

**Study Team Response to Comments and Recommendations  
contained in the  
NWRI Independent Advisory Panel Final Report  
(dated January 12, 2018)**

**Introduction**

The LOTT Clean Water Alliance (LOTT) is completing a scientific study of reclaimed water and groundwater recharge called the Reclaimed Water Infiltration Scientific Study (RWIS). LOTT has contracted with the National Water Research Institute (NWRI) to convene an expert panel to perform a scientific third-party peer review of the RWIS project. This panel held its second project meeting on November 17, 2017, at which the LOTT Study Team presented technical material and posed questions to the panel. The NWRI peer review panel issued a report dated January 12, 2018, titled “*Final Panel Report for Meeting #2 LOTT Clean Water Alliance Reclaimed Water Infiltration Study*”. The report presents the comments and recommendations from the peer review panel regarding the topics and documents discussed at Meeting #2.

The HDR Study Team has reviewed the peer review panel report. This document presents a response to the comments and recommendations contained within the report. Panel report text is provided, as formatted within the panel report. Study team responses are provided in [blue text](#).

### 3.0 FINDINGS AND RECOMMENDATIONS

---

The principal findings and recommendations derived from the material presented and discussed during Meeting #2 are provided below. The findings and recommendations are organized under the following categories:

- General Comments
- Orientation to the Project and Timeline
- Hydrogeologic Characterization Report
- Draft Tracer Test/Water Quality Monitoring Work Plan
- Panel Response to LOTT's Questions regarding the Tracer Work Plan
- Panel Response to Additional Questions from LOTT

#### 3.1 General Comments

The following comments pertain to the Panel's overall review of the Reclaimed Water Infiltration Study.

- **Meeting #2 Materials and Presentation.**
  - The Panel appreciated the pre-meeting material, presentations, and site tour of the Prairie Hawks Recharge site.
  - In the future, please number the presentation slides for ease of reference.

#### Study Team Response

Comment noted; this will be done in the future.

- **Panel Meeting #2 Report Schedule:** The tracer test and groundwater quality characterizations are scheduled to begin January 2018. Due to this schedule, LOTT requested that the Panel submit its draft final report for Meeting #2 by December 15, 2017.
- **Study Scope.** The study as presented succeeds at evaluating water quality performance and system performance, but needs to be linked to the broader context of potential interaction with downgradient drinking water wells. Discuss this aspect of the scope of the study, which is lightly developed. For example:
  - As written, and consistent with the stated goals of Task 2 of the study, the current experimental design and data collection efforts described below are most effective in defining aquifer hydraulics and contaminant attenuation rates for the area in relatively close proximity (<3,500 feet) to the infiltration basins. These data will help to resolve aquifer flow paths and describe relationships between hydraulic retention time and contaminant attenuation for time scales of 6 months or less. The Panel notes that the current scope of Task 2 (and, more likely, an output of later project tasks) does not focus on understanding aquifer hydraulics and water quality impacts over longer time scales

(>6 months) or defining potential effects at downgradient drinking water wells and drinking water consumers at greater distances (>3,500 feet) from the infiltration basins.

- **Communication of Study Results.** Clarify how the results of the tracer test and groundwater quality characterization will be presented to and used with the public and regulators.

### Study Team Response

Evaluation of effects of reclaimed water aquifer recharge on local-scale groundwater quality (up to 3,500 feet downgradient from the recharge basins and within a 10-month travel time) will be determined by monitoring groundwater quality and correlating this information with travel times. Longer-scale effects (if any) on groundwater quality will be determined using a calibrated flow model. The general work scope for the groundwater flow model is described in the project proposal (previously provided). A detailed modeling work plan will be prepared in 2018 for review and comment that describes the level of effort, hydrogeologic conceptual model and proposed numerical modeling approach.

The study results will be communicated as they become available. Specific methods of outreach will be discussed as the study progresses and be matched to the audience.

- **Data from past studies by LOTT.** Because reclaimed water has been used for spreading at the Hawks Prairie site for 10 years or more, the Panel suggests that it would be useful to summarize historical reclaimed water and groundwater data (e.g., flows, water quality data). This data may help put in context certain data and/or observations based on current or future studies.

### Study Team Response

The following documents have been prepared that summarize this information.

- HDR, June 20, 2013, Hawks Prairie Reclaimed Water Ponds and Recharge Basins (Lacey, WA) “Case Study” Memorandum for the LOTT Clean Water Alliance, Task 4.2 (Reclaimed Water Case Studies), Groundwater Recharge Scientific Study, Phase I (Public Opinion Research and Technical Data Review. Prepared for LOTT Clean Water Alliance, Olympia, Washington. (This memorandum has been provided along with this response to comments.)
- HDR, November 20, 2014, Startup Monitoring Report, Hawks Prairie Ponds and Recharge Basins, Reclaimed Water Infiltration Study. Section 7. Prepared for LOTT Clean Water Alliance, Olympia, Washington. (This memorandum has been provided along with this response to comments.)
- HDR, 2017, Wastewater and Reclaimed Water Quality Characterization Technical Memorandum, Reclaimed Water Infiltration Study. Section 6. Prepared for LOTT Clean Water Alliance, Olympia, Washington. (Available online at: <http://lottcleanwater.org/wp-content/uploads/2015/01/RW-Characterization-Tech-Memo.pdf>.)

## 3.2 Orientation to the Project and Timeline

The following comments pertain to the presentation provided on the structure, framework, status, and timeline of the Reclaimed Water Infiltration Study.

- The Panel appreciated the update on the status and schedule of the study.
- The Panel would like to receive more information about monitoring for potential interactions with downgradient drinking water wells, particularly from the standpoint of bromide (see Sections 3.4 and 3.5). In addition, the Panel would like more information on methods that have been used to identify, classify, and quantify sources of non-municipal waste inputs into sewers (e.g., industrial, commercial, medical facilities, and permitted discharges). How was this information used to inform the study design?

### **Study Team Response**

Groundwater quality monitoring is proposed to be conducted on groundwater monitoring wells, and is not proposed to be conducted on drinking water wells. To our knowledge, there are no drinking water wells within the 3,500 foot area downgradient from the recharge basins where groundwater monitoring is proposed.

### **3.3 Hydrogeology Characterization Report**

The following comments pertain to the draft report and presentation provided on the hydrogeologic characterization of the Hawks Prairie site, particularly focusing on (1) on-site wells and lysimeter installation, and (2) off-site monitoring wells.

- The report provides a good summary of the known and suspected hydrogeology of the Hawks Prairie recharge area. Substantial work has been accomplished to increase the spatial understanding of hydrogeologic conditions beneath and around the LOTT Hawks Prairie managed aquifer recharge site.

### **Study Team Response**

Comment noted.

- One aspect revealed by the data is the degree of heterogeneity in terms of hydraulic conductivity values and aquifer composition. The identification and characterization of geologic layers are paramount in developing the understanding of local hydrogeology, and LOTT has done an excellent job in the latest round of well installations by using the best technology in the form of sonic drilling. This method provides continuous cores of the subsurface formations, which reveal fine-scale layers of sands with silts that may have an important role in the movement of recharge water through the vadose zone. The data advanced the understanding of perched groundwater zones encountered beneath Basin 4 during drilling for the lysimeter installations.

### **Study Team Response**

Comment noted.

- On a broader scale, the work conducted to date has enhanced the understanding of the Shallow Aquifer, confining layer, and deeper Sea Level Aquifer. The main constraints to this work have been finding suitable drilling sites for new monitoring wells and securing the associated access agreements.
  - These constraints have restricted the spatial distribution of the well network, thereby limiting the well network's coverage of the complex and potentially multi-faceted groundwater flow paths that infiltrated reclaimed water will follow as it reaches the water table.
  - Because the monitoring wells are unlikely to capture all variations in the flow paths, the Panel cautions that predictions of groundwater movement may be over-generalized, and that the real system will behave in a more spatially variable manner.

### Study Team Response

Comment noted.

- Understanding the groundwater flow at a managed aquifer recharge project is complicated by the creation of a groundwater mound that may dissipate recharge water away radially from the centroid of the recharge area. At least, in theory, it is what the textbooks would suggest in uniform aquifer conditions; however, the presence of regional groundwater flow in the Shallow Aquifer, determined to be generally from northeast to southwest across the facility footprint, can distort the shape of the mound and, therefore, the direction of spreading from the centroid, especially if other variables are present.

### Study Team Response

Comment noted.

- Variables at the Hawks Prairie site that could distort the groundwater mound include substantial changes in saturated aquifer thickness and a suspected thinning or “pinching out” of the underlying confining layer.
  - The interpretation of the water-level data from the set of completed wells suggests that the saturated aquifer thickness declines significantly to the southeast, becoming effectively zero at MW-22, where the well installed just above the confining layer has been measured as dry. The confining layer still has appreciable thickness (~55 feet), as logged in the adjacent deeper well MW-21, but the water levels recorded in the nested pair of wells installed below and above the aquitard (MW-21 and MW-22, respectively) are so close as to be effectively identical.
  - This finding is significant because it confirms that (a) the Qf aquitard is absent to the southwest of the Hawks Prairie site and (b) the Shallow Aquifer and the Sea Level Aquifer are in direct hydraulic communication.
  - The conditions to the southwest of the Hawks Prairie site contrast with conditions directly beneath the site and extending to the north and east, where the Qf aquitard is

80 to 190 feet thick and sustains a vertical gradient of 9 to 45 percent across the upper confining units of the Qf aquitard.

- The groundwater level contours suggest that the confining layer may be absent below significant areas of the Shallow Aquifer to the southwest of the Hawks Prairie site, especially in the area between Wells 11, 20, and 27. Co-mingling likely occurs, with groundwater and infiltrated recharge water from the Shallow Aquifer entering the Sea Level Aquifer within closer proximity to the Hawks Prairie site, such that the travel time to the Sea Level Aquifer and its production wells may be significantly reduced.

### **Study Team Response**

Comment noted.

It is unlikely the Confining Unit (Qf) is absent to the south and southwest of the LOTT Hawks Prairie recharge basins property. The confining unit was encountered in the borings drilled for MW-20, 21, 25 and 27. However, the Confining Unit does appear to dip down to the southwest and may be pinching out (thinning).

Potential reasons for the similar groundwater levels in MW-21 and 22 include: 1) heterogeneity and high-permeability zones in the Confining Unit (Qf) that allow water to co-mingle, 2) groundwater is beginning to encounter a regional discharge area near Woodland Creek and Beatty Springs causing transitioning vertical gradients, 3) another unknown reason. These factors will be evaluated further in the conceptual and numerical groundwater modeling task to be completed in 2018. Additional groundwater level data will also be collected in all of these monitoring wells which may assist in evaluating this subject.

### **3.4 Draft Tracer Test/Water Quality Monitoring Work Plan**

The following comments pertain to the presentation provided on the draft work plan for tracer testing and water quality monitoring of treatment effectiveness in the Hawks Prairie site.

- The Panel suggests that LOTT verify the dosage calculation in Table 4-3 on “Estimated Potassium Bromide Mass, Concentration, and Flow Rates Required for Tracer Test at 1 mgd Reclaimed Water Recharge Flow Rates.” Information provided by LOTT following Meeting #2 shows that two separate dosage calculations (to achieve average bromide concentrations of 20 mg/L or 50 mg/L in the recharge water, respectively) appear to have become conflated in the single calculation shown in Table 4-3.

### **Study Team Response**

Table 4-3 has been checked and edited. The bromide concentration has been adjusted to 25 mg/L, per discussions with the LOTT Science Task Force (see later responses for more discussion of this).

- Regarding mixing the tracer:

- The Panel recommends bypassing the constructed wetlands at the Hawks Prairie site for the tracer addition effort. If the wetlands are bypassed, and if there is no free chlorine residual in the effluent distribution system, it could be most effective to add the tracer at the end of the wastewater treatment plant and allow it mix in the distribution system before the effluent discharges to the recharge basin.
- If access to the treatment plant is not allowed, or if there are concerns that a free chlorine residual in the distribution system could contribute to low concentrations of brominated DBPs in the effluent before it reaches the recharge basin, then the tracer could be added at the recharge basin. During the Panel's visit to the Hawks Prairie site during Meeting #2, it appeared that the logical place to add the tracer is a centralized mixing box located at the recharge basin.
- The Panel recommends maximizing the possibility for effective mixing and tracer dilution by (a) choosing an additional location as far upstream of the recharge area as possible and (b) promoting hydraulic or mechanical mixing within the distribution pipework to the degree possible.
- The Panel recommends that LOTT sample the infiltration basin for trihalomethanes (THMs) during the tracer test.

### Study Team Response

The wetlands will be bypassed during the tracer test. A small amount of water will be added to the wetlands to keep them from drying out during the summer, but wetland water flow to the recharge basins will be minimal.

The tracer input location will be within the inflow pipeline at Vault 5 which is approximately 1,000 feet upgradient from the basins. This will allow for turbulent mixing in the pipeline as the tracer is introduced to the reclaimed water flow. Mixing will then continue to occur as the tracer travels ~1,000 feet to the point of introduction into the basins.

THMs will be sampled at the recharge basins, in the vadose zone lysimeters and in twelve of the groundwater monitoring wells on a quarterly basis. THMs also have been sampled annually at the LOTT monitoring wells annually since 2007.

- In addition to measuring total coliform, the Panel recommends measuring *E. coli* as a water quality parameter to evaluate the potential for fecal organisms to contaminate recharge water. Although it is unlikely there will be significant migration of coliform and *E. coli* in the subsurface, it is possible that coliform could be introduced into the wetland system.

### Study Team Response

*E. coli* results are provided along total coliform results, pursuant to the laboratory methods being used. Therefore, although we do not expect *E. coli* to be present, we will be obtaining that information.

### 3.5 Panel Response to LOTT's Questions regarding the Tracer Work Plan

LOTT compiled a list of questions directed to the Panel and the Science Task Force. The Panel's responses to these questions are provided below.

**Question 1 – The current Tracer Test Work Plan calls for sampling 26 wells (Slides 1-2). It is possible that some proposed sampling locations for tracer may be redundant. If the proposed sampling plan was streamlined to 19 wells (Slides 3-4), instead of the 26-well layout as shown in the current work plan, what effect would the changed monitoring well network have on the overall study?**

Panel response to Question 1:

- The streamlined work plan seems reasonable to the Panel.
- The Panel has the following comments:
  - The proposed tracer testing involves accepted hydrogeologic methods and procedures. The resulting data will provide significant value that is a requirement for defensible model development and calibration.
  - The Panel has questions about the heterogeneity of the system (See Section 3.3).
  - Concentration of the tracer may vary due to inadequate mixing in the spreading basins.
  - The Panel suggests adding a monitoring well in the area where groundwater contour lines suggest aquifer comingling may be occurring (i.e., between MW-11 and MW-22).

#### Study Team Response

Comment noted. The bromide tracer injection location has been moved so that it will be injected into the pipeline and allowed to mix prior to reaching the recharge basins. Due to the schedule of the project and the limited available locations for monitoring wells, it will not be possible to add additional monitoring wells.

**Question 2 – Should the tracer test attempt to characterize interaction between the shallow and deep aquifers southwest of the Hawks Prairie site?**

- a) **Would it be useful to evaluate samples from deep monitoring well MW21 as part of the tracer test? The well is near the intersection of the shallow and deep aquifers, and there is interest in knowing if the tracer will appear in the deep aquifer and that location.**
- b) **Is the proposed monitoring well network sufficient to characterize the potential effects of the shallow/deep aquifer interaction on water quality? Currently there is no monitoring well to the east (downgradient) of deep well MW21 to evaluate water quality in the deep aquifer where the shallow and deep aquifers meet.**

Panel response to Question 2:

- The Panel agrees that the tracer test should characterize the interaction between the shallow and deep aquifers southwest of the Hawks Prairie site to the extent possible; however, the study will be constrained by the distribution of available monitoring wells.
- The Panel recommends sampling Deep Wells MW-21 and MW-23. Sampling can be done once or twice a month, as feasible.
- Regarding the schedule: Clarify the use of Deep Well M-21 or Shallow Well M-22. These two wells are listed on the monitoring schedule as alternatives to each other, but they are not located in the same aquifer.

### **Study Team Response**

MW-21, 22, 23 and 24 will all be sampled for tracer.

#### **Question 3 – Constructed Wetlands**

***Should the study account for the potential role of the constructed wetlands? (The constructed wetlands were not designed to provide treatment, although they may do so. Future infiltration projects will likely not include wetlands.)***

- a) ***The work plan states that for the first half of 2018, reclaimed water used for all recharge operations will flow first into the LOTT wetland ponds and then into the recharge basins. For the second half of 2018, the reclaimed water will be routed directly into the recharge basins and will bypass the wetland ponds.***
- i. ***Is this the best plan? Should half the study period include the wetlands and half the study period not include the wetlands? Or should the reclaimed water either flow through the wetlands or bypass the wetlands for the duration of the tracer test?***
  - ii. ***If the study is constructed so that for half of the study period the wetlands are included, and for the other half the wetlands are bypassed, the four sampling events will be split; two when the wetlands are included and two when they are bypassed. What potential effect of changing the wetlands variable have on interpretation of the data?***
- b) ***If the wetlands are bypassed, the results will present a “worst case scenario” because soil aquifer treatment (SAT) will only occur in the recharge basins, instead of in both the recharge basins and the wetlands. Also, there may be less variability in the results because the inclusion of the wetlands would create another variable. The results from the bypassed-wetlands scenario will be more applicable to future infiltration sites, which are unlikely to include added wetlands. If the wetlands are included, however, the study results will reflect how the Hawks Prairie site is operated currently.***
- i. ***If the wetland ponds are bypassed, could the resulting higher levels of chlorine in the reclaimed water negatively affect the microorganisms in the vadose zone, change the degree to which the microorganisms would contribute to SAT, and influence the results of the study?***

- ii. ***If the wetland ponds are bypassed and a dechlorination agent is added to the reclaimed water, could that negatively affect the microorganisms in the vadose zone, change the degree to which they would contribute to soil aquifer treatment, and impact the results of the study?***
- iii. ***If the wetlands are bypassed, will it affect the study in such a way that the findings will not be directly applicable to the Hawks Prairie site?***

Panel response to Question 3:

- Without more data about the potential for the removal of contaminants through the constructed wetlands or the concentration of the chlorine residual in the reclaimed water, the Panel cannot answer this question. For example, if there is minimal removal of the more persistent trace contaminants found in the previous groundwater sampling, then bypassing the wetland should not affect the applicability of this study to the Hawks Prairie site.
- Bypassing the wetlands would allow for a cleaner experiment and better model for the proposed long-term system operations.
- If the wetlands are bypassed during the tracer experiment, the LOTT project team could still evaluate changes to water quality that could occur when reclaimed water travels through the wetlands. For example, sampling could be conducted at the start of the tracer study to at least determine: (1) the wetland capability to reduce trace contaminants in the reclaimed water; and (2) any water quality effects that the wetlands effluent has on contaminant removal when water from the wetlands travels through the vadose zone below the recharge ponds.
- If LOTT decides to further study the wetlands alternative, the Panel has the following comments:
  - Changing the wetland variables would complicate data interpretation.
  - Sampling methods need to be improved to evaluate the performance of the constructed wetlands, which could help with future project design.
    - Composite samples for trace contaminants should be collected from the effluent at the reclaimed water treatment plant. These samples should provide an accurate indication of the influent load to the wetlands and the infiltration beds. Effluent concentrations in wastewater treatment systems vary over a diurnal pattern. Influent flowrates vary also, but the Panel's understanding is that the reclaimed water satellite facility receives a constant flow rate. An example of variations in influent concentrations is the typical pattern for influent ammonia nitrogen (NH<sub>3</sub>-N): Most of the NH<sub>3</sub>-N to the treatment facility is from urine, which is higher in both concentration and total load to facilities at certain times of the day, especially in mid- to late-morning hours and in the late afternoon. Many trace contaminants (e.g., household chemicals, drugs, and hormones) are derived from urine; therefore, their concentration can be expected to vary over the day. Consequently, a single grab sample to characterize the treatment performance of the wetland, as well as the load to the wetland and infiltration basin, is not representative of average conditions.

- Column testing may be needed to determine how chloramine affects SAT, although discussions with LOTT's project team indicated that chloramines are dissipated in the first two inches of the vadose zone. Furthermore, dechlorination agents like thiosulfate are fairly reactive and should not travel very far into the subsurface.

### Study Team Response

Comments noted. Based on the earlier comments provided, it has been decided to bypass the wetlands. The effects of the wetlands on water quality were examined to a limited extent in the Task 1.3 (Wastewater and Reclaimed Water Quality Characterization) effort. Those data and interpretation are documented in the Task 1.3 Technical Memorandum (HDR, February 7, 2017). The summary below is extracted from Section 6.1 of that document.

- The Hawks Prairie wetland ponds reduce the total organic carbon and nitrogen content in reclaimed water before it is infiltrated through the recharge basins, but have a minimal impact on the concentrations of residual chemicals. Of the 16 residual chemicals detected in MWRWP reclaimed water during all four events, most demonstrated no appreciable changes or trends in observed concentrations between the pre- and post-wetlands samples. However, it is noted that the pre- and post-wetlands grab samples were obtained typically within the space of one hour and were not timed to reflect sampling of the same aliquot of water as it traveled through the wetlands (i.e., the sampling does not directly take into account the approximately 20 day residence time in the wetlands). However, this sampling protocol is considered adequate to provide a general characterization of water quality before and after the time spent in the wetlands on a given day.

#### Question 4 – Ecological considerations for tracer chemicals.

- c) **Two conservative tracers, bromide and sulfur hexafluoride (SF<sub>6</sub>), are proposed to measure travel time of groundwater flowing from Basin 4 through the vadose zone and groundwater.**
- i. **Potassium bromide is the preferred salt for the bromide tracer. The recommended concentration of potassium bromide delivered to the recharge basins is 50 mg/L over a 7-day period, which will result in downgradient maximum concentrations of 12 to 3 mg/L at distances of 250 to 2,500 feet. Standing water in the basin will contain 50 mg/L KBr. Is there a risk to wildlife to have standing water in the recharge basin with such a high salt (KBr) concentration (due to the introduction of the tracer prior to water flowing into the basin)?**
  - ii. **Is there a risk to microorganisms in the vadose zone due to the high salt (KBr) concentration from the tracer?**
  - iii. **Will the KBr or SF<sub>6</sub> tracers potentially impact the microorganism population and/or effectiveness of soil aquifer treatment/degradation?**

Panel response to Question 4:

- Public health issues:

- It would be useful for LOTT and/or its project team to estimate (a) the bromide concentration expected at the closest drinking water well and (b) how long after the tracer addition that bromide concentrations may occur. It also would be important to know what water treatment processes are provided for the extracted drinking water. This information can help determine relative risk and if any actions are warranted to reduce risk, such as adding a process at the drinking water well if needed to remove bromide during the tracer study.
- The Panel concludes there is no indication that wildlife will be harmed by the presence of the tracer in the recharge ponds because (a) the tracer will be present for only a short time period, and (b) the proposed bromide concentration of 50 mg/L is equal to or less than that of seawater.
- If incomplete mixing occurs, there may be a risk of creating high-concentration hot spots of bromide. Microbes are sensitive to bromide, and the effect of the tracer on the microbial community depends on the bromide concentration. Based on limited scientific literature (see the comments below), the Panel cannot conclude that there will be no effect to the microbial community.
  - The Panel also notes that nearly all hydraulic and water quality changes will affect the microbial community structure and function to some degree. It is likely that the microbes can recover function and community abundance with time; however, to limit any adverse effects on microbial populations, effective mixing is recommended to avoid the potential for hot spots.
  - Thorough mixing also would help to maintain the capability for contaminant attenuation in the vadose zone and improve the quality of the tracer data for subsequent hydraulic modeling.
- A study by Bech et al. (2017) on the effect of potassium bromide addition on the degradation of three pesticides for four soil types suggests there will be little effect, if any, on the soil microbial population at the potassium bromide concentrations to be used in the proposed study (50 mg/L). A comparison of the abundance of operational taxonomic units (OTUs) from 16 S amplicon sequencing between experiments with and without pesticides, and potassium bromide showed no significant effect on the abundance of the majority of species. In cases where an effect was observed, there was still a significant abundance of bacteria. These results suggest that potassium bromide at the concentrations to be used may not be high enough to have a significant effect on the soil microorganisms.

### Study Team Response

The estimated downgradient concentrations of bromide were provided in the draft work plan and were presented during the peer review meeting. Since then, two changes have been made and the work plan has been revised:

- The concentration of potassium bromide has been changed to 25 mg/L from the original concentration of 50 mg/L, based on discussion with the Science Task Force and in response to Peer Review input.

- The introduction of the potassium bromide has been changed to be upstream of Basin 4 and will be completely mixed prior to entering Basin 4.

There are no drinking water wells in the immediate vicinity of the project site that withdraw water from the same aquifer (Qva) into which the tracers are being introduced. Based on a review of well log records maintained by the State Department of Ecology, the nearest downgradient drinking water wells in the Qva that are in the expected flowpath of the tracers (i.e., to the southwest of the project site) are located south of Interstate-5, and are more than one mile south of the project site. At least one public supply drinking water system has drinking water wells in the Qva aquifer and is located approximately 1.5 miles to the west/northwest of the project site; however, these wells are anticipated to be upgradient (i.e., above the flow path) from the project site.

As described in the Work Plan, tracer breakthrough modeling was conducted under various hydrogeologic scenarios and considering an initial bromide concentration of 20 mg/L. As noted above, LOTT has decided to use an initial bromide concentration of 25 mg/L, as compared with the originally-considered 50 mg/L. The model results for two model runs were extrapolated to determine bromide concentrations given an initial concentration of 25 mg/L. The results from the run having the most conservative (i.e., highest) downgradient bromide concentration is shown below. This indicates that at a distance of 3,000 feet from Basin 4, the peak downgradient bromide concentration, in addition to the existing background concentration of 0.01-0.04 mg/L, is expected to be 1 to 2 mg/L at a time of 150 days after tracer introduction. Further downgradient (down the flow path) beyond 3,000 feet, the groundwater gradient flattens considerably and bromide concentrations are anticipated to decrease significantly.

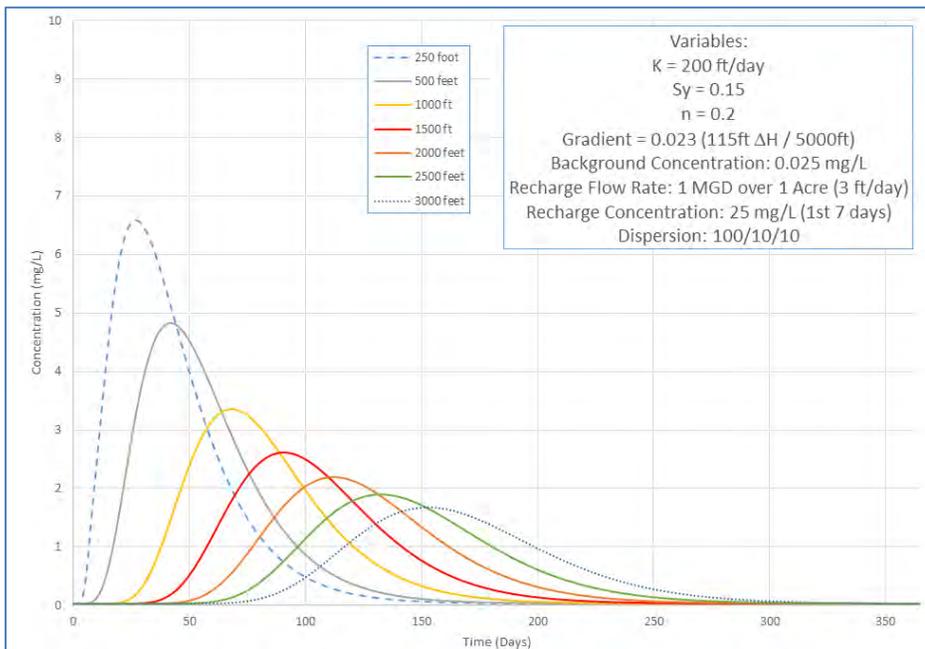


Figure 1. Estimated concentration of bromide in groundwater downgradient from recharge basins assuming an inflow concentration of 25 mg/L.

The treatment processes related to the nearest wells to the south of the site are not known. Regarding the public water system located 1.5 miles to the west/northwest of the project site (i.e., Eagle Estates), a review of the State Department of Health Sentry database indicates that no treatment is employed at these wells.

**Question 5 was removed from the list of questions.**

**Question 6 – Is the data representative?**

- a) The tracer test plan calls for four water quality sampling events. Are four events adequate to obtain the data needed to accurately answer the study questions?**

Panel response to Question 6:

- Four quarterly sampling events over a 1-year period are normal and representative for groundwater sampling.
- Because groundwater moves slowly, it is important to allow sufficient time to elapse between successive samples to ensure that groundwater quality data are statistically independent.
- Gibbons (1994, pages 163 and 185) recommends sampling groundwater no more than quarterly to increase the likelihood of obtaining statistically independent data.

### **Study Team Response**

Comment noted. The quarterly events will have 2 months of time between each event.

**Question 7 – The RWIS is designed for 1 MGD recharge for 6-12 months. Does the Panel feel that the water quality results produced by the study will be representative of the full-scale project, which will recharge 5 MGD across eight basins for the duration of the project (assume 30-40 years)?**

Panel response to Question 7:

- The groundwater flow, mound development, and spatial extent of the recharge water flow path(s) may change substantially under greater recharge loading. Groundwater modeling may be used to examine the effect of increasing the scale of recharge operations, but changing the scale would increase the uncertainty of the predictions. LOTT may reduce uncertainty and improve confidence in the model and study predictions going forward by maintaining ongoing operational monitoring of the full-scale project, including periodic reassessment and recalibration of the groundwater model.
- If this study can establish a clear relationship between the hydraulic retention time and the attenuation/removal of constituents, then the LOTT project team could scale the results up to 5 mgd. If the tracer test can be used to predict the expected hydraulic retention times at the different monitoring wells, and these hydraulic retention times are stable for different seasons and different operational conditions, then the project team can develop quantitative relationships between hydraulic retention time and water quality parameters. These relationships are expected to be valid at higher recharge rates. To confirm validity, the Panel

recommends that the project team calculate the expected change in hydraulic retention time to monitoring wells that may occur when the hydraulic loading rate is increased. This type of analysis should be possible once the hydraulic modeling of the aquifer is completed.

### Study Team Response

Comment noted. The analysis described in the comment will be completed as part of the numerical groundwater modeling evaluation to be completed as part of the next phase of the project.

### 3.6 Additional Questions from LOTT

LOTT requested the Panel's feedback on the following three additional questions.

**1. Does the Panel agree with the proposed use of potassium bromide (KBr) tracer, to be delivered to the recharge basins at a concentration of 50 mg/L? (See Chapter 4, pp. 23-25)**

Panel response:

- It is the Panel's opinion that (a) the likely impact on human health from proposed use of potassium bromide (KBr) tracer at a concentration of 50 mg/L can be evaluated as described below and (b) the use of KBr is unlikely to cause a risk to wildlife; however, the Panel cautions that potential "hot spots" of KBr created by incomplete mixing may create some elevated risk in some downgradient drinking water wells, which will not be addressed in the analysis.
- Because the bromide tracer will be deliberately added at a concentration of 50 mg/L to an aquifer that supplies drinking water wells that may be downgradient from the location of the tracer addition, it is incumbent on LOTT to assure the public consuming the water that the bromide addition will not adversely affect public health.
  - The Panel calls LOTT's attention to the need to ensure that the health risks associated with introducing high concentrations of bromide tracer into a drinking water source are minimal.
  - An assessment of the probability of potential health consequences is required. In the case where bromide will be used as a conservative tracer of water flow, a large amount of potassium bromide tracer will be introduced into the reclaimed water spreading basin(s) over a 7-day period.
  - There are two pathways by which elevated bromide can contribute to adverse health effects: (a) through direct absorption of bromide into the body; and (b) indirectly by changing the nature and amounts of disinfection byproducts produced when water containing elevated bromide is disinfected for use as a drinking water source.
- Bromide is known as a normal constituent of the body and has a low level of toxicity, but if there are downgradient drinking water wells, the probability is high that the exposure of

bromide to consumers of the infiltrated water will be 50 to 100 times greater than background (0.025 mg/L) as the plume of bromide works its way through the aquifer(s).

- The information in the Material Safety Data Sheets (MSDS) for potassium bromide is not sufficient to draw conclusions about the safety of doses that will be experienced.
- Bromide has a relatively long terminal half-life (100 to 300 hours in rats). The steady state concentration in total body water will steadily increase as the bromide is consumed each day (see Cousins et al., 2002; Sosa and Stone, 2010). Using the rat half-life, it will take 20-60 days of intake for bromide to reach steady state in the body (rule of thumb is 5 times the half-life).
- In particular, the long terminal half-life for humans that is implied but not estimated in Cousins et al. (2002) is as least as long as the half-life for rats. The half-life probably reflects the fact that bromide mixes with total body water in a similar fashion as chloride does. There appear to be some “deep” compartments for bromide from which it is released slowly that have not been thoroughly characterized.
- The influence of bromide on disinfection byproduct (DBP) formation can be assessed by evaluating the formation potentials for the different classes of DBPs in downgradient drinking water wells (or a sampling point located on the path to drinking water wells).
  - This effect is most easily addressed with all nine halo acetic acids (HAA9) and regulated trihalomethane (THM4) classes of byproducts because the analytical methods for these DBPs are well established in the drinking water community. Many other classes of DBPs are produced, but the toxicological data available for those classes are more limited. It is important to realize that the construction of the HAA5 and THM4 regulations are tenuously linked to risk.
  - To properly address risk, it is necessary to use estimates of concentrations of each chlorinated, brominated, and mixed bromo-chloro byproducts in these classes as they vary widely in their carcinogenic potency to arrive at an accurate estimate of the impact of increased amounts of brominated byproducts (Hua et al., 2006).
  - Nevertheless, the U.S. Environmental Protection Agency (USEPA) used the epidemiological data that associated bladder cancer risk most closely to brominated derivatives (Regli et al., 2015). It is an easier analysis even though none of these compounds have been shown to induce bladder cancer (tacitly recognizing that the THMs are not the carcinogens, but using the amount of bromine substitution in this class as a surrogate for the extent of bromine substitution in other DBPs).
- The Panel recommends that LOTT should: (a) estimate the dose of bromide that humans might be exposed to over the likely period of increased exposure to bromide resulting from the introduction of the tracer; and (b) estimate the incremental increase in cancer risk that would ensue from the greater formation of brominated DBPs formed when water containing bromide is withdrawn from the aquifer and disinfected for use as drinking water.

- **Appendix A** provides a short discussion of the health issues associated with elevated bromide intake and suggests an approach that might be used to assure the public that the tracer test is unlikely to cause adverse health effects.
- Any analyses performed should be presented to the Panel for review.

### Study Team Response

- a) Estimated bromide dose in drinking water. See Study Team response to Panel response to LOTT Question #4, regarding discussion of estimated bromide concentrations that might be observed downgradient from the project site. Given that the estimated bromide concentration in groundwater 3,000 feet downgradient from the site is expected to be in the 1-2 mg/L range, the bromide concentration in groundwater more than one mile downgradient from the site, within which distance there are no known drinking water wells, is anticipated to be well below the threshold concentration of 0.7 mg/L in drinking water that is noted in Appendix F of the Panel report in relation to USEPA's approach considering consumption of 1 liter of water by a 3.3-kg child, due to continued dilution and mixing.
- b) Impact on DBP formation. While increased bromide concentration could impact the DBP formation potential of downgradient drinking water if it is disinfected upon withdrawal, per the discussion provided by the Panel in Appendix F, the Study Team has determined this increased risk to be low. This is because the organic content of the regional groundwater is low, and therefore the DBP formation potential is likely limited by this factor. As the Study Team advisor, Dr. Peter Fox, notes: *"Most wells have low dissolved organic carbon (DOC) concentrations (< 1 mg/l) and disinfection by-products issues are rare. The organic carbon compounds in groundwaters are usually highly stable/recalcitrant organic compounds."* Also, many private residential wells do not use chlorine disinfection.

### 2. Does the Panel agree with the proposed use of sulfur hexafluoride (SF<sub>6</sub>) in the groundwater monitoring wells? (see Chapter 4.2, pp. 26-27)

Panel response:

- SF<sub>6</sub> has been used as a tracer in other groundwater infiltration systems (see NWRI, 2004); however, the Panel was concerned that the data for safety are based on studies conducted as far back as the 1950s, before modern concerns of toxicity had evolved. Only a few peer-reviewed papers have been published since that time outside of medical/clinical journals.
  - SF<sub>6</sub> is used extensively in medicine as a contrast agent that is administered intravenously (Morel et al., 2000) or with as much as 79 percent SF<sub>6</sub> in inhaled air (Ostlund et al., 1992) and in certain clinical procedures (see Harada et al., 1984; Hattori et al., 1994).
  - A review of 352 consecutive echo contrast examinations in 274 patients (Geleijnse et al., 2009) with the product SonoVue found mild adverse reactions in two of 198 patients (1 percent) with single dose (usually <1.0 mL iv total injection as stabilized

bubbles of the gas) examinations or in two of 76 patients given multiple examinations. Severe reactions were observed in three patients that were associated with allergic reactions. Allergic reactions to SF<sub>6</sub> cannot be ruled out, but it is more probable that these effects were due to other components of the administered bubbles, such as polyethylene glycol, which is used as a stabilizer.

- In addition to the study mentioned above, a pharmacokinetic study of the elimination of SF<sub>6</sub> in 12 subjects (seven men, five women) given SonoVue at doses of 0.03 or 0.3 milligrams per kilogram (mg/kg) body weight (Morel et al., 2000) found that SF<sub>6</sub> was eliminated from the blood with a terminal half-life of between 5 and 7 minutes; therefore, SF<sub>6</sub> does not bioaccumulate.
  - The Panel recommends that LOTT review the doses administered in these studies (especially Geleijnse et al., 2009 and Morel et al., 2000) and compare them to doses that people could experience from the amounts of SF<sub>6</sub> introduced into the aquifer(s) at the proposed concentrations of 0.07 to 0.01 millimoles per liter.
  - It is important to note the low level of toxicity of SF<sub>6</sub> implied in these studies is consistent with older data (Hodge et al., 1958 and those cited within the MSDS).

### Study Team Response

The maximum SF<sub>6</sub> that can be dissolved into water is 0.07 to 0.1 mmol/L as explained in Section 4.2 of the updated Work Plan. Most of the SF<sub>6</sub> will be lost to off-gassing and initial testing of water traveling from the vault where SF<sub>6</sub> is introduced to the recharge basins (during the week of January 15) shows a SF<sub>6</sub> concentration of 0.00002 to 0.00005 mmol/L. It is likely that the actual concentration arriving at a downgradient well will be significantly less than this due to off-gassing during the introduction process and travel through the vadose zone and due to advection and dispersion in the ground water. However, this maximum value is considered, so as to be conservative.

Under these conservative assumptions, the concentrations in downgradient groundwater is much less than the referenced dose values in the studies referenced by the Panel, as demonstrated in the following calculations:

- Comparison to Geleijnse et al. To make this comparison, the initial recharge concentration of 0.00002 to 0.00005 mmol/L is converted to a “dose” that would be consumed by drinking two liters of water at this concentration. Such a “dose” would equal 0.00004 to 0.0001 mmol. By comparison, the “dose” considered in Geleijnse et al, assuming 1.0 mL of solution at 100% solubility of 7 mmol/L, would be approximately 0.007 mmol.
- Comparison to Morel et al. To make this comparison, the “dose” described above (0.00004-0.0001 mmol) is converted to mass (in mg) by multiplying the molarity by the molar mass (146.06 mg/mmol), resulting in a mass-based dose of 0.006 – 0.015 mg. To then convert this mass dose to one applicable to a 3.3 kg newborn child, half of the mass dose is assumed (to reflect consumption of one liter of water versus two) and the mass is divided into the 3.3 kg weight to arrive at a

dose of 0.009-0.002 mg/kg. By comparison, the dose considered in Morel et al is 0.03 mg/kg.

**3. Can the Panel provide feedback on the proposed streamlined sampling plan?**

Panel response:

- The Panel feels the streamlined sampling plan, which calls for collecting samples from 19 wells instead of the 26 illustrated in the original tracer test work plan, is reasonable.
- See also the Panel's Response to Question 1 in Section 3.5.

**Study Team Response**

Comment noted.