CITY OF BAINBRIDGE ISLAND

Groundwater on Bainbridge Island: A Fact Sheet

We depend on groundwater for all our water-supply needs on Bainbridge Island. Groundwater also supports our streams and wetlands. The Environmental Technical Advisory Committee (ETAC) for the City of Bainbridge Island consists of community volunteers with expertise in environmental issues. ETAC prepared this fact sheet to provide a summary of our understanding of the groundwater system and as a starting point for the development of a Groundwater Management Plan (GWMP). The GWMP will provide the necessary framework to responsibly manage this precious resource today and into the future.

What is Groundwater?

- According to the USGS, groundwater is water that exists underground in saturated zones beneath the land surface (Fig. 1). The upper surface of the saturated zone is called the water table. Contrary to popular belief, groundwater generally does not form underground rivers. It fills the pores and fractures in underground materials (soil, sand, gravel, and rocks), much the same way that water fills a sponge. If groundwater flows naturally out of rock materials or if it can be removed by pumping (in useful amounts), the permeable saturated zones are called aquifers. Groundwater moves slowly from higher to lower water levels, typically at rates of 3 to 25 inches per day. As a result, water could remain in an aquifer for hundreds or thousands of years.
- Aquifers are separated by less permeable layers of soil or rock called confining layers. Despite these confining layers, there is usually some water exchange between aquifers.
- Groundwater quantity (storage in aquifers) is estimated by measuring water levels in wells. Water levels vary seasonally due to rainfall and pumping, so measurements at the same time each year will give the best information on changes in the amount of groundwater storage in aquifers on an annual basis (from: USGS FAQs; www.usgs.gov/faq/water).
- Some surface waters (i.e., ponds, wetlands, streams) receive significant contributions from groundwater depending on groundwater levels.

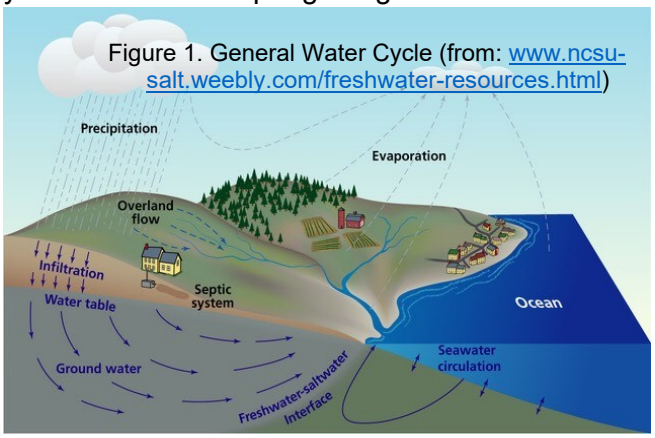


Figure 1. General Water Cycle (from: www.ncsu-salt.weebly.com/freshwater-resources.html)

Groundwater on Bainbridge Island

- According to the USGS, there are five aquifers on Bainbridge Island (shown in Fig. 2 cross-section of BI from Port Orchard Bay on the left to Puget Sound on the right). However, the permeable interbeds (QC1pi) aquifer produces little water. The four main aquifers are:
  - **Vashon (Perched)(Qva)** (water table at elevation 0 to 300 ft),
  - **Sea Level (QA1)** (-200 to +200 ft),
  - **Glaciomarine (QA2)** (-500 to -300 ft), and
  - **Deep (Fletcher Bay)(QA3)** (-900 to -600 ft)

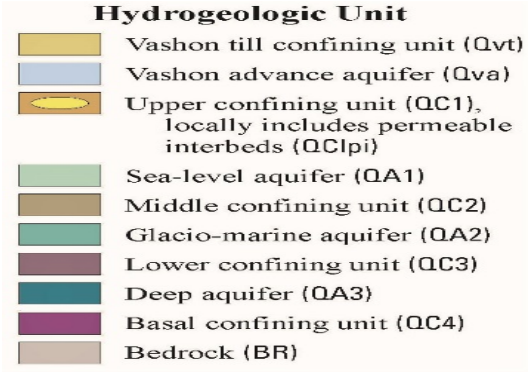
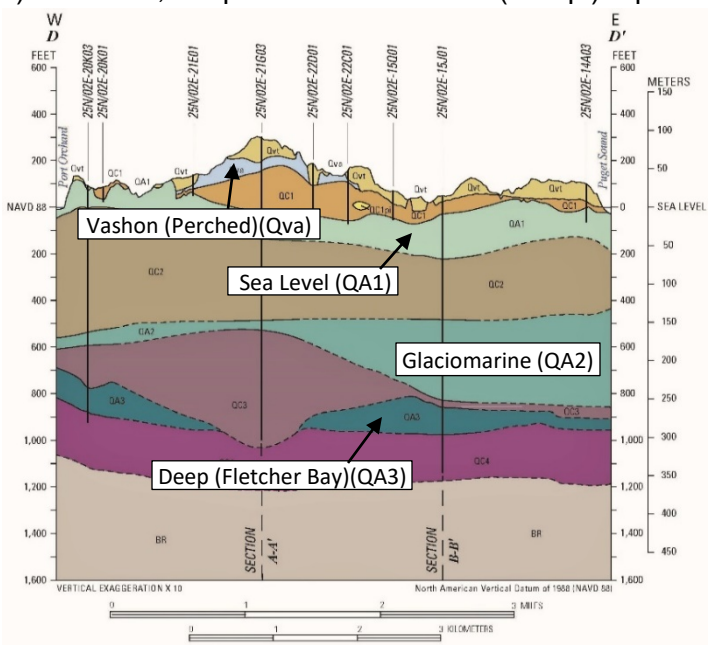


Figure 2. Hydrogeologic Units on Bainbridge Island (from: Frans and others, 2011)



Fact Sheet concept approved by COBI City Council in November 2018; reviewed by USGS and KPUD in December 2020; revised and approved by ETAC in February 2021; approved by COBI City Council in April 2021

- The four major aquifers are separated by five confining layers: Qvt (Vashon till near ground surface), QC1, QC2, QC3, and QC4.
- 97% of usage (pumped well water) comes from the Vashon (Qva), sea level (QA1), and deep aquifers (QA3).
- All the recharge water for the aquifers originates as precipitation (and septic-system returns) on the island, except for about 5% that flows under Port Orchard Bay from the Kitsap Peninsula to the sea level, glaciomarine, and deep aquifers (from: Frans and others, 2011).

Sole Source Aquifer Designation

- In 2013, USEPA designated the aquifers of BI as a sole source aquifer, meaning that it "supplies at least 50% of the drinking water consumed in the area overlying the aquifer, and for which there is no alternative source or combination of alternative drinking water sources which could physically, legally, and economically supply those dependent upon the aquifer" (from: www.epa.gov/dwssa).
- Sole source designation can affect Federal funding for any project with the potential to contaminate the groundwater on Bainbridge Island.

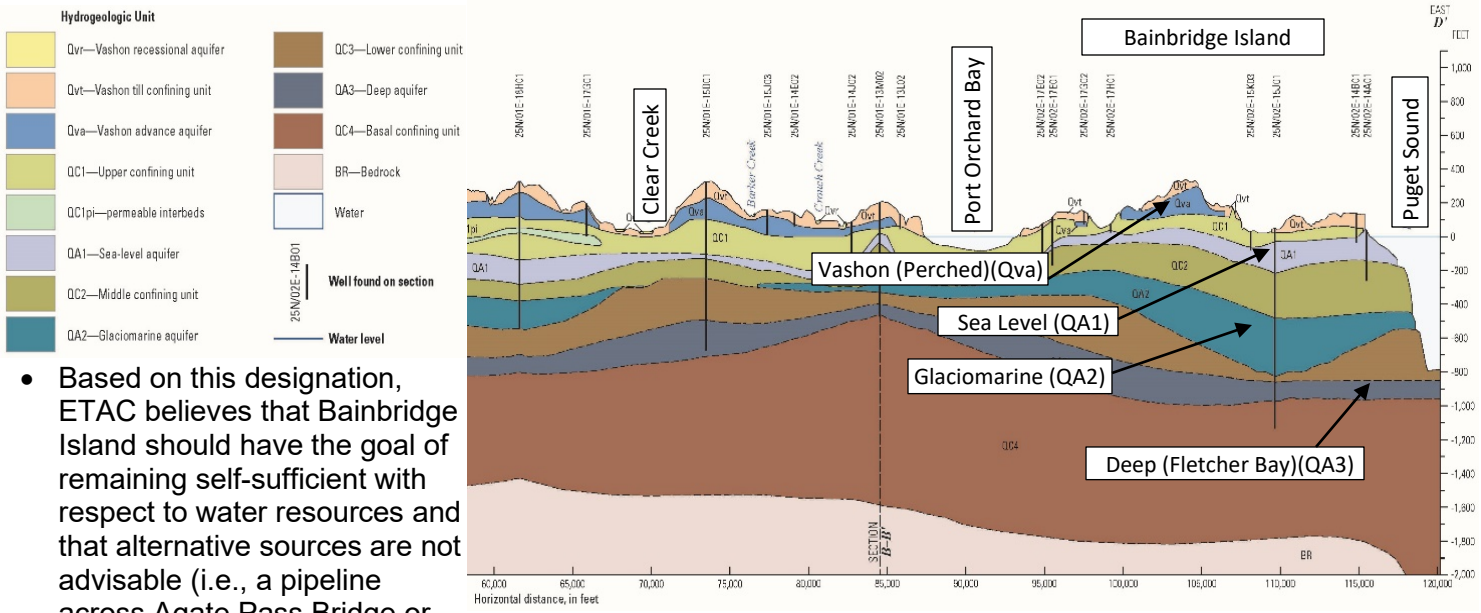


Figure 3. Hydrogeologic Units on Kitsap Peninsula (modified from: Welch and others, 2014)

- Based on this designation, ETAC believes that Bainbridge Island should have the goal of remaining self-sufficient with respect to water resources and that alternative sources are not advisable (i.e., a pipeline across Agate Pass Bridge or desalination of seawater).
- The cross-section of the Kitsap Peninsula (Fig. 3) from Clear Creek (Silverdale) on the left to BI/Puget Sound on the right depicts the connection of the glaciomarine and deep aquifers under Port Orchard Bay. However, as stated above the contribution of off-island water from these aquifers is only about 5% of the total GW recharge for BI aquifers, as the actual movement towards BI depends on several factors – pumping rates, recharge rates, and head/pressure differences between BI and Kitsap Peninsula.

Seawater Intrusion

- Seawater can potentially be drawn into near-shoreline wells if groundwater is over-pumped.
- COBI checks for potential seawater intrusion (Fig. 4) by monitoring chloride as a surrogate for seawater in near-shoreline wells (Cl>100 mg/L is used as an early warning level for potential seawater intrusion).
- Historically, seawater intrusion has not been a significant problem, but as an island this issue is always of concern.
- Freshwater sits on top of seawater due to density differences; hence, for every 1 foot of GW above sea level, GW extends roughly 40 feet below sea level.

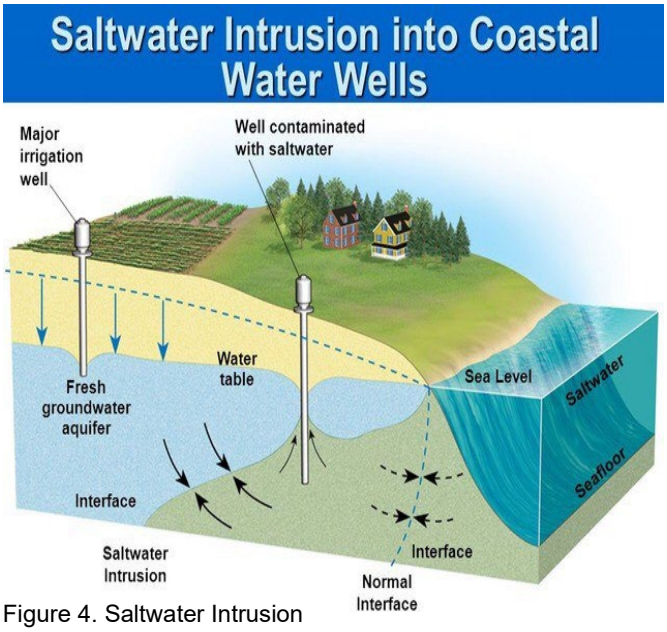


Figure 4. Saltwater Intrusion (from: www.whoi.edu/oceanus/feature/charette)

USGS Bainbridge Island Groundwater Model

The numerical groundwater models developed by USGS to model both Bainbridge Island and the entire Kitsap Peninsula use the free, publicly-available, industry-standard MODFLOW program (https://www.usgs.gov/mission-areas/water-resources/science/modflow-and-related-programs?qt-science_center_objects=0#qt-science_center_objects). The model specifics for the Bainbridge Island application are (Fig. 5):

- Horizontal discretization (grid size) – 800 feet by 800 feet; total of 139 columns by 197 rows for all of Bainbridge Island. Cells are categorized by:
  1. bordering surface waters (streams, coastline) are specified "drains" (flows from GW to SW),
  2. presence or absence of the Vashon till confining layer in the surface layer, and
  3. Gazzam Lake represented by "general head" recharge source (flows from SW to GW)
- Vertical discretization – 33 layers from land surface to bedrock
- Model inputs – monthly precipitation, soils, surface water features, streamflow, wells and monthly pumping, measured monthly water levels
- Model outputs – simulated monthly water levels
- Model calibration – calibrate simulated water levels to measured water levels; adjust model inputs until there is an optimized match of water levels

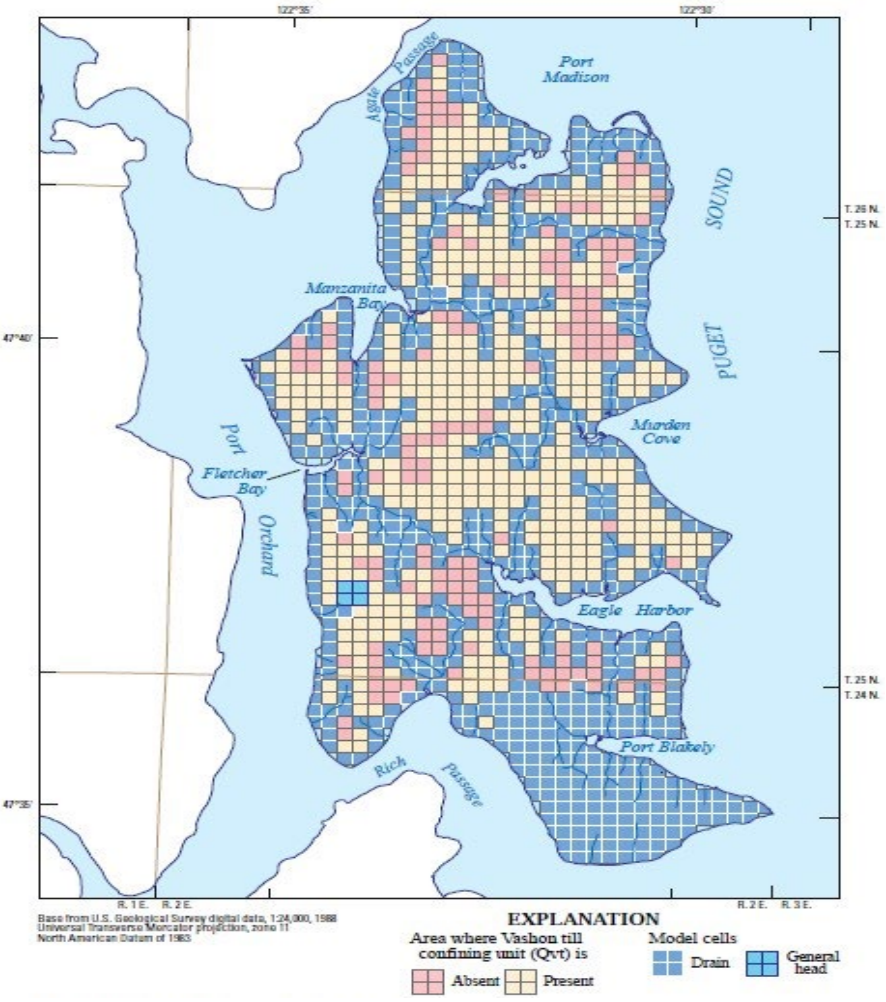


Figure 5. MODFLOW Grid for BI (from: Frans and others, 2011)

Water Budget for Bainbridge Island

In its' simplest terms, the simulated water budget for Bainbridge Island from the USGS model can be expressed as (Fig. 6):

Inflows – Outflows = Change in Storage

- Inflows: recharge from precipitation (85-90%); recharge from septic systems (5-10%); off-island aquifer flow to BI from Kitsap Peninsula (5%)
- Outflows: pumping (5-10%); discharge to BI surface waters (50-60%); discharge to Puget Sound (30-40%)
- Change in Storage: reflected in (calculated from) change in water levels

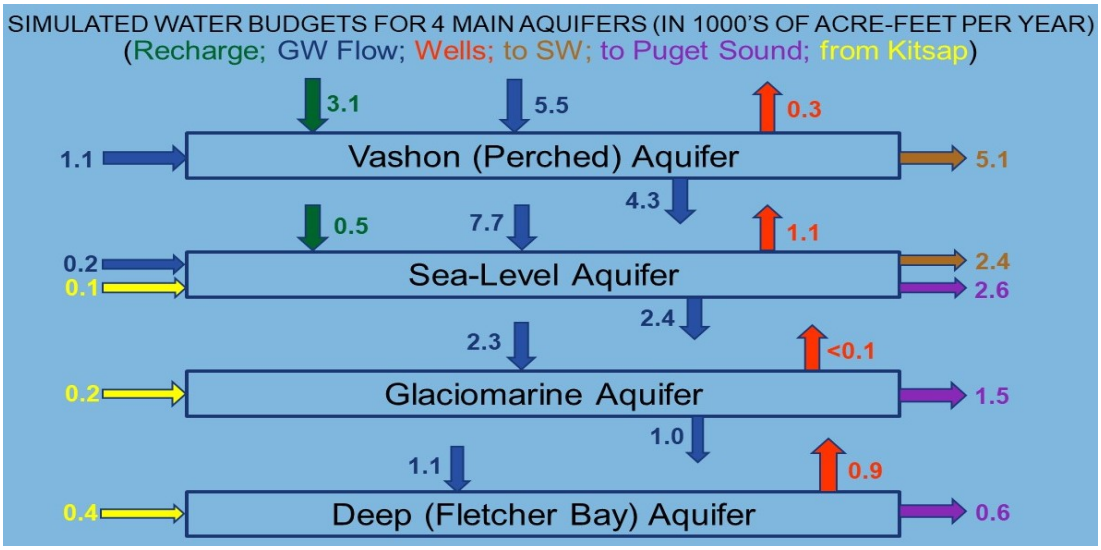


Figure 6. Water Budget for Bainbridge Island Aquifers (modified from: Frans and others, 2011)

USGS Kitsap Groundwater Model

- Simulations using the MODFLOW program indicate that changes in groundwater recharge have a larger effect on water levels than changes in groundwater pumping.
- Two examples of this for the Kitsap Peninsula: A 15% decrease in long-term annual recharge resulted in up to an 18% decrease in stream baseflow over seven years, while a 15% increase in long-term annual groundwater pumping resulted in up to a 0.3% decrease in stream baseflow over seven years (Frans and Olsen, 2016).

Importance of Monitoring

Although the number and frequency of water-level monitoring wells is in flux, long-term monitoring wells are shown in Fig. 7 by aquifer.

- Changes in water levels over the long-term provide an indication of potential issues (water availability, seawater intrusion).
- Thus, COBI and KPUD should continue monitoring water levels and water quality, and expand the monitoring to include more near-shoreline wells.
- Monitoring of water levels in Fall (lowest) and Spring (highest) is most important, depending on specific precipitation trends.

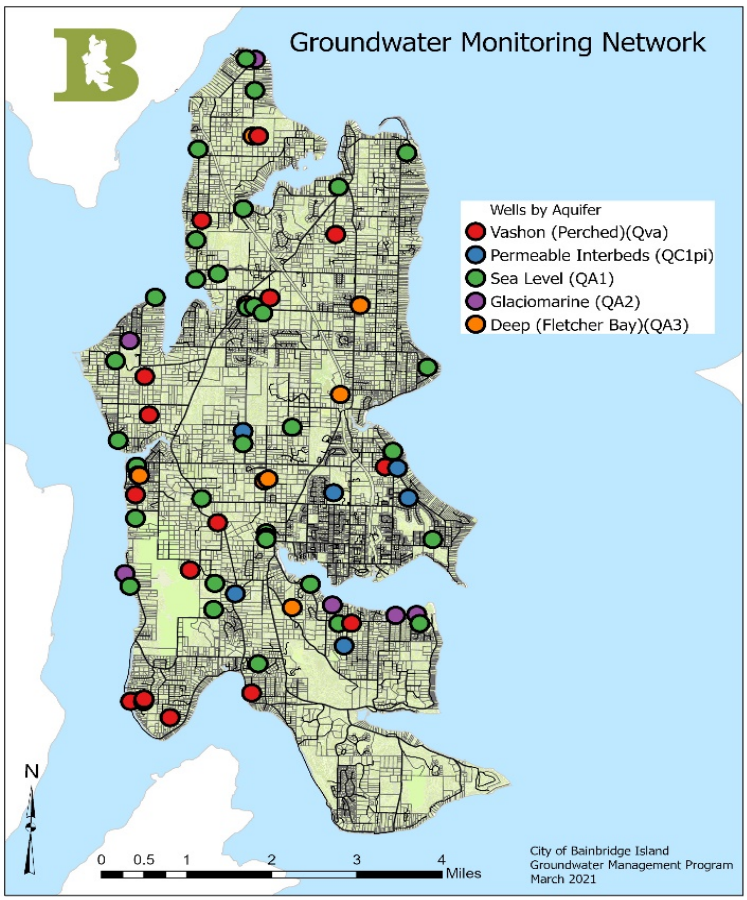


Figure 7. Long-term Monitoring Wells on Bainbridge Island (from: Christian Berg, COBI GW Management Program, written communication, March 9, 2021)

Recommendations for the Groundwater Management Plan

- COBI and KPUD should expand their groundwater and surface water monitoring program
- COBI should create aquifer conservation zones to enhance recharge, develop a water conservation program to reduce water usage, incentivize and facilitate the reuse of stormwater and grey water, and develop a community-wide education program on the aquifers of BI
- COBI should improve wastewater treatment to tertiary and recharge GW with effluent via surface infiltration instead of discharging the effluent to Puget Sound
- COBI should improve stormwater management to keep more stormwater on BI for recharging the aquifers instead of running off to Puget Sound
- COBI should coordinate recommendations in the GWMP with those in the Climate Action Plan (https://www.bainbridgewa.gov/DocumentCenter/View/14270/Draft-Bainbridge-Island-Climate-Action-Plan-for-City-Council-Review-October-22nd-2020)

References:

- Frans, L.M., Bachmann, M.P., Sumioka, S.S., and Olsen, T.D., 2011, Conceptual model and numerical simulation of the groundwater-flow system of Bainbridge Island, Washington: USGS Scientific Investigations Report 2011-5021, 96 p., www.doi.org/10.3133/sir20115021
- Welch, W.B., Frans, L.M., and Olsen, T.D., 2014, Hydrogeologic framework, groundwater movement, and water budget of the Kitsap Pensinsula, west-central Washington: USGS Scientific Investigations Report 2014-5106, 44 p., www.doi.org/10.3133/sir20145106
- Frans, L.M. and Olsen, T.D., 2016, Numerical simulation of the groundwater-flow system of the Kitsap Peninsula, west-central Washington: USGS Scientific Investigations Report 2016-5052, 63 p., www.doi.org/10.3133/sir20165052

Abbreviations: BI – Bainbridge Island; SW – surface water; GW – groundwater; COBI – City of Bainbridge Island; KPUD – Kitsap Public Utility District; USGS – U.S. Geological Survey; Cl – chloride; ETAC – Environmental Technical Advisory Committee; USEPA – U.S. Environmental Protection Agency; GWMP – Groundwater Management Plan