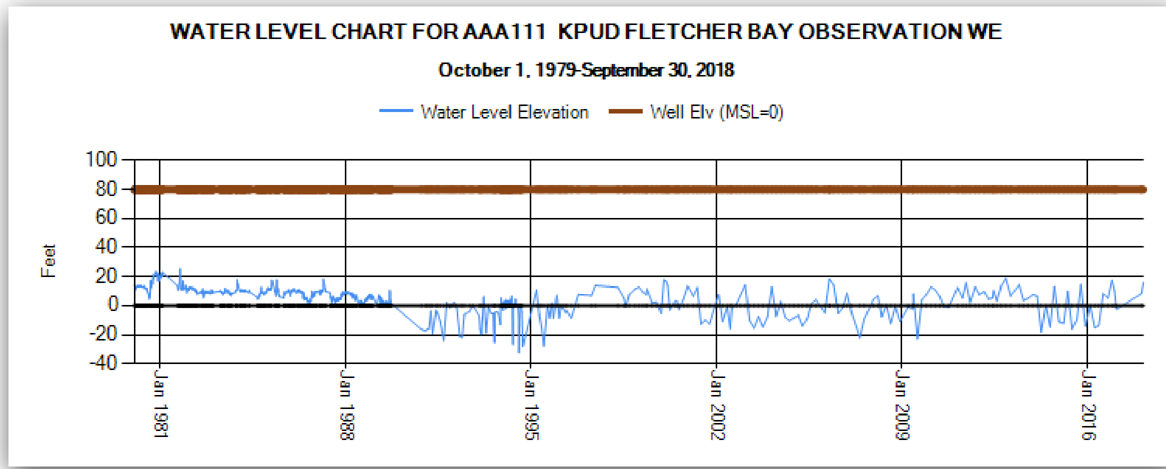
References: http://kpudhydrodata.kpud.org/APSFED_WELLS.aspx

COBI Well Monitoring Network Database - SCADA






WATER LEVEL CHART FOR AAA110 PRIVATE WELL (FORMERLY KPUD ISLA
October 1, 1990-September 30, 2018
Water Level Elevation
Well Elv (MSL=0)
Feet
350
300
250
200
150
100
50
0
Jan 1995
Jan 2000
Jan 2005
Jan 2010
Jan 2015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60
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20
0
-20
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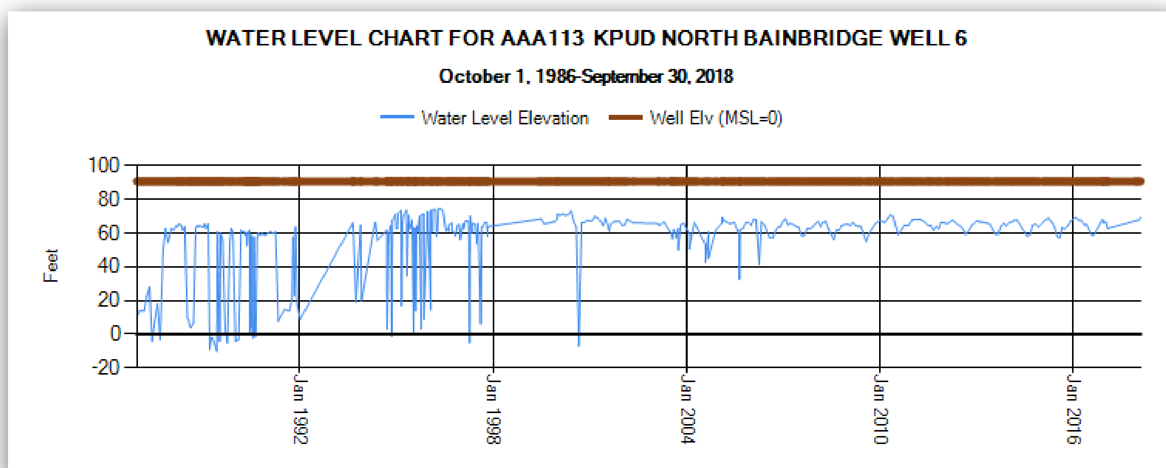
Jan 1981
Jan 1988
Jan 1995
Jan 2002
Jan 2009
Jan 2016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Feet
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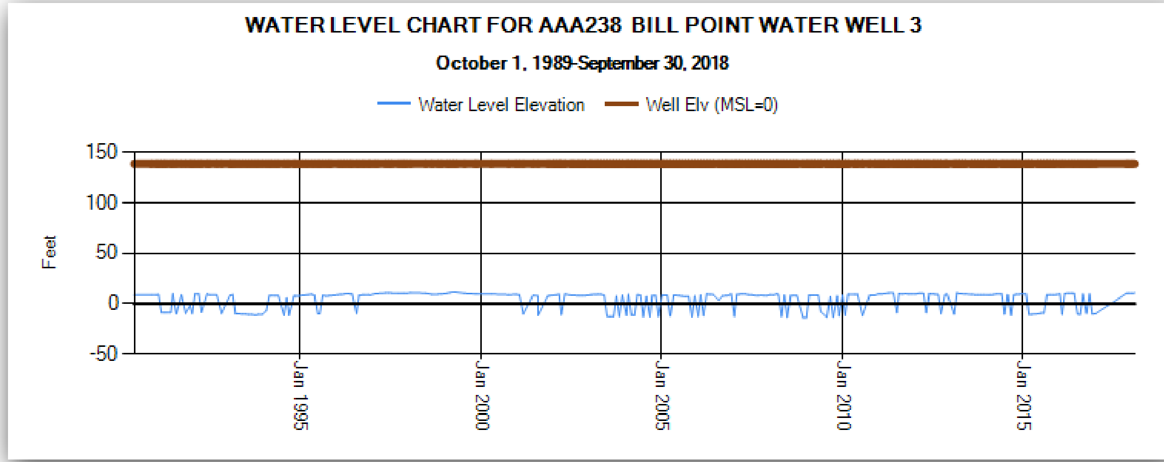
80
60
40
20
0
-20
Jan 1992
Jan 1998
Jan 2004
Jan 2010
Jan 2016



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Feet
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50
0
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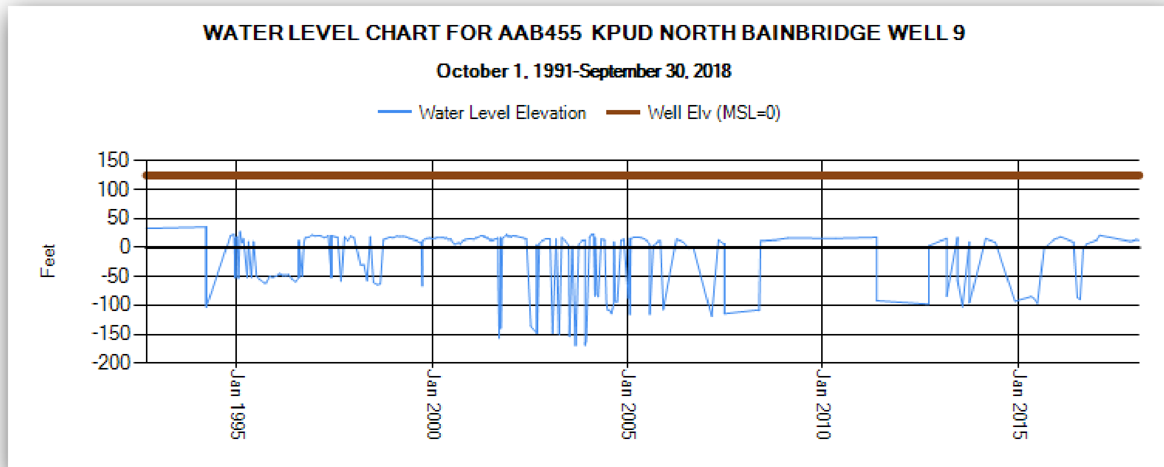
Jan 1995
Jan 2000
Jan 2005
Jan 2010
Jan 2015



WATER LEVEL CHART FOR AAB455 KPUD NORTH BAINBRIDGE WELL 9
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Water Level Elevation
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0
-50
-100
-150
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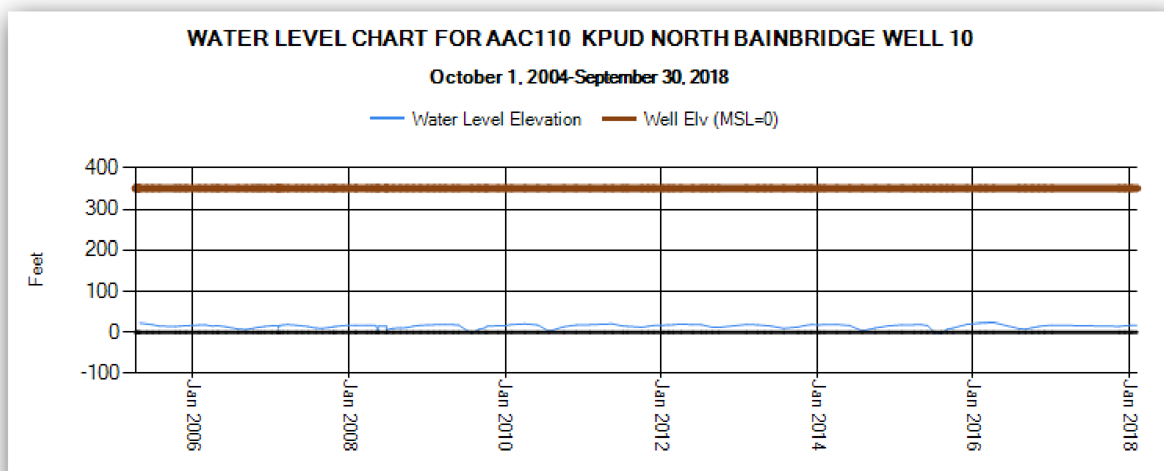
Jan 1995
Jan 2000
Jan 2005
Jan 2010
Jan 2015



WATER LEVEL CHART FOR AAC110 KPUD NORTH BAINBRIDGE WELL 10
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Water Level Elevation
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200
100
0
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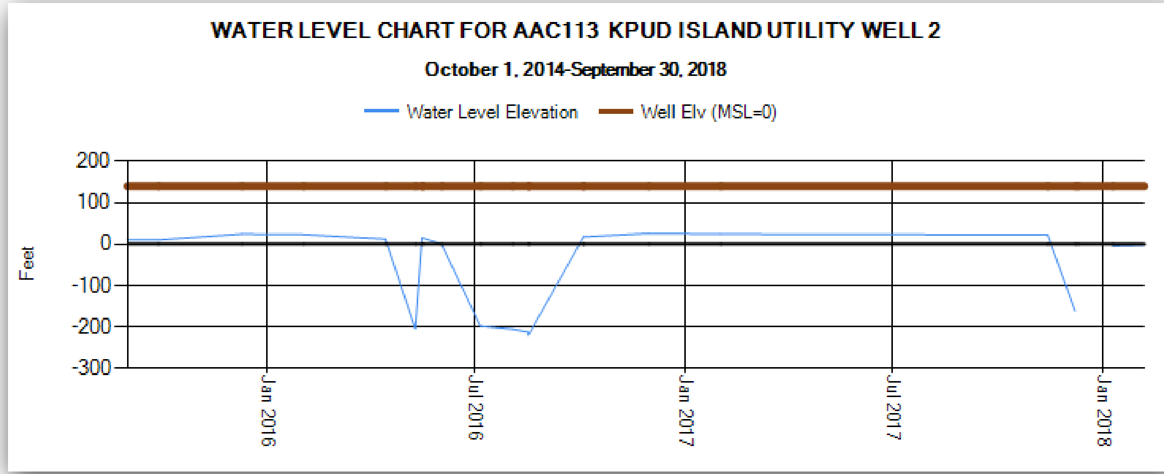
Jan 2006
Jan 2008
Jan 2010
Jan 2012
Jan 2014
Jan 2016
Jan 2018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Water Level Elevation
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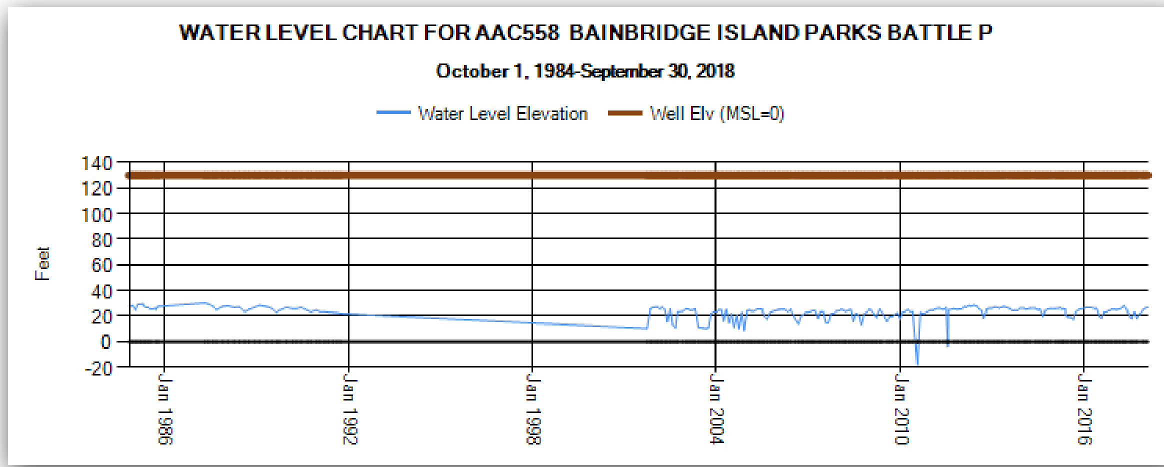
100
0
-100
-200
-300
Jan 2016
Jul 2016
Jan 2017
Jul 2017
Jan 2018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Well Elv (MSL=0)
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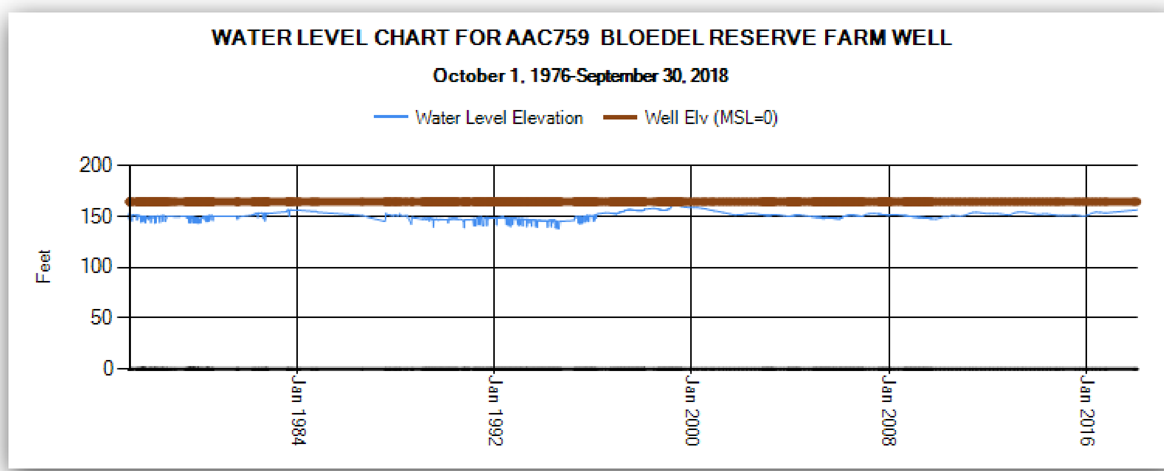
40
20
0
-20
Jan 1986
Jan 1992
Jan 1998
Jan 2004
Jan 2010
Jan 2016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100
50
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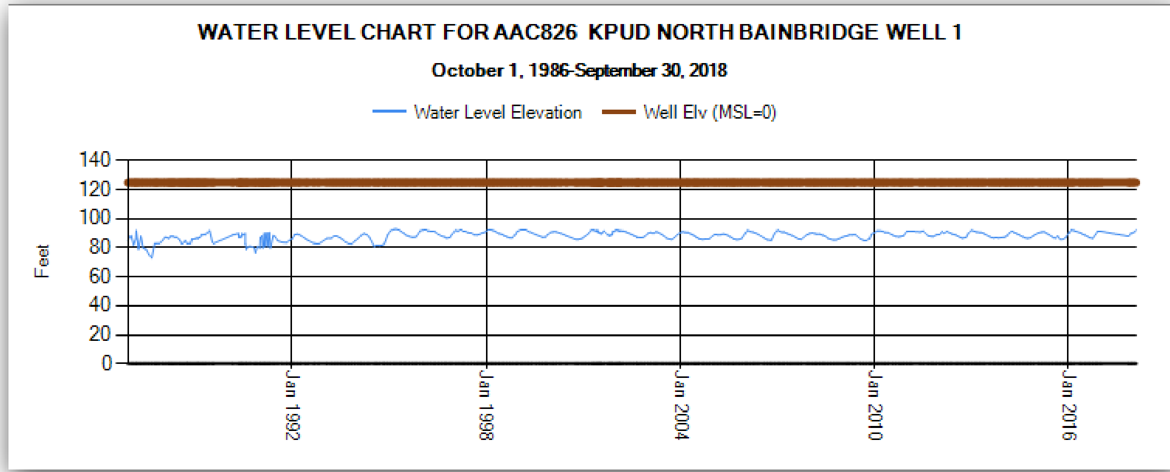
Jan 1992
Jan 2000
Jan 2008
Jan 2016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Water Level Elevation
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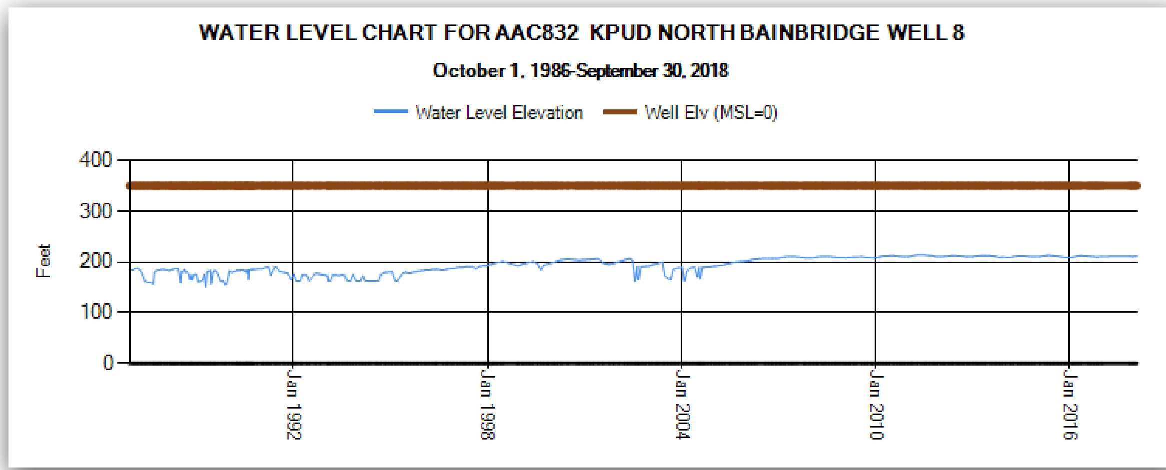
120
100
80
60
40
20
0
Jan 1992
Jan 1998
Jan 2004
Jan 2010
Jan 2016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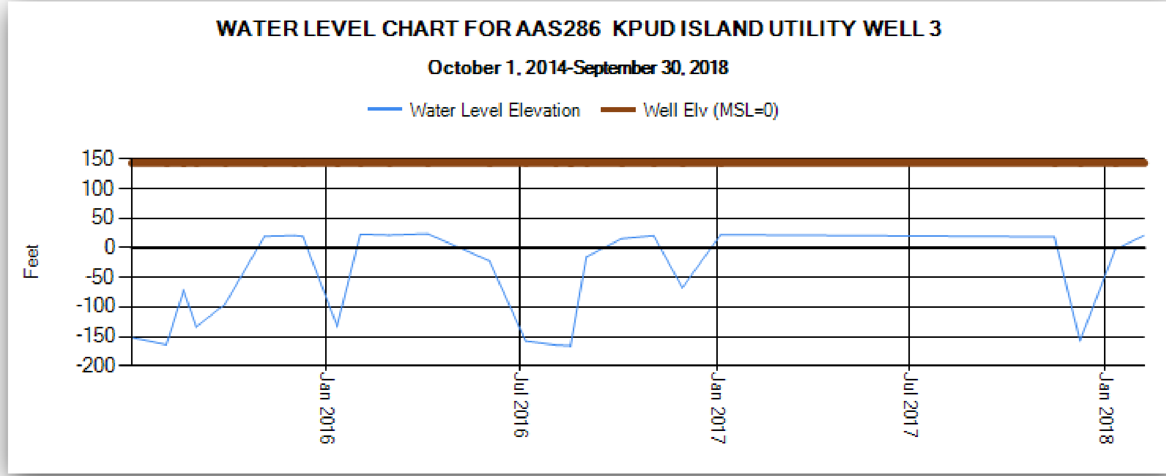
300
200
100
0
Jan 1992
Jan 1998
Jan 2004
Jan 2010
Jan 2016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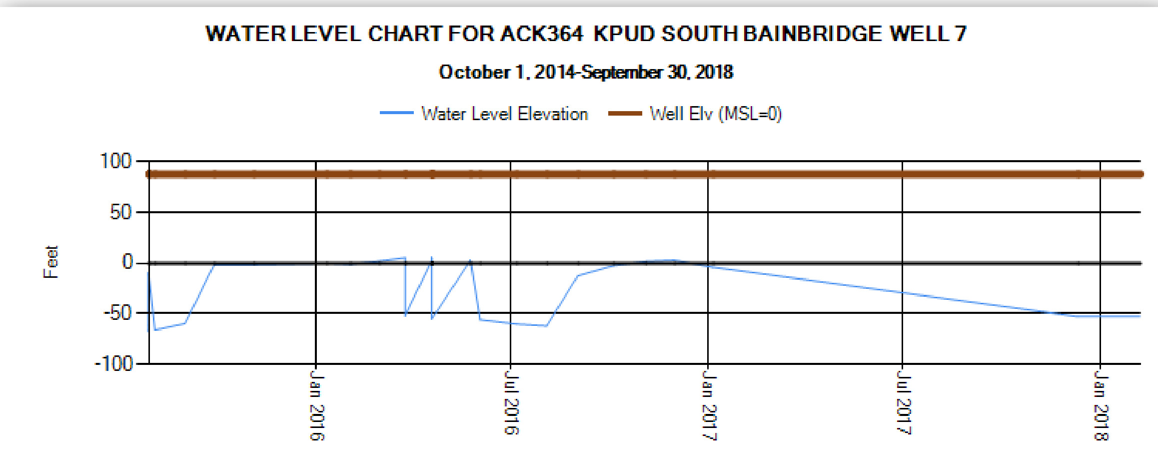
-150
-200
Jan 2016
Jul 2016
Jan 2017
Jul 2017
Jan 2018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-100
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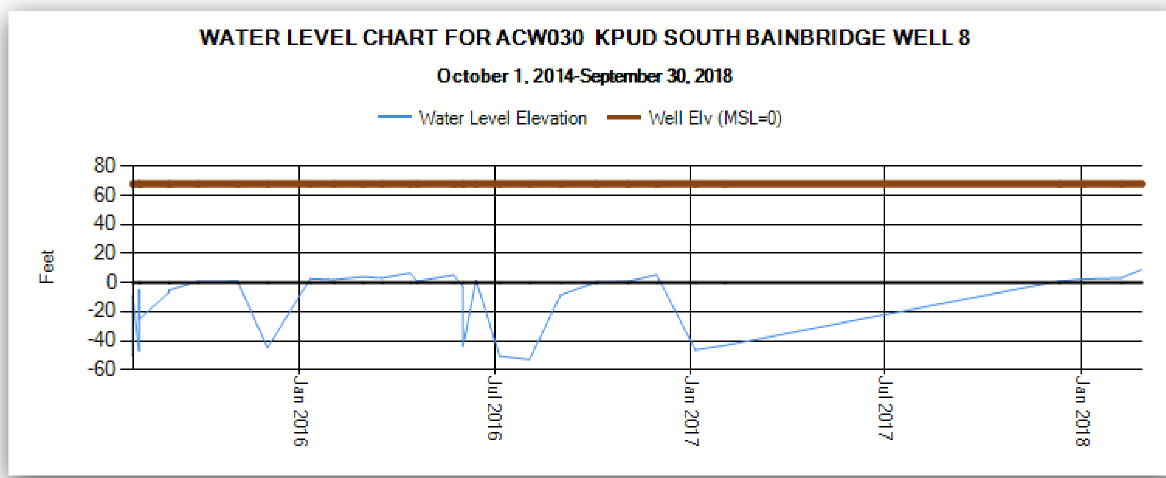
Jul 2016
Jan 2017
Jul 2017
Jan 2018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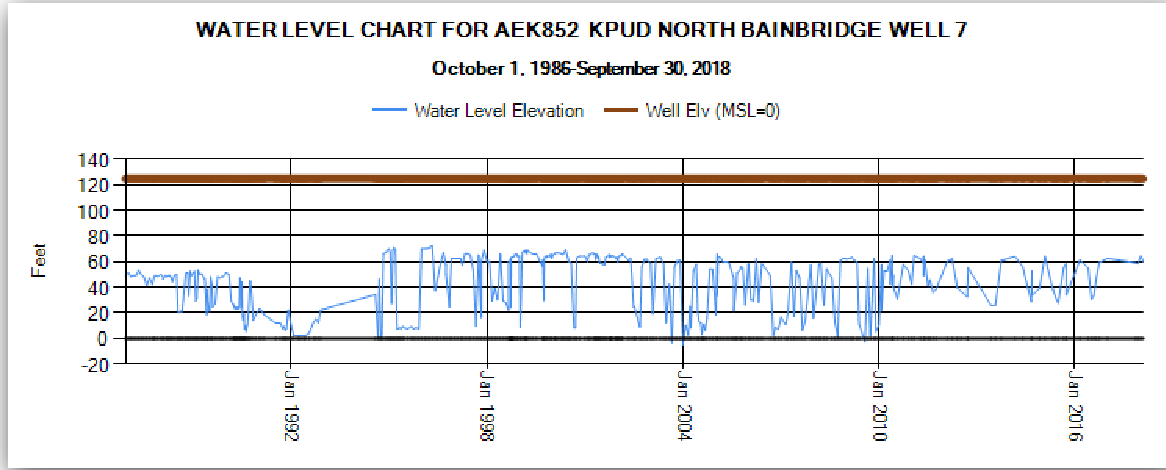
-60
Jan 2016
Jul 2016
Jan 2017
Jul 2017
Jan 2018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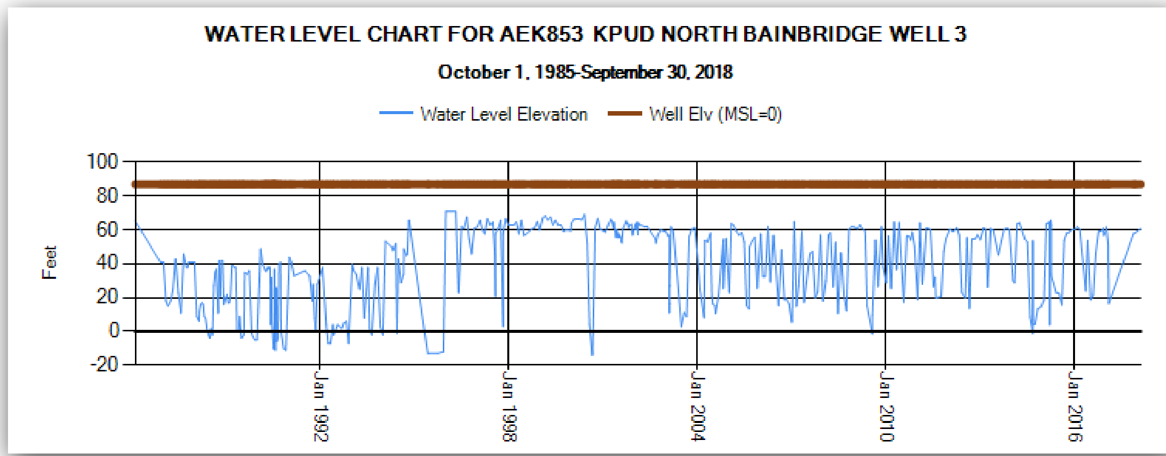
0
-20
Jan 1992
Jan 1998
Jan 2004
Jan 2010
Jan 2016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Feet
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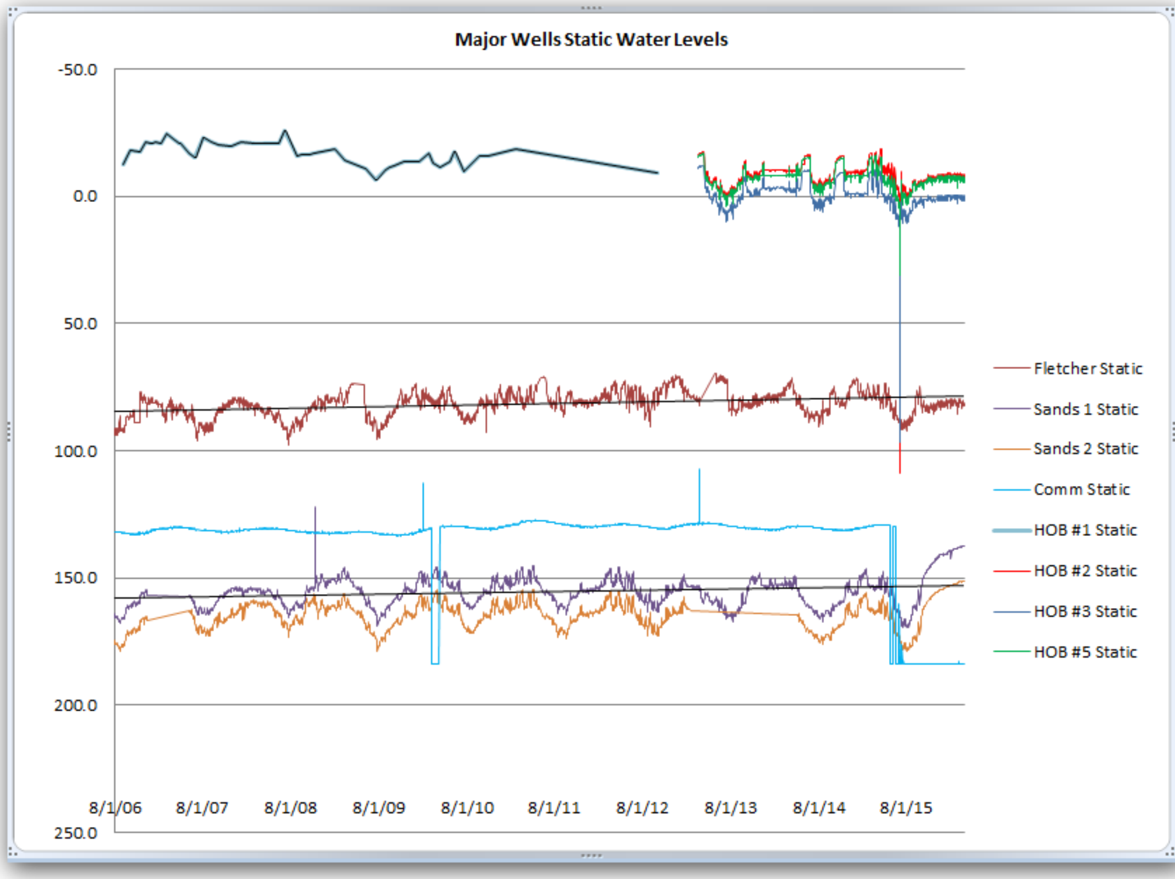
60
40
20
0
-20
Jan 1992
Jan 1998
Jan 2004
Jan 2010
Jan 2016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150.0
200.0
250.0
8/1/06
8/1/07
8/1/08
8/1/09
8/1/10
8/1/11
8/1/12
8/1/13
8/1/14
8/1/15
Fletcher Static
Sands 1 Static
Sands 2 Static
Comm Static
HOB #1 Static
HOB #2 Static
HOB #3 Static
HOB #5 Static

Appendix B: Groundwater Management Plan Content

The program for each groundwater management area will be tailored to the specific conditions of the area. The following guidelines on program content are intended to serve as a general framework for the program, to be adapted to the particular needs of each area. Each program shall include, as appropriate, the following:

(1) An area characterization section comprised of:

1. A delineation of the groundwater area, subarea or depth zone boundaries and the rationale for those boundaries;
2. A map showing the jurisdictional boundaries of all state, local, tribal, and federal governments within the groundwater management area;
3. Land and water use management authorities, policies, goals and responsibilities of state, local, tribal, and federal governments that may affect the area's groundwater quality and quantity;
4. A general description of the locale, including a brief description of the topography, geology, climate, population, land use, water use and water resources;
5. A description of the area's hydrogeology, including the delineation of aquifers, aquitards, hydrogeologic cross-sections, porosity and horizontal and vertical permeability estimates, direction and quantity of groundwater flow, water-table contour and potentiometric maps by aquifer, locations of wells, perennial streams and springs, the locations of aquifer recharge and discharge areas, and the distribution and quantity of natural and man-induced aquifer recharge and discharge;
6. Characterization of the historical and existing groundwater quality;
7. Estimates of the historical and current rates of groundwater use and purposes of such use within the area;
8. Projections of groundwater supply needs and rates of withdrawal based upon alternative population and land use projections;
9. References including sources of data, methods and accuracy of measurements, quality control used in data collection and measurement programs, and documentation for and construction details of any computer models used.

(2) A problem definition section that discusses land and water use activities potentially affecting the groundwater quality or quantity of the area. These activities may include but are not limited to:

1) Commercial, municipal, and industrial discharges
2) Underground or surface storage of harmful materials in containers susceptible to leakage
3) Accidental spills
4) Waste disposal, including liquid, solid, and hazardous waste
5) Storm water disposal
6) Mining Activities
7) Application and storage of roadway deicing chemicals
8) Agricultural activities
9) Artificial recharge of the aquifer by injection wells, seepage ponds, land spreading, or irrigation
10) Aquifer over-utilization causing seawater intrusion, other contamination, water table declines or depletion of surface waters
11) Improperly constructed or abandoned wells
12) Confined animal feeding activities

The discussion should define the extent of the groundwater problems caused or potentially caused by each activity, including effects which may extend across groundwater management area boundaries, supported by as much documentation as possible. The section should analyze historical trends in water quality in terms of their likely causes, document declining water table levels and other water use conflicts, establish the relationship between water withdrawal distribution and rates and water level changes within each aquifer or zone, and predict the likelihood of future problems and conflicts if no action is taken. The discussion should also identify land and water use management policies that affect groundwater quality and quantity in the area. Areas where insufficient data exists to define the nature and extent of existing or potential groundwater problems shall be documented.

(3) A section identifying water quantity and quality goals and objectives for the area which

1. Recognize existing and future uses of the aquifer,

2. Are in accordance with water quality standards of the department, the department of social and health services, and the federal environmental protection agency, and

3. Recognize annual variations in aquifer recharge and other significant Hydrogeologic factors.

(4) An alternatives section outlining various land and water use management strategies for reaching the program's goals and objectives that address each of the groundwater problems discussed in the problem definition section. If necessary, alternative data collection and analysis programs shall be defined to enable better characterization of the groundwater and potential quality and quantity problems. Each of the alternative strategies shall be evaluated in terms of feasibility, effectiveness, cost, time and difficulty to implement, and degree of consistency with local comprehensive plans and water management programs such as the coordinated water system plan, the water supply reservation program, and others. The alternative management strategies shall address water conservation, conflicts with existing water rights and minimum instream flow requirements, programs to resolve such conflicts, and long-term policies and construction practices necessary to protect existing water rights and subsequent facilities installed in accordance with the groundwater management area program and/or other water right procedures.

(5) A recommendations section containing those management strategies chosen from the alternatives section that are recommended for implementation. The rationale for choosing these strategies as opposed to the other alternatives identified shall be given;

(6) An implementation section comprised of:

1. A detailed work plan for implementing each aspect of the groundwater management strategies as presented in the recommendations section. For each recommended management action, the parties responsible for initiating the action and a schedule for implementation shall be identified. Where possible, the implementation plan should include specifically worded statements such as model

ordinances, recommended governmental policy statements, interagency agreements, proposed legislative changes, and proposed amendments to local comprehensive plans, coordinated water system plans, basin management programs, and others as appropriate;

2. A monitoring system for evaluating the effectiveness of the program;

3. A process for the periodic review and revision of the GWMP.

Appendix C: Groundwater Management Plan Experience

a. **King County**:

i. South King County – Draft completed in 2003 but never certified nor approved. Its implementation is limited to water purveyors and thus, the implementation is far less then described in their GWMP.

ii. Issaquah Creek Valley: Plan approved 1999 and implemented in the early 2000's. It became inactive as of 2007 due to lack of funding. The paired back activity deemed to be of value was merged into existing groundwater monitoring programs for Sammamish.

iii. East King County - Plan approved 1999 and implemented in the early 2000's. It became inactive as of 2004 due to funding issues. No current actions being conducted.

iv. Redmond-Bear Creek Valley - Plan approved 1999 and implemented in the early 2000's. It became inactive as of 2007 due to funding issues. No county coordinated activities currently being conducted. Data collection is limited to water purveyors and cities.

v. Vashon-Maury Island – Plan approved 2000 and has been pared back to a well monitoring plan which is presently active. The impetus for the implementation of the plan was discovery of chlorine levels in a few wells on the island. This problem has not persisted. The GWMP was approved and implemented which includes an oversight Committee. Primary concern is with growth impacts as it related to: overuse, contamination (land-use activities [i.e. pesticides] and septic concerns), saltwater intrusion, and loss of recharge zones. The groundwater monitoring program, which has an annual cost of approximately $200,000, consists of:

1. 24 sites for water quality on an annual basis

2. 9 monitoring wells have water level data loggers providing daily data – downloaded quarterly

3. 4 self-monitoring volunteers who take monthly water levels and monthly meter readings

The estimate for the entire program as envisioned in 1998 was $500,000 at that time.

b. **Island County:** Island County experienced significant sea water intrusion issues at several of their coastal wells. Benefiting from King County's experience they decided to address their problem through a watershed planning process. They became the first county in the state to develop a sea water intrusion policy not using chloride as the primary indicator. Instead they created an Island County Code with two prongs for evaluating sea water intrusion risks. Primarily they are using the trend of in- well measured high water level elevations. They developed a matrix where projects are rated for risk and go through a sea water intrusion planning process. They established water level criteria which are designed to prevent sweater intrusion. They monitor 60 wells and are funded through a clean water utility tax.

c. **Kitsap County:** Kitsap County developed a Groundwater Management Plan in 1991. This recommended a hydrologic monitoring network which Kitsap PUD established and presently maintains. It currently consists of 28 precipitation monitoring sites, 28 stream flow monitoring sites, 128 groundwater (level) monitoring sites and 80 sites that are monitored (semi-annually) for seawater intrusion (link: http://kpudhydrodata.kpud.org/). The purpose of the network is to provide information relevant to understanding long term sustainability of groundwater resources. In addition, Kitsap PUD owns and operates 27 “Group A” public water systems. For these systems they do not rely on EWLs but maintain a focus on well water levels for short term sustainable production goals. Source wells for these systems are routinely monitored for water quality as required by the Safe Drinking Water Act. Kitsap PUD has 2 FTEs allocated to the monitoring network at an annual cost of approximately $238,000.

Appendix D: Definitions

Aquifer Storage - groundwater stored in aquifers or in water-bearing confining layers between the aquifers