MEMORANDUM

Project No.: 140369

September 1, 2017

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Charles Krumheuer, COBI
Martin Sebren, Kitsap County PUD (KPUD)
Mark Morgan, KPUD

From:

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Re: Groundwater Production Field Test Summary and Comparison

This memorandum describes the findings from the field test conducted to evaluate changes in groundwater conditions associated with temporarily transferring groundwater production from the deeper Fletcher Bay Aquifer to the Sea Level Aquifer for the two largest water systems on Bainbridge Island. These two systems include the City of Bainbridge Island (COBI) Winslow Water System, and the Kitsap Public Utility District (KPUD) North Bainbridge Water System. The field test results are summarized, with reference to simulated conditions using the Bainbridge Island groundwater model reported in a memorandum dated December 2, 2016 (Aspect, 2016b). Aspect Consulting, LLC (Aspect) conducted this analysis and reporting under a cost-sharing agreement between the COBI and the KPUD.

Summary of Findings

The COBI Winslow Water System and the KPUD North Bainbridge Water System successfully conducted a field test of temporarily transferring production from the Fletcher Bay Aquifer to the Sea Level Aquifer. The field test was designed to address issues of water system and aquifer system resiliency, as well as the accuracy of the Bainbridge Island groundwater model results. The field test was conducted from January through April 2017 with production rates approximating planned and simulated conditions, followed by normal operations. Observed groundwater conditions were
provided through May 2017. Above normal precipitation was reported regionally before and during the aquifer test.

Overall, the aquifer test was a good demonstration of how the water systems and aquifer systems respond to temporarily transferring production from the Fletcher Bay Aquifer to the Sea Level Aquifer. Based on the results of the field test, the Sea Level Aquifer appears resilient to temporary increases in production, and the benefits and risks for seasonally transferring production from the Fletcher Bay aquifer to the Sea Level Aquifer appear neutral. We recommend continued monitoring of water levels and water quality to confirm the sustainable use of the aquifer resources as sole-source drinking water supplies.

The Bainbridge Island groundwater model generally simulated the changes in conditions observed during the field test. Differences between model results and actual conditions were attributable to differences between planned and actual production, above normal precipitation, and model bias.

**Field Test Description**
The groundwater production field test started on January 17, 2017, and ended on April 24, 2017. During the field test, production from wells completed in the Fletcher Bay Aquifer were safely reduced, and water demand was met by safely increasing production from wells completed in the Sea Level Aquifer. Groundwater conditions in production wells and nearby monitoring wells were monitored through May 31, 2017. Production and monitoring wells are listed in Attachment 1, and their mapped locations are shown on Figure 1.
**COBI Winslow Water System**

For the field test, COBI’s Winslow Water System planned to meet demand with 50 percent of production from wells completed in the Sea Level Aquifer and 50 percent of production from the wells completed in the Fletcher Bay Aquifer. This planned production distribution was also used to simulate the field test (Aspect, 2016b). Under actual field conditions, the distribution of production operationally achieved was 43 percent from Sea Level Aquifer wells and 57 percent from Fletcher Bay Aquifer wells. Table 1 shows the average production distribution for the COBI Winslow Water System, and compares the distribution from January through May 2016, the planned distribution, and the actual distribution during the field test in 2017.

Production from the COBI Winslow Water System wells in the Fletcher Bay Aquifer was distributed very differently during the field test compared to the previous year. Due to maintenance activities, Sands Well 1 and Sands Well 2 were not operated from November 2015 through February 2016, and production was limited in April and May 2016. As a result, the Fletcher Bay well delivered nearly half of the water supply from January to April 2016.

### Table 1. Average Production Distribution for COBI Winslow Water System

<table>
<thead>
<tr>
<th>Well Name</th>
<th>Ecology Well ID</th>
<th>Production Distribution from January to April 2016</th>
<th>Planned/Modeled Distribution of Production during Operational Scenario</th>
<th>Actual Production Distribution during Field Test from January to April 2016</th>
</tr>
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<tbody>
<tr>
<td><strong>Sea Level Aquifer Wells</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
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<td>16%</td>
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<td>19%</td>
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<td>1%</td>
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<td>7%</td>
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<td>0%</td>
<td>0%</td>
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<td><strong>Fletcher Bay Aquifer Wells</strong></td>
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<td>Sands Well 2</td>
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<td>14%</td>
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</table>

For context, Figure 2 shows the COBI Winslow Water System production from 2015 through the field test. Figure 3 shows the distribution of COBI production between wells completed in the Sea Level Aquifer (upper graph) and the Fletcher Bay Aquifer (lower graph).
**KPUD North Bainbridge Water System.**

For the field test, KPUD’s North Bainbridge Water System planned to meet demand with 100 percent production from wells completed in the Sea Level Aquifer. Under actual field conditions, the distribution of production operationally achieved was 90 percent from the Sea Level Aquifer wells and 10 percent from the Fletcher Bay Aquifer well. Table 2 shows the average production distribution for the KPUD North Bainbridge Water System, and compares the distribution from January through May of 2016, the planned distribution, and the actual distribution during the field test in 2017.

<table>
<thead>
<tr>
<th>Well Name</th>
<th>Ecology Well ID</th>
<th>Production Distribution from January to April 2016</th>
<th>Planned/Modeled Distribution of Production during Operational Scenario</th>
<th>Actual Production Distribution during Field Test</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sea Level Aquifer Wells</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>Well 3</td>
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<td>62%</td>
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<td>Well 9</td>
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<td>55%</td>
<td>0%</td>
<td>10%</td>
</tr>
</tbody>
</table>

For context, Figure 4 shows the KPUD North Bainbridge Water System production from 2015 through the field test. Figure 5 shows the distribution of KPUD production between wells completed in the Sea Level Aquifer (upper graph) and the Fletcher Bay Aquifer (lower graph).
**Observed Precipitation**

During the field test, the precipitation rates were generally greater than normal, indicating that recharge rates were greater than normal. The effects of above normal recharge would vary spatially depending on infiltration rates, depth to groundwater, aquifer thickness, and relative aquifer depth. In general, above normal recharge would result in increased groundwater levels, which would be more pronounced in shallower aquifers than in deeper aquifers. The cumulative rainfall starting January 1 is shown for both 2016 and 2017 in Figure 6.

![Figure 6: Cumulative Precipitation as Indication of Recharge](image-url)
Field Test Results
Both the COBI and the KPUD water systems provided groundwater monitoring data from production wells, and the COBI Groundwater Monitoring Program provided data for nearby monitoring wells (Figure 1). This data included water levels and groundwater quality. The monitoring schedule is provided as Attachment 1.

Observed Changes in Groundwater Levels
To assess changes in groundwater levels, the static water levels observed in 2017 during the field test were compared to 2016 static water levels. Static water levels do not account for potential head losses during pumping associated with the well screen.

Similar to the groundwater model results, observed water levels were lower at wells with greater production in 2017 than in 2016, and water levels were higher at wells with lower production. However, quantitative comparison between groundwater model results and observed conditions should be made in the context of differences between simulated groundwater production and recharge rates, and actual conditions.
COBI Winslow Water System

At COBI’s Fletcher Bay well in the Fletcher Bay Aquifer, water levels in 2017 were between approximately 3 and 6 feet higher than in 2016. At Sands Well 1 and Sands Well 2, also in the Fletcher Bay Aquifer, water levels in 2017 were between approximately 1 and 9 feet lower than in 2016. These observed changes were not accurately simulated during the modeling effort primarily due to the substantial differences in production distribution between 2016 and 2017. As previously mentioned, Sands Well 1 and Sands Well 2 had lower than normal production during early 2016 due to maintenance activities.

In the Sea Level Aquifer, average water levels observed in 2017 at the Head of the Bay (including wells #2, #3, and #5) were similar to those observed in 2016. These stable water levels for the Head of the Bay wells were not simulated during the modeling effort, due to one or more of the following factors: lower than planned production, above normal recharge, and model bias.

Figure 7 shows the monthly average changes in groundwater levels for the COBI Winslow Water System during and just after the field test.

![Figure 7. Observed Groundwater Level Changes—COBI Winslow Water System](image-url)
KPUD North Bainbridge Water System

At KPUD’s Well 9 in the Fletcher Bay Aquifer, water levels observed in 2017, during the field test, were between approximately 4 and 8 feet higher than in 2016, reflecting lower production during the field test. Model results indicated higher water levels (approximately 12 feet).

At Well 7 in the Sea Level Aquifer, water levels in 2017 were between 3 and 6 feet lower than in 2016, reflecting the increased production during the field test. Comparable water levels at Well 3\(^1\) were not available for 2016, so a similar comparison could not be made. Following the test, the water level in Well 7 recovered to levels above those measured in 2016. Model results indicated water levels would have been up to 20 and 25 feet below normal at Wells 3 and 7, respectively.

Differences between simulated and actual water levels for the KPUD North Bainbridge Water System may reflect one or more of the following factors: slightly different production than planned, above normal recharge during 2017, and model bias. Figure 8 shows the changes in groundwater levels for the KPUD North Bainbridge Water System during and just after the field test.

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\(^{1}\) Comparisons of Well 7 and Well 9 water levels were made using monthly averages of continuous data from 2016 and 2017, but continuous data for Well 3 from 2016 was not available. Monthly water level measurements at Well 3 from 2016 and 2017 are available, however, measurements during 2016 and 2017 were not made during comparable conditions: measurements from 2016 were primarily collected during static conditions, while measurements from 2017 were collected during pumping or recovery conditions.
Groundwater Level Changes at Nearby Monitoring Wells

Groundwater levels in monitoring wells near production wells did not appear influenced by changes in production during the field test. Groundwater levels in some monitoring wells completed in the Perched Aquifer, the Semi-Perched Aquifer, and the Sea Level Aquifer increased during the field test, possibly reflecting the above average recharge to groundwater. Groundwater levels in other monitoring wells appeared stable.

Cost Analysis of Field Test

Cost analysis results indicate that the costs for the COBI Winslow Water System were temporarily greater during the field test than during 2016 operations, and the costs for the KPUD North Bainbridge Water System were temporarily less during the field test than during 2016 operations. However, it appears both water systems returned to little-to-no cost benefit by May 2017, compared to 2016 operations. This cost analysis was based on changes in static water levels, and does not consider the well efficiency and actual pumping lift costs. We recommend that costs for electricity and operations/maintenance be compared for a more accurate analysis. The cumulative projected pumping costs for each water system were calculated starting in January 2017, and are shown in Figure 9.

Figure 9. Groundwater Production Field Test Cost Analysis
**Observed Water Quality**

The field test observations showed no trend in water quality associated with seawater intrusion during this exercise, similar to model results. Higher frequency monitoring during the field test provided additional information regarding the ranges in observed specific conductance and/or chloride. In all cases, chloride concentrations at production wells were significantly less than the regulatory threshold.

The Bainbridge Island groundwater model simulated Puget Sound as a potential source of seawater, and did not simulate other sources of chloride or other water quality parameters. Observed water quality and operational scenario model results are consistent with results from the long-term modeling analysis supporting the aquifer system carrying capacity assessment (Aspect, 2016a). The temporary operational changes field-tested as part of this exercise do not appear to pose a risk of causing seawater intrusion.

**Conclusions**

The COBI Winslow Water System and the KPUD North Bainbridge Water System conducted a field test of temporarily transferring production from the Fletcher Bay Aquifer to the Sea Level Aquifer. The field test was designed to address issues of water system and aquifer resiliency, as well as the accuracy of the Bainbridge Island groundwater model results. The field test was successfully conducted from January through April 2017, followed by normal production.

Overall, the aquifer test was a good demonstration of how the water systems and aquifer systems respond to temporarily transferring production from the Fletcher Bay Aquifer to the Sea Level Aquifer. The field test did not appear to influence water levels in monitoring wells near the production wells, and there was no indication of seawater intrusion. Based on the results of the field test, the Sea Level Aquifer appears resilient to temporary increases in production, and the benefits and risks for seasonally transferring production from the Fletcher Bay aquifer to the Sea Level Aquifer appear neutral. We recommend continued monitoring of water levels and water quality to confirm the sustainable use of the aquifer resources as sole-source drinking water supplies.

The Bainbridge Island groundwater model generally simulated the changes in conditions observed during the field test. Differences between model results and actual conditions were attributable to differences between planned and actual production, above normal precipitation, and model bias.

**References**

Aspect, 2016a, Bainbridge Island Groundwater Model: Aquifer System Carrying Capacity Assessment (Task 3 Scenario), Prepared for the City of Bainbridge Island, March 2, 2016.


**Limitations**

Work for this project was performed for the City of Bainbridge Island and the Kitsap Public Utility District (Clients), 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
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**Attachments**

Table 1—Average Production Distribution for COBI Winslow Water System (in text)
Table 2—Average Production Distribution for KPUD North Bainbridge Water System (in text)
Figure 1—Monitoring Locations
Figure 2—COBI Winslow Water System Production Summary
Figure 3—COBI Production Distribution by Aquifer
Figure 4—KPUD North Bainbridge Water System Production Summary
Figure 5—KPUD Production Distribution by Aquifer
Figure 6—Cumulative Precipitation as Indication of Recharge (in text)
Figure 7—Observed Groundwater Level Changes—COBI Winslow Water System (in text)
Figure 8—Observed Groundwater Level Changes—KPUD North Bainbridge Water System (in text)
Figure 9—Groundwater Production Field Test Cost Analysis (in text)

Attachment 1—Observation Monitoring Network

V:\140369 COBI - GW Assessment and Modeling Support\Deliverables\Aquifer Test Technical Memo\Aquifer Test Tech Memo_Final.docx
Monitoring Locations
Groundwater Production Field Test
City of Bainbridge Island
Bainbridge Island, Washington

Well Type (Indicated by Symbol)
- City of Bainbridge Island Production Well
- KPUD Production Well
- KPUD Observation Well
- Private and Exempt Wells

Aquifer (Indicated by Color)
- Fletcher Bay Aquifer
- Sea Level Aquifer
- Semi-perched Aquifer
- Perched Aquifer

Basemap Layer Credits || Copyright (C) 2015 - Kitsap County, Puget Sound Aerial Mapping Project
COBI Sea Level Aquifer Production Summary

Monthly Production (Million Gallons)


2016 Production  Field Test

COBI Fletcher Bay Aquifer Production Summary

Monthly Production (Million Gallons)


2016 Production  Field Test

Figure 3

COBI Production Distribution by Aquifer

Groundwater Production Field Test

Bainbridge Island, WA
KPUD North Bainbridge Water System Production Summary

- **Total Production**
- **Fletcher Bay Aquifer Production**
- **Sea Level Aquifer Production**

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**Figure 4**

**Groundwater Production Field Test**

Bainbridge Island, WA
Figure 5

KPUD Production Distribution by Aquifer

Groundwater Production Field Test
Bainbridge Island, WA
ATTACHMENT 1

Observation Monitoring Network
## Attachment 1 - Observation Monitoring Network (Jan 17 - Apr 24, 2017)

### 140369 Groundwater Production Field Test

#### Bainbridge Island, WA

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<th>Longitude</th>
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<th>Surface Elevation (NAVD 88)</th>
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**Notes:**

1. New water level transducers were installed in North Bainbridge 3 and North Bainbridge 6 in Jan 2017 and Dec 2016 respectively. They were previously monitored monthly.