Herrera Environmental Consultants, Inc.

Memorandum

To	David Bricklin, Bricklin Newman
From	Robin Kirschbaum and Rob Zisette, Herrera Environmental Consultants
Date	March 2, 2010
Subject	Water Quality Review of The Villages and Lawson Hills Master Development Plan Environmental Impact Statements

This memorandum briefly summarizes Lake Sawyer water quality and presents our findings based on review of the water quality analysis presented in The Villages and Lawson Hills Environmental Impact Statements (EISs). Also presented are the results of independent calculations performed by Herrera Environmental Consultants (Herrera) to estimate potential changes in total phosphorus (TP) loading rates and growth of algae biomass in Lake Sawyer as a result of the projects.

Summary of TP Loading History and Capacity

Lake Sawyer water quality and beneficial uses are impaired from high TP loading. The TP loading capacity of the lake is 715 kilograms/year (kg/yr) based on the Total Maximum Daily Load (TMDL) allocation approved by EPA in 1993 (Findley 1993). Measurements have shown that this TP load allocation for the lake was exceeded before (1,117 kg/yr in 1989-1990) and after (1,342 kg/yr in 1994-1995) diversion of effluent from the Black Diamond Wastewater Treatment Plant (WWTP) to the King County sewer system. WWTP effluent was diverted from the lake in November 1992 for compliance with the TP load allocation of zero specified for the WWTP by the TMDL.

Loading measurements in 1989-1990 and 1994-1995 clearly indicate that diversion of the WWTP loading in 1992 did not immediately decrease TP loading to the lake. The high TP loading observed 2 years after the diversion is likely due to the continued release of phosphorus from sediments that were deposited in the lake or watershed during the WWTP discharge period. Water quality monitoring by King County (2010) has shown that the summer (June through September) mean TP concentration in the surface of the lake decreased to acceptable levels in 1998 that have since met the TMDL for the summer mean TP concentration in the surface of the lake (16 ug/L). These monitoring results suggest that internal TP loading from sediment release continued to elevate TP concentrations in the lake for approximately 5 years after the WWTP diversion. The King County (2010) monitoring results show that Lake Sawyer exhibited a delayed response to phosphorus diversion and is sensitive to future increases in phosphorus loading, which has also been shown for many other lakes in urban watersheds.

Future development in the Lake Sawyer watershed is expected to increase TP loading and exacerbate water quality degradation based on the calibrated phosphorus loading model developed for the Lake Sawyer Management Plan (King County 2000). Assuming that stormwater controls are in place and continue to function properly, King County (2000) estimated that TP loading to the lake will increase from 1,318 to 2,255 kg/yr under the full build-out scenario (i.e., the area of residential land use increases from 769 to 3,625 acres), which is approximately 1,540 kg/yr over the established Lake Sawyer TP load limit of 715 kg/yr set by the TMDL (see Table 1). Excessive TP loading from future watershed development would likely require an expensive (>$1 million) in-lake treatment to meet water quality goals and support beneficial uses.

Table 1. Lake Sawyer annual total phosphorus loadings.

	Annual TP Loading (kg/yr)	Annual TP Loading > TMDL (kg/yr) [a]
Ecology 1991 Diagnostic Study of Lake Sawyer		
Measured in 1989-90 (pre-WWTP Diversion)	1,117	402
Modeled Typical Year (with WWTP Diversion)	715	0
Modeled Future Build-out (with WWTP Diversion)	1,805	1,090
King County 2000 Lake Sawyer Management Plan		
Measured in 1994-95 (post-WWTP Diversion)	1,342	627
Modeled Typical Year	1,318	603
Modeled Future Build-out (with Stormwater Controls)	2,255	1,540
Predicted Future with Villages and Lawson Hills		
King County (2000) Model Output Interpolation [b]	1,695	980
Washoff Model [c]	1,502	787

WWTP = Black Diamond Wastewater Treatment Plant

[a] Annual TP loading in excess of the TMDL loading capacity of 715 kg/yr.

[b] Assumes TP loading is proportional to the area of future residential development (1,150 acres for Villages and Lawson Hills versus 3,625 acres for Future Build-out with Stormwater Controls).

[c] Assumes an average TP loading of 1,318 kg/yr with additional TP loading from conversion of 1,150 acres of forest having a washoff rate of 0.04 kg/acre/yr to urban land use having a washoff rate of 0.4 kg/acre/yr (Cooke et al. 2005) and a 50 percent reduction for stormwater controls.

Water Quality Technical Analysis Issues

Below is a summary of Herrera Environmental Consultants' findings based on review of *The Villages MPD Water Quality Technical Analysis Draft EIS* prepared by A.C. Kindig & Company in September 2008 and *Lawson Hills MPD Water Quality Technical Report* prepared by A.C. Kindig & Company in May 2008.

1. **Limited data used to assess total phosphorus concentrations in untreated stormwater runoff**. Water quality analyses for The Villages and Lawson Hills MDP predicted stormwater total phosphorus (TP)

concentrations in untreated stormwater runoff based on a limited amount of data. Table 3-10 in *The Villages MPD Water Quality Technical Analysis* and Table 3-8 in the *Lawson Hills MPD Water Quality Technical Report* list the following sources of untreated water quality data:

- 75 ug/L TP for single family residential development in Snoqualmie Ridge
- 40 ug/L TP for multi-family residential development in Snoqualmie Ridge
- 160 ug/L TP for mixed land use in the Pine Lake Shopping Center
- 170 ug/L TP for commercial development in the Eastgate Business Park
- 170 ug/L TP for arterial roads from Lake Washington Boulevard
- 200 ug/L TP for parks from a golf course in Snoqualmie Ridge

These sources of data are considered to be insufficient because only one source for each land use type was used and only one local site (Snoqualmie Ridge) is represented. The reports do not specify the amount nor the quality of the data that were used as the basis for these untreated TP concentrations. As discussed further below, this assumed range of untreated TP concentrations for residential land uses is considered to be unrealistically low for these MPD projects.

2. **Assumed TP concentrations for untreated stormwater runoff are unrealistically low.** The National Stormwater Quality Database (Shaver et al. 2007) reports that the median TP concentration in stormwater runoff from residential land use is 300 ug/L. Although the level of stormwater treatment is not specified in this database, we expect that samples of both treated and untreated stormwater are included in the database. Thus, it is reasonable to expect that stormwater TP concentrations in untreated runoff from the Villages MDP and Lawson Hills MDP may exceed 300 ug/L, and would likely exceed the 40 to 200 ug/L documented in the water quality analysis reports by A.C. Kindig & Company.

3. **Assumed TP reduction rate is unsubstantiated for The Villages MPD.** The water quality analysis for the Villages MPD predicted that stormwater TP concentrations in treated runoff would range from 38 to 53 ug/L, assuming that wet ponds would achieve a 50 percent reduction in TP concentration for stormwater runoff from the MPD site. This 50 percent TP reduction rate is considered to be unrealistically high based on the following:

- The analysis did not account for additional TP loading from untreated stormwater that bypasses the wet ponds during high flow conditions.

- Removal efficiencies vary directly with pollutant concentrations, such that a 50 percent removal efficiency would not be expected if the TP concentration in untreated stormwater is below average. In fact, the Center for Watershed Protection (2000) reported that stormwater TP concentrations less than 150 to 200 ug/L are irreducible, or too low to be reduced by standard stormwater treatment practices. Thus, it is likely that the wet ponds would remove less than 50 percent of the TP in untreated stormwater having an estimated range of 40 to 200 ug/L.

4. **Basis of predicted stormwater TP reduction rate is unclear for Lawson Hills MPD.** The water quality analysis for the Lawson Hills MPD predicted that stormwater TP concentrations in treated runoff would range from 36 to 72 ug/L. The report does not sufficiently document the removal rates that were assumed in this analysis.

5. **TP loading rates were not evaluated.** While TP *concentrations* (e.g., 36 to 72 ug/L) were predicted for treated stormwater discharging to receiving waters in the Lake Sawyer watershed, TP *loading rates* (in units of kg/yr) to Lake Sawyer were not evaluated for either The Villages or Lawson Hills MPDs. Evaluation of TP loading rates is essential in order to understand the potential impacts to lake water quality from the associated increase in the amount of algae. Herrera performed an independent evaluation of TP loading rates to Lake Sawyer that is summarized below.

6. **Results from independent calculations indicate a significant potential increase in TP loading to Lake Sawyer**. Potential TP loading impacts to the lake as a result of The Villages and Lawson Hills MPDs can be estimated using a variety of methods. Two approaches were used here in order to estimate the potential range of loading impacts. Those methods include 1) an interpolation of loading rates provided in the Lake Sawyer Management Plan (King County 2000) and 2) development of a simple washoff model. The assumptions and methods used for these calculations are presented in detail the following section of this memorandum. The results of these independent calculations are summarized below:

   - The annual TP loading rate from the MPDs is estimated to be 377 kg/yr using the King County model interpolation method and 184 kg/yr using the washoff model method.

   - These two calculated loading rates would result in a 29 and 14 percent increase, respectively, in the TP loading rate for an average year (1,318 kg/yr) over current conditions.

- These two calculated loading rates would result in a total TP loading rate of 1,695 and 1,502 kg/yr, respectively, to Lake Sawyer for an average year that are more than twice the TP loading capacity (715 kg/yr) established by the TMDL for the lake.
- The TP loading rate to Lake Sawyer would likely be higher than these estimates during the construction period due to erosion of disturbed soils.

7. **Simple chlorophyll model predicts significant increase in algae biomass in Lake Sawyer.** As noted in the Lake Sawyer Management Plan (King County 2000), algae growth in the lake will increase at an even higher rate than the increase in TP loading. The increase in algae biomass from the additional TP loading by the MPDs can be predicted using linear interpolation of the King County model output for annual TP loading and the resulting summer mean concentration of chlorophyll *a* (which is a measure of algae biomass) under current land use and future full build-out land use conditions in the watershed. The assumptions and methods for these calculations are presented below. These calculations indicate that there would be a 38 percent increase in the summer mean chlorophyll *a* concentration from the MPDs. The increased TP loading and chlorophyll *a* concentrations would likely increase the trophic state of the lake and the abundance of bluegreen algae (cyanobacteria) that could result in closures of the lake to all recreational activity for protection of public health from cyanobacteria toxicity. Cyanobacteria toxicity has resulted in many lake closures and some dog deaths in Washington.

8. **Future water quality evaluations should use the King County (2000) model directly.** For future water quality evaluations, we recommend that the applicant use the publicly available Hydrologic Simulation Program – FORTRAN (HSPF) model of the Lake Sawyer watershed and the associated spreadsheet model of TP loading developed for the Lake Sawyer Management Plan (King County 2000). This model was calibrated based on observed flow, water level, and water quality data for Lake Sawyer and represents the best available science for estimating TP loadings under existing and post-project conditions.

9. **Future water quality evaluations should account for stormwater treatment bypass.** Future water quality evaluations should explicitly consider the amount of bypass expected for the stormwater treatment facilities, based on review of engineering design plans and details (not currently available). Overflows during infrequent but large storms can contribute significant amounts of phosphorus to the lake, which needs to be accounted for in the analysis.

10. **On-site stormwater management discussions are inadequate.** Section 3.1.2 of *The Villages MPD Water Quality Technical Analysis* discusses that on-site stormwater would be collected and directed to temporary or permanent facilities. Several methods of temporary on-site stormwater management are discussed, but methods for permanent on-site management are not presented.

    On-site stormwater management strategies are required by City Code (18.98.020 B) and are critical to the long term performance of the proposed end-of-pipe regional treatment facilities. With on-site stormwater strategies maximized throughout both MPD sites, the amount of stormwater runoff and pollutants conveyed to the end-of-pipe regional facilities will be greatly reduced, thereby reducing the amount of overflow that would otherwise occur and providing a much needed factor of safety for their long term performance. Given the importance of this issue, the report should discuss specific on-site stormwater strategies that will be used. We recommend the following strategies be evaluated and used to the maximum extent feasible throughout both MPDs:

    - Minimize the amount of impervious areas.
    - Amend soils in all disturbed pervious areas (such as lawns) with non-phosphorus-exporting compost material.
    - Collect and reuse rainwater from residential and commercial roof areas.
    - Use pervious pavement for non-roadway impervious surfaces, such as parking lots, sidewalks, driveways, trails, and walkways.
    - Use bioretention facilities extensively in residential and commercial areas and along roadways. It is noted that bioretention is discussed in Section 3.2.4.1 of *The Villages MPD Water Quality Technical Analysis*, but the extent of its use is not discussed. Bioretention is a very powerful on-site tool and should be used as extensively as possible. As with compost amendments, non-phosphorus-exporting bioretention soil mix should be specified.
    - Install vegetated roofs where appropriate.

11. **Monitoring and adaptive management programs need to be developed.** The analyses did not propose a monitoring program to evaluate effectiveness of stormwater treatment facilities or impacts of the development on water quality. A monitoring program should be developed to collect water quality and hydrologic data during baseline (pre-construction), construction, and operation periods for both projects. Comprehensive monitoring programs are required by King County for

master plan developments (see guidelines in King County 1995) and have been implemented for other MDPs (e.g., Snoqualmie Ridge and Issaquah Highlands). At a minimum, the monitoring program should be designed to collect sufficient data for accurate calculation of TP removal efficiency of the wet ponds and other treatment facilities (e.g., see TAPE guidelines in Ecology 2008), and calculation of annual TP loadings from the site to receiving waters during construction and operation periods. Furthermore, adaptive management approaches should be identified to provide additional TP removal if the monitoring results show a low TP removal rate or a high TP loading rate that impacts water quality in Lake Sawyer.

Loading Model Assumptions and Calculations

This section documents the assumptions and methods used to estimate TP loading rates to Lake Sawyer as a result of The Villages and Lawson Hills MPDs. As described above, two methods were used. The first method entailed interpolating TP loading rates reported for existing and future conditions in the Lake Sawyer Management Plan (King County 2000). The second method entailed development of a simple washoff model.

Method 1 – King County (2000) Model Output Interpolation

Assumptions:

- The increase in the annual TP loading rate predicted for the future full build-out scenario modeled by King County is proportional to the increased area of residential development in the watershed.
- The annual TP loading rate from the MDPs is proportional to the area of residential development for the MDPs compared to that for the future full build-out with stormwater controls scenario modeled by King County.
- Current residential development area = 769 acres (Table 2-1 in King County 2000)
- Future residential development area under full build-out conditions = 3,625 acres (Table 2-1 in King County 2000)
- MDP area draining to the lake = 1,150 acres (65 percent of the 1,190-acre Villages MPD drains to the lake based on a comparison of the MDP analysis map and discussion to the lake watershed map in King County, and 100 percent of the 376-acre Lawson Hills MPD drains to the lake)
- Current TP loading to the lake = 1,318 kg/yr for a typical year (King County 2000)

- Future TP loading to the lake for the future full build-out condition with stormwater controls = 2,255 kg/yr (King County 2000)

Calculations:

- TP loading from MDPs = 1,150 acres * (2,255 – 1,318 kg/yr)/(3,625 – 769 acres) = 377 kg/yr
- Percent increase in TP loading from MDPs = 377/1,318 kg/yr * 100% = 29%
- Lake TP loading capacity exceeded with MDPs = (1,318 + 377 kg/yr) - 715 kg/yr = 980 kg/yr

Method 2 – Washoff Model

Assumptions:

- The existing land use in the MDP area consists primarily of forest that will be converted to urban land use.
- MDP area draining to the lake = 1,150 acres (65 percent of the 1,190-acre Villages MPD drains to the lake based on a comparison of the MDP analysis map and discussion to the lake watershed map in King County (2000), and 100 percent of the 376-acre Lawson Hills MPD drains to the lake)
- TP yield coefficients for forest = 10 mg/m^2/yr (0.04 kg/acre/yr) based on a study of 473 drainage basins in 1978 (Table 3.4 in Cooke et al. 2005)
- TP yield coefficients for urban land use = 100 mg/m^2/yr (0.4 kg/acre/yr) based on a study of 473 drainage basins in 1978 (Table 3.4 in Cooke et al. 2005)
- Stormwater controls would reduce phosphorous loads from urban land use by 50 percent.

Calculations:

- TP loading from MDPs = (1,150 acres * 0.4 kg/acre/yr *0.5) – (1,150 acres *0.04 kg/acre/yr) = 184 kg/yr
- Percent increase in TP loading from MDPs = 184/1,318 kg/yr * 100% = 14%
- Lake TP loading capacity exceeded with MDPs = (1,318 + 184 kg/yr) - 715 kg/yr = 787 kg/yr

Chlorophyll Prediction Assumptions and Calculations

Assumptions:

- Summer mean concentration of chlorophyll *a* will increase in proportion to the increase in the annual TP loading rate.
- Current annual TP loading rate for existing lane use = 1,318 kg/yr (King County 2000)
- Future annual TP loading rate with MDPs = 1,318 + 377 = 1,695 kg/yr based on the King County (2000) model output interpolation conducted above

Calculations:

- Linear regression of the annual TP loading for an average year with existing land use (1,318 kg/yr) and the future full build-out without stormwater controls scenario (2,414 kg/yr) versus the summer mean chlorophyll *a* concentration for an average year with existing land use (6.6 ug/L) and the future full build-out without stormwater controls scenario (13.8 ug/L) from the King County (2000) model output yields the following equation for predicting the summer mean chlorophyll *a* concentration as a function of annual TP loading:
  - Chl*a* (ug/L) = 0.0066 * TP (kg/yr) - 2.0584
- Chlorophyll *a* concentration without MDPs = 0.0066 * 1,318 kg/yr - 2.0584 = 6.6 ug/L
- Chlorophyll *a* concentration with MDPs = 0.0066 * 1,695 kg/yr - 2.0584 = 9.1 ug/L
- Percent increase in the summer mean chlorophyll *a* concentration from the MDPs = (9.1 - 6.6 ug/L)/6.6 ug/L * 100% = 38%

Other Considerations

- King County Ordinance 16392, effective January 2011, bans the use of lawn fertilizers containing phosphorus. Given that lawns are the largest source of total phosphorus in residential areas (Waschbusch et al. 1999), a similar ban should be considered for both MPDs.

- While the project applications state that stormwater runoff will be managed in accordance with the 2005 Ecology manual, which requires that stormwater treatment facilities achieve a 50 percent reduction in TP where enhanced treatment requirements apply, there are known technologies that provide significantly higher removal rates, such as alum treatments and full infiltration. Selection of stormwater treatment practices should be based on an evaluation of all known, achievable, and reasonable methods (AKART) in order to minimize or prevent phosphorus from leaving the project sites.

- The City of Sammamish adopted recommendations from the Beaver Lake Management Plan (King County 2007) in its Environmentally Critical Areas Code (Lake Management areas – Special district overlay 21A.50.355). The Code establishes an 80 percent annual TP load reduction goal for new impervious surfaces. A similar annual TP load reduction goal for the project impervious surface areas, or for the Lake Sawyer watershed as a whole, should be considered for Lake Sawyer.

References

Center for Watershed Protection. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection, Ellicott City, Maryland. June 2000.

Center for Watershed Protection. 2007. National Pollutant Removal Performance Database, Version 3. Center for Watershed Protection, Ellicott City, Maryland. September 2007.

Cooke, G.D., E.B. Welch, S.A. Peterson, and S.A. Nichols. 2005. Restoration and Management of Lakes and Reservoirs. Third Edition. CRC Press, Taylor & Francis Group, LLC, Boca Raton, Florida.

Ecology. 1991. Diagnostic Study of Lake Sawyer, King County, Washington. Prepared by J.V. Carroll and G.J. Pelletier, Washington State Department of Ecology, Olympia, Washington.

Ecology. 2008. Guidance for Evaluating Emerging Stormwater Treatment Technologies, Technology Assessment Protocol – Ecology (TAPE). Washington State Department of Ecology, Water Quality Program, Olympia, Washington. January 2008 Revision. <http://www.ecy.wa.gov/biblio/0210037.html>.

Findley, Charles. 1993. Personal communication (letter to Michael Llewelyn, Water Quality Program Manager, Washington Department of Ecology, Olympia, Washington). Director, Water Division, U.S. Environmental Protection Agency, Region 10, Seattle Washington. February 12, 1993.

King County. 1995. Master Drainage Planning for Large Site Developments, Process and Requirement Guidelines. King County Department of Development and Environmental Services, Surface Water management, and Department of Public Works, Seattle, Washington.

King County. 2000. Lake Sawyer Management Plan. Prepared by King County Surface Water Management, Seattle, Washington with assistance from Entranco, Bellevue, Washington. July 2000.

King County. 2007. Beaver Lake Management Plan Update; A Report on the Water Quality of Beaver Lake for 2001 to 2006. Final Report for Beaver Lake Management District No. 2, prepared for the City of Sammamish by Sally Abella and Michael Murphy of King County Water and Land Resources Division. December 2007.

King County. 2010. Lake Sawyer Water Quality – A Report on Water Quality Monitoring Results for Water Year 2009 at Lake Sawyer. Prepared for the City of Black Diamond by the King County Lake Stewardship Program, Seattle, Washington. January 15, 2010.

Shaver, E. R. Horner, J. Skupien, C. May, and G. Ridley. 2007. Fundamentals of Urban Runoff Management, Technical and Institutional Issues. Second Edition. North American Lake Management Society, Madison, Wisconsin.

Waschbusch, R.J., W.R. Selbig, and R.T. Bannerman. 1999. Sources of Phosphorus in Stormwater and Street Dirt from Two Urban Residential Basins in Madison, Wisconsin. U.S. Geological Survey, Middleton, Wisconsin.