2020 Lacamas Shores Biofilter Status Report

by Marie Tabata-Callerame and Rodger Hauge

Purpose

1) To investigate the water quality of the stormwater draining from the Lacamas Shores Biofilter (“Biofilter”) into the shoreline wetlands of the Conservancy Zone of Lacamas Lake.
2) To determine whether the Biofilter is meeting “compliance criteria”, i.e., compliance standards set for the site via City permit.
3) To determine the efficiency of Biofilter by comparing water quality parameters at the inlets against the outlets.
4) To form a shared understanding of the current state of the Biofilter that could allow for repair, restoration and/or enhancement of the Biofilter as needed.

Abstract

In 2020, Lacamas Lake tested positive for harmful algae toxins 26 out of 29 times between April and October. The harmful algae blooms occurred along the southwest shoreline of Lacamas Lake, three-quarters of which is bordered by the Lacamas Shores neighborhood. Stormwater samples taken September 2020 in the Biofilter and the adjacent shoreline wetlands were tested for the three water quality parameters shown to be of concern in recent tests. Those three parameters are total phosphorus µg/L (“TP”), total suspended solids mg/L (“TSS”) and conductivity uS/cm. The results indicated that the water coming into the Biofilter had better water quality values than the water discharged. The Biofilter was unable to slow the flow of water coming through the drainage system. Under fast flowing/high-volume conditions, the results for TP, TSS and conductivity at the outlets were elevated above inlet conditions. Those elevated concentrations put the stormwater outlets well over the compliance levels for those water quality parameters. By comparing the 1990 results with current results, we see that inlet/incoming concentrations are little changed; the efficiency of the Biofilter today is degraded.

Background

Built in 1988, the Biofilter consists of 5.62 acres of stormwater treatment wetlands owned solely by the Lacamas Shores Homeowners Association ("LSHOA").[1] The Biofilter works by collecting stormwater runoff from LSHOA properties[2] and routing the runoff into a bubbler system where it is released below ground into the treatment wetlands. The Biofilter was designed to process the stormwater from approximately 36.4 acres of the Lacamas Shores development[3] before reaching the Lake and its shoreline wetlands.

Excerpts from a 1993 national magazine article about the Biofilter[4] summarize its intended design:

> "The Washington Department of Ecology required that the quality and quantity of stormwater runoff from the [Lacamas Shores] development could not exceed predevelopment conditions. Therefore, runoff discharged to the lake had to be treated and detained in an on-site facility [i.e., the Biofilter] before discharge."
>
> "French drains, or 'bubblers,' were designed to direct runoff below grade and create a sheet flow several centimeters deep that enters the upgradient edge of the emergent [treatment] wetlands. The wetlands then 'treat' the inflowing stormwater before it enters Lacamas Lake."

The only surface water connection between the Biofilter's treatment wetlands and the shoreline wetlands of Lacamas Lake (the "Lake") is under two concrete bridges embedded in the Heritage Trail. Aerial maps of the Biofilter are contained in Appendices A, B, and C. Storm drainage facilities of the Biofilter are shown in red.

The largest part of the Biofilter is the filtering biology and sediments. The Stormwater Partners of SW Washington explains that stormwater treatment wetlands ". . . treat stormwater through the biological processes associated with aquatic plants. These facilities use dense wetland vegetation and settling to filter sediment and oily materials out of stormwater."[5] Their webpage as also states that "As stormwater passes through the

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[1] For this report, the "Biofilter" means the stormwater treatment wetland/facility on the LSHOA common property adjacent to the shoreline along Lacamas Lake. It is next to but separate from the 0.25-acre Lacamas Shores Bioswale and Sediment Settling Pond system. The "Swale/Pond" system is not part of the testing in this report.

[2] Approximately 65 of the 254 LSHOA lots drain into the Biofilter according to the map in Appendix E.

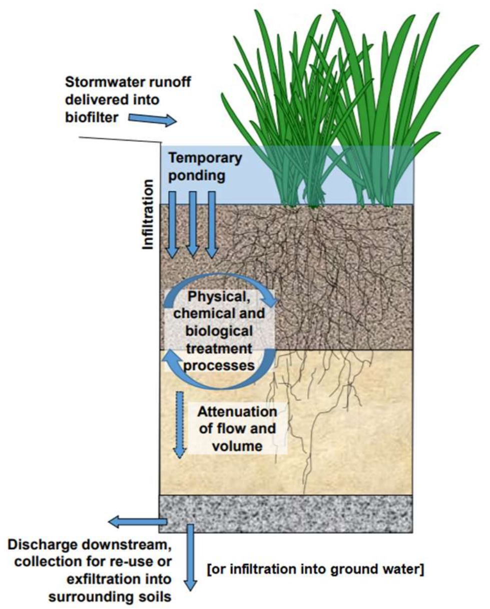
[3] Appendix E shows the sections that drain into the Biofilter: J, K and an unlabeled area. J+K=32.0 acres. The unlabeled area drains 4.4 acres according to a 1991 "Shipler Property Bio-Filter Basins Map" (p. 19) where it is labeled as "K". Therefore, as designed, the Biofilter should have a total drainage basin of 36.4 acres. Mackay & Sposito, 9 July 1996, *Modifications to Lacamas Shores Stormwater Disposal System: Drainage Calculation*, p. 19.

[4] See Appendix F, pages 50 and 52.

[5] Stormwater Partners. *Stormwater Facilities.* Accessed 03/28/2021. https://www.stormwaterpartners.com/facilities-treatment-wetland and https://www.stormwaterpartners.com/facilities-biofiltration-swale. The density of the plants' root systems is important to effective filtration.

plants, pollutants are removed by the combined effects of filtration, infiltration, and settling." (Fig.1 [6])

Figure 1. Key Principals of Stormwater Biofiltration.



Properly dense and well rooted vegetation is key. Vegetation "[s]erves multiple roles in water treatment via uptake, transformation to organic forms, carbon provision to microbes, transpiration reducing stormwater volume, stabilising media surface, helping to maintaining infiltration rates, provides cooling to surrounding environment, amenity and aesthetics. The microbial community associated with plant roots facilitates uptake, decomposition and transformation of stormwater pollutants and plant litter."[7]

Pollutants collected from filtered stormwater leave a biofilter in only three major ways: use by plants and the attached microbes for biochemical processes; physical removal of dead or dying/seasonal plant matter and sediments; or flowing into the lake in dissolved form or attached to solids.

All filtration systems require maintenance to their filters. For biofilters, that means removal of dead or seasonal plant matter and sediment. According to Clark County, "Proper maintenance helps ensure that facilities operate as they were designed and that trapped pollutants, such as sediment and oils, are cleaned out *so that the facilities do not become pollutant sources*."[8] [emphasis mine] Maintenance was considered important enough that the City permit for the property required the creation of the LSHOA specifically to ". . . be responsible for monitoring and maintaining the storm drainage system . . .",[9] at Ecology's directive (Appendix K).

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[6] Payne, E.G.I., Hatt, B.E., Deletic, A., Dobbie, M.F., McCarthy, D.T. and Chandrasena, G.I., 2015. *Adoption Guidelines for Stormwater Biofiltration Systems - Summary Report*, Australian Government, Department of Industry and Science, Melbourne, Australia: Cooperative Research Centre for Water Sensitive Cities. p.3 "*Figure 1. Key Principles of Stormwater Biofiltration*"

[7] *Adoption Guidelines For Stormwater Biofiltration Systems*, *Table 1. Key components of stormwater biofilters and their functional roles* from p. 7.

[8] *Clark County Stormwater Manual 2015, Book 4 – Stormwater Facility Operations and Maintenance*, Clark County, Washington, November 24, 2015, p. 1. https://clark.wa.gov/sites/default/files/dept/files/environmental-services/Stormwater/Code/ccsm2015-book-4.pdf.

[9] City of Camas. 15 June 1988. *City of Camas Permit No. 2-87 (C-2-87) and Shoreline Conditional Use Permit, Camas Permit No. 590-14-7806*. https://www.lacamasshoresbiofilter.org/uploads/1/2/2/5/122588755/ls_hoa_approved_permit_june_1988.pdf See bullet #12.

In a 1993 letter from Doug Quinn of the City of Camas[10] ("City"), it was noted that the Biofilter's treatment wetlands worked to reduce pollutants. Quinn quoted the firm that conducted the 5-year Monitoring Program required by permit[11]: "In cases where the inflowing concentrations of the monitored water quality parameters are greater than the established site-specific levels, there is always a decrease in these parameters after passing over the wetlands."

The Monitoring Program was designed specifically to measure the efficiency of the Biofilter and set compliance standards to protect the water quality ("WQ") entering the Lake. The Program and the standards were required by the 1988 SDP/CUP Permit and 1988 Agreed Order. The Order was entered by the Shoreline Hearings Board with the agreement of the City and Washington Department of Ecology.

Specifically, the permit required "triggers" (i.e., "compliance criteria" or "compliance standards") to be created after the first year of the Monitoring Program.[12] Those criteria were published in the annual reports for the Monitoring Program and sent to Ecology.[13] They were also published in a 1993 article about this innovative Biofilter in a national water technology magazine. See Table 1 from Appendix F and Appendix G.

Table 1. Compliance Standards Required and Set by City of Camas Permit (Appendix F)

Compliance Criteria Determined from Site Monitoring

Parameter	Units	Compliance level[a] Bubbler, wetland 1 (S4)	Bubbler, wetland 2 (S2)
Primary			
TP	mg/L	0.118 [0.223]	0.110 [0.251]
PO_4	mg/L	0.061 [0.131]	0.042 [0.090]
NO_3	mg/L	0.159 [0.565]	0.188 [0.607]
Secondary			
pH		6.3 [4.7–7.9]	6.1 [4.4–7.8]
Conductivity	µmho/cm	63 [97]	87 [135]
TSS	mg/L	19.4 [51.6]	25.8 [72.0]
Oil and grease	mg/L	1.5 [4.2]	1.8 [4.5]
Chromium	mg/L	Wash. wq stds.[b]	Wash. wq stds.
Copper	mg/L	Wash. wq stds.	Wash. wq stds.
Lead	mg/L	Wash. wq stds.	Wash. wq stds.
Zinc	mg/L	Wash. wq stds.	Wash. wq stds.
Organophosphate pesticides	µg/L	detection limit	detection limit
Chlorinated pesticides	µg/L	detection limit	detection limit
Chlorinated herbicides	µg/L	detection limit	detection limit

[a]Numbers in brackets are the compliance concentration plus twice the standard deviation.
[b]Wash. wq stds. = Washington state water quality standards.

After 1993, an adjacent but separate "swale/pond system" was added to accommodate re-routed stormwater from another 38.0 acres of LSHOA properties southeast of the swale.[14]

[10] Quinn, D. Letter re: "Lacamas Shores Shoreline Permit", Received by the "Shoreline Committee Members", 22 June 1993, page 6. This letter was included in the 1993 Permit Revisions packet. Quinn was the Director of Public Works and City Engineering.

[11] City of Camas Permit. See bullet 9b. "During the first year, discuss appropriate use of the background data to produce maximum contaminant levels. Most likely, these will have to use concentration values (mg/L). Develop the 'formula' to convert concentrations into implementation trigger. This will be done in conjunction with Ecology."

[12] City of Camas Permit. See bullet 9c. "Implement the trigger criteria at the end of the first year. "

[13] Final year report: SRI/Shapiro, Five-Year Stormwater Runoff and Wetland Biofilter Monitoring Program for the Lacamas Shores Development: Fifth Year Report, March 11, 1994. See also the appendices in Appendix G below.

[14] Mackay & Sposito, 9 July 1996, *Modifications to Lacamas Shores Stormwater Disposal System: Drainage Calculation*, p. 19. Shipler Property Bio-Filter Basins Map

During the Biofilter's first years, the property, named "Meadowlands Park" by the developer, was a mix of grassland and wetmeadow with a few scattered trees. Now, the Biofilter's wetlands are a mature stand of pacific willow, red alder, and other riparian species.

Historical Scientific Data

One way to test the efficiency of any filtration system is to compare what goes into it against what comes out of it. The majority of data about the Biofilter's efficiency comes from 1988-1993, as listed in the 5-Year Monitoring Program's last annual report in Appendix A, Table 1.[15] (Appendix G)

Between 1993 and last September, there had been no tests comparing the major water quality parameters at the inlets to those at the outlets. The only known tests of the Biofilter since 1993 are:

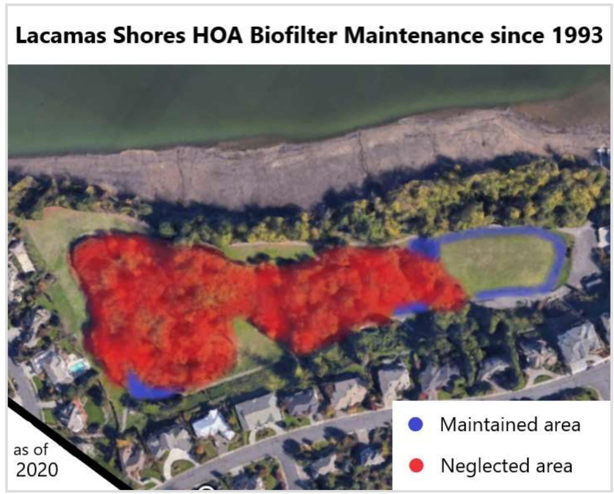
- 04/2018 - Chemical Oxygen Demand ("COD") grab samples testing inlets and outlets (Appendix H).
- 12/2019 - City of Camas/Otak/BSK Outlet Samples testing outlets for organic and inorganic parameters (Appendix I).
- 05/2020 - City of Camas/Otak/BSK Outlet Samples testing outlets for organic and inorganic parameters (Appendix J).
- 09/2020 – Current sampling ("Current") testing inlets and outlets for the three major parameters, the main topic of this report (Table 3).

In 2019, the City committed to testing the stormwater runoff from the Biofilter. Using the sampling locations in the Monitoring Program, the City selected the two outlet locations closest to the Lake for sampling. The City did not include the compliance points, although it is unclear whether the City knew of the compliance locations at the time of the testing. The City did not include inlet points in their testing, so there was no determination of the Biofilter's effectiveness. While the City contracted for quarterly testing of the two points, only two tests were conducted between Dec 2019 and Dec 2020.

[15] The full report is here: Bautista, Mark and Geiger, Stan (11 March 1994) *Fifth Year Report: 5-year Stormwater Runoff and Wetland Biofilter Monitoring Program for the Lacamas Shores Residential Development*. SRI/Shapiro, Lake Oswego, OR.

The City's December 2019 test and the 2018 chemical oxygen demand ("COD") sample results indicated that there may be a problem with the Biofilter's efficiency[16]. However, the 5.62-acres of the filtering biology and sediments of the Biofilter have not been maintained or modified since inception. The reason was the understanding explained in a letter written in 2018 by Ecology stating that "In this case, Ecology is unlikely to approve the CUP Permit" to allow vegetation removal other than invasive species.[17] The City's response to that letter was, as before, to disallow all maintenance that might require tree removal. While the City has required the LSHOA to complete some maintenance to pipes and the adjacent biofiltration system,[18] there are no plans to require maintenance to the largest part of the Biofilter - the filtering plant biology and sediments (Fig. 2 [19]). While there are plans to work with Clark County and the State to address Lacamas Lake's toxic algae problem,[20] there are currently no commitments to test/monitor any other Lake inlets nor the effectiveness of any biofilters in treating stormwater.

Figure 2. The "Filter" of the Biofilter Remains Un-maintained



[16] The 2018 COD Grab sample testing of inlets and outlets shows that the outlets had worse WQ than the inlets (Appendix H). The December 2019 WQ testing by the City of Camas showed all three parameters were out of compliance and above the maximum allowable levels (Appendix I).

[17] Rothwell, Rebecca. Letter to R. Maul and S. MacPherson. *Re: Lacamas Shores Wetlands.* 22 Feb 2018. https://www.lacamasshoresbiofilter.org/documents.html. p. 3. The author of the 2018 Ecology letter qualified her conclusion, stating that she "had found no evidence that the wetland was constructed from upland for the purpose of stormwater treatment or detention." It is likely that the author was unaware of a letter Ecology wrote in 1988 (Appendix K) showing their clear expectation that the Biofilter property was to be used and tested as a "wetland filtering" system that was "on the periphery" of what they knew about biofiltering efficiency at that time. The 1988 letter and the compliance standards were brought to light by M. Tabata-Callerame in a 2020 email to Steve Wall. Tabata-Callerame, M. "Re: RE: Lacamas Shores failed biofilter test plan/results". Email to Steve Wall. 05/26/2020.

[18] The HOA has maintained the following: the nearby bioswale and sediment settling pond system ("swale/pond system") via annually removing the vegetation and periodically dredging; the Biofilter bubblers pipes in 2019 for the first time by cleaning them out from the inside; and the manholes coming from the City's storm vaults.

[19] *The Promise of the Lacamas Shores Biofilter: The Meadowlands Biofilter "Rediscovered" - FAQs.* (n.d.) https://www.lacamasshoresbiofilter.org/faqs.html, Accessed 2/11/2021.

[20] In 2020, Lacamas Lake tested positive for harmful algae toxins 26 out of 29 times between April and October, per the Dept. of Ecology's website. Wa Dept of Ecology, 2020, *Washington State Toxic Algae: Freshwater Toxic Algae Bloom Monitoring Program [Lacamas Lake]*, https://www.nwtoxicalgae.org/Data.aspx?SiteID=94. Reports of toxic algae blooms substantially increased from two in 2018, to three or four in 2019 (one test officially recorded on the toxic algae website in June, others were reported by residents in September and October after funds for the testing program had depleted), to the near-continual toxic algae blooms in 2020. Reports for Round Lake are similar.

Citizen Testing

On September 23, 2020, samples were collected of runoff flowing into the Biofilter and from the outlets flowing into the Lake. These samples were delivered to Columbia Laboratories for analysis. The purpose of this testing was to provide a snapshot in time of the Biofilter's effectiveness. This snapshot only addressed the parameters that were non-compliant in the 2019 and 2020 testing: total phosphorus ("TP"), total suspended solids ("TSS") and conductivity.

The Collection Process

Sample locations were selected based on the inlets and outlets sampled in the Monitoring Report. The City's sampling locations L1 and L2,[21] also chosen from the Monitoring Report, were added to allow for comparison to the City's December and May samplings. Samples were taken as listed chronologically in the Table 3. Sample locations were documented on Columbia Laboratories ("Lab") Environmental Chain of Custody Record by Marie Tabata-Callerame before sampling. The collection process was video recorded by reporter John Ley.

Optimal timing for sampling would have been during the first flush of the month, which occurred September 18th and 19th, when it rained 2.16 inches after several dry days. However, due to the unusually large amount of wildfire smoke before the first flush, the decision was made to use the second flush, which occurred September 23rd. On that day, sampling was accomplished in a moderate rain.

All sample containers were delivered from the Columbia Laboratories by the vendor to Todd Schoenlein's house in a cooler. There were 250 ml plastic bottles containing 2 ml of dilute sulfuric acid for each Total Phosphorus ("TP) sample and 1-liter plastic bottles without acid preservative, i.e., empty, for each total suspended solids ("TSS")/ conductivity sample.

Containers were labeled by Schoenlein. Tabata-Callerame verified the sampling locations and proper labeling. Samples for B1, B2, S2, and S4 were taken by Prof. Rodger Hauge. Samples for L1 and L2 were taken by Schoenlein. Only Schoenlein and/or Hauge handled open collection containers and put them in the storage cooler. Samples were transported from site to car by Schoenlein and Hauge, then to the Lab by Schoenlein and Ley.

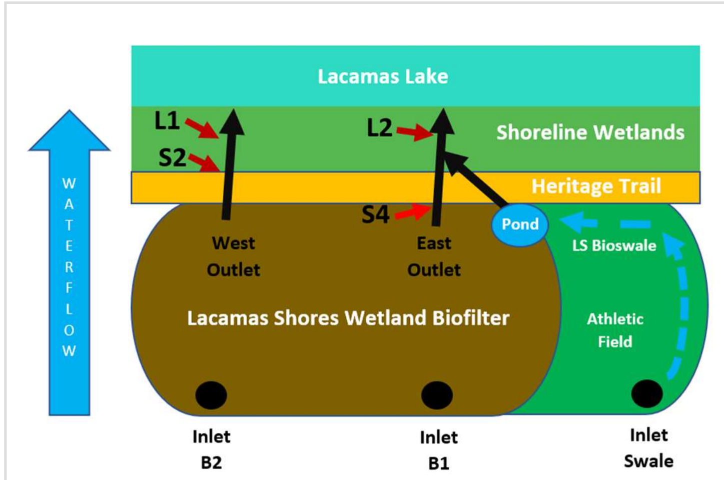
[21] The City's sampling locations were shown in a document provided by the City's Director of Public Works Steve Wall. "Exhibit A: City of Camas, Quarterly Sampling of Outfalls, Scope of Work, Otak Project #19447, November 13, 2019." was attached to: Wall, Steve. *RE: Lacamas Shores failed biofilter test plan/results.* Message to Steven D. Bang. 05/15/2020. Email.

Standard Operating Procedures

The samplers wore gloves to avoid sample contamination. Onsite, Hauge tested water temperature in-stream using an aquatic thermometer. He tested pH using a broad range LaMotte pH test kit.

All samples for TP, TSS and conductivity were processed and reported by Columbia Laboratories (Appendix D).

Figure 3. Diagram of Biofilter Waterflow



Sampling Observations

Please see the maps in Appendix A-C and/or Fig. 3 for reference.

Figure 4. B2 Inlet manhole cover after 20 min. of rain

1. Inlet B2 was overflowing on the day/time it was sampled (Fig. 4). The water was flowing vigorously out the top of the manhole and flowing down a channel through the Biofilter towards the Lake.[22] No measure of flow was made.
2. Inlet B1 was also overflowing but with less volume than B2. There was evidence that there had been excavation around B1.[23]
3. The volume of the stream at S4 was much smaller than any other inlet or outlet tested.
4. The separate sediment settling pond system ("swale/pond system") was functioning. The swale has stormwater running through it and was flowing into the swale/pond system as designed (Appendix E). The swale vegetation was short and well maintained. The pond was discharging through two black outlets into the shoreline wetlands upstream of the L2 location.

[22] It was noted two weeks later, after a rain, that stormwater was seen flowing from the bottom of the B2 man-hole riser down a channel into the Biofilter.

[23] It was noted two weeks later, after a rain, that the B1 manhole cover was observed as underwater. On 02/28/2021, the manhole was observed to be fully submerged.

5. The stormwater running from S4 (the Biofilter outlet) converged with water from the black outlets of the swale/pond to run through L2 and into the Lake. The volume coming from the two black swale/pond outlets was much greater than the volume coming from S4.

6. Stormwater at the Biofilter outlets showed visible suspended solids. Stormwater at the Biofilter inlets appeared clearer in comparison, indicating erosion of sediment as it flowed across the Biofilter.

7. The only surface water connection between the Biofilter and the shoreline wetlands are underneath two concrete bridges on the Heritage Trail, one located at S2 and the other at S4. All water exiting the Biofilter as surface water must go through one or the other of these two points.

8. The S outlet locations are compliance points at the Biofilter's exits. The L outlet locations are 16-30m downstream of the S locations and are within the shoreline wetlands near the Lake waterbody.

Tables 2a, 2b, and 2c. Precipitation Results for Recent Sample Dates from the NOAA Database for Station # US1WACK0029, located in Camas, WA, (45.584519, -122.373998).

Date 2019	Precipitation (inches)	Samples taken
12/15	0	
12/16	0	
12/17	0	
12/18	0	
12/19	0.9	X
12/20	0.1	
12/21	0.88	
12/22	0.06	
12/23	0.24	
12/24	0.02	
12/25	0	
12/26	0	

Date 2020	Precipitation (inches)	Samples taken
5/10	0	
5/11	0	
5/12	0.33	
5/13	0.07	
5/14	0.17	
5/15	0.19	
5/16	0.02	
5/17	0.36	
5/18	0.47	
5/19	0.36	
5/20	0.03	
5/21	0.64	X
5/22	0.09	
5/23	0	

Date 2020	Precipitation (inches)	Samples taken
9/15	0	
9/16	0	
9/17	0	
9/18	1.96	1st flush
9/19	0.2	
9/20	0	
9/21	0	
9/22	0	
9/23	0.69	X
9/24	0.77	
9/25	0.77	
9/26	0.25	
9/27	0	
9/28	0	

9. See the precipitation information in Tables 2a-c showing the amount of rain for the recent datasets. Sampling during the first 12-hours of a storm event is the proper protocol for stormwater sampling, according to Ecology.[24] For the Current

[24] Stormwater sampling standards require sampling during ". . . the first fall storm event each year. The [NPDES] permit defines the first fall storm event as the first time after October 1st that precipitation occurs and results in a stormwater discharge from the facility." It is also stated that one should "Collect samples within the first 12 hours

sampling (as with the Dec 2019 sampling), the prior 3 days were rainless. Note that the May 2020 sampling was taken outside that protocol.

10. Biofilter vegetation was consistent with typical riparian species, including red alder and pacific willow.

The Test Results

September 23, 2020 Data ("Current")

The dataset resulting from the 09/23/2020 sampling ("Current") is summarized in Table 3, illustrated in Appendices A, B and C, and is compared to datasets from the 1990's and the more recent 2019 and 2020 datasets ("Recent") in Tables 4-8. The Current dataset (Table 3) shows that:

- The results for the inlets are high for most parameters,
- The results for the outlet compliance points are higher than the inlets, i.e., the water is more contaminated going out of the Biofilter than it was coming into the Biofilter.
- The results for the points that the City tested (L locations) have values lower than their respective upstream compliance points (S locations).
- All inlets and outlets are above the acceptable levels set by City permit.

Note: To understand these observations better, reference Figure 3 or the maps in Appendices A, B, and C, each of which illustrate the locations from which the samples and measurements were taken.

of stormwater discharge. If you are not able to collect a sample within the first 12 hours, collect the sample as soon as possible. In the sampling records, keep documentation explaining why you could not collect samples within the first 12 hours." Washington State Department of Ecology. "Stormwater Sampling Manual: A guide for the Industrial Stormwater General Permit". December 2015. Olympia, WA. Publication No. 15-03-044. p. 16

Table 3. Sample Information and Results (listed chronologically)

	Sample Collection Taken From	Time Taken	pH	Water Temperature	TP µg/L	CC TP [Max]	TSS mg/L[25]	CC TSS [Max]	Conductivity uS/cm	CC Cond. [Max]
B1 Inlet	Waterflow outside the manhole cover near athletic field (west edge of cover)	~~13:55~~ 14.02	6.5	17°C	145		14		83.5	
B2 Inlet	Water overflowing the top of the manhole by the SW Corner	14:22	6.0	18°C	225		98		71.8	
S2 Outlet	Channel coming out of the lakeside (N) of west bridge COMPLIANCE POINT	After B2	6.5	18°C	555*	110 [251]	260*	25.8 [72]	115	87 [135]
L1 Outlet	Channel downstream of S2 before reaching the Lake - City sample location for Dec 2019 and May 2020	After S2	-	-	319		140		90.5	
S4 Outlet	Channel before entering east bridge[6] (S) COMPLIANCE POINT	14:44	6.0	18°C	976*	118 [223]	184*	19.4 [51.6]	105	63 [97]
L2 Outlet	Channel downstream of S4 and the sediment pond outlets before reaching the Lake - City sample location for Dec 2019 and May 2020	14:50	-	-	135		82		84.8	

*Indicates that the reading is higher than any reading taken at that location, including since 1988.

Note that the maximum standard allowed ("max allowed") is calculated as the compliance level plus two standard deviations. It was set to require maintenance action and/or to indicate a violation of the permit.[26]

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[25] This report and Appendix B were edited 8/16/2021 to correct the units of measurements for TSS, which were consistently and erroneously reported in µg/L instead of mg/L in the initial report (dated 4/10/2021). No other changes to data nor substance of the report were made. The TSS values throughout the 4/10/2021 report were correct for mg/L. Ex: A TSS of 14 reported in µg/L should have been reported as a TSS of 14 in mg/L.

[26] "In general, water quality values outside the range of *two standard deviations* from the baseline were considered of concern and warranting further consideration as to origin and impacts. . . . Exceeding the criteria would

At the compliance locations, Current TP and TSS are the highest ever recorded for those points. For S2:

- All three parameters are over the compliance level.
- TP is 5x the compliance level and over double the max allowed,
- TSS is 10x the compliance level and over 3 times the max allowed.

The S4 results show similarly noncompliant WQ levels:

- All three parameters are over the compliance level.
- TP is 8x the compliance level and over 4x the maximum allowed,
- TSS is 9x the compliance level and also over 3 times the maximum allowed (about the same as S2).
- Conductivity is also over the maximum allowed.

The L2-S4 difference is explained by dilution with the swale/pond outlet. The stream coming from S4 merges with the much larger volume from the swale/pond system. It is likely that any eroded sediments from the adjacent swale gets settled out into the pond. That would be expected, since the City has required that system to be annually mowed with the clippings taken away, as well as periodically excavated. The swale/pond system was not sampled.

The L1 point (downstream of S2) seems to have been either diluted or filtered between the two points, but no surface water source is visible.

provide a signal that the particular monitored parameter was varying outside of the annual baseline conditions and that it may be necessary to implement contingencies." 5-Year Monitoring Program Report. p. 5. Per Ecology, such "contingencies" could include ". . . the development of a tightlined offsite stormwater facility." Appendix K, p.3

Compared to Prior Datasets

Is the Current stormwater sample better or worse than in the past? Are there more pollutants in the water now than when the Biofilter was created?

Comparing the Current parameter readings with the maximum readings at either compliance point shows that the Biofilter is not working as it was in the 1980-90's (Table 4). Note the low maximum and minimum readings for TSS, indicating a low rate of erosion in the system and/or a high sediment settling rate.

Table 4. 1988-93 Minimum and Maximum Levels Recorded at the Compliance Locations

S2 and/or S4	Min Recorded	Max Recorded	Sept 2020 S2	Sept 2020 S4
Conductivity uS/cm	33	162	115	105
TP µg/L	28	243	555	976
TSS mg/L	0.5	66	260	184

To easily compare the Current results from Table 3 to prior datasets, Tables 5 and 6 are configured to show the flow of water. The applicable compliance criteria were added for reference.

Table 5 compares the inlet on the westside of the Biofilter (B2) with the compliance point outlet on the same side (S2). It also shows the most recent datasets from the 1990's taken within 14 days of the same date of each of the recent datasets (Appendix G). There are some interesting observations. Specifically, the TP, TSS and conductivity concentrations coming into the Biofilter are relatively the *same* as they were in the 1990's. Flow rate was not measured to determine total load.

Table 5. Westside of Biofilter Comparison: Inlets vs. Outlets and Current vs. 1990's

	Inlet B2				Outlet at Compliance Point S2				Determined 1989-90 S2	
B2 ⇨ S2	10/03 1990	09/24 1992	09/22 1993	09/23 2020	10/03 1990	09/24 1992	09/22 1993	09/23 2020	Compliance levels	Max Level allowed
Water Temp °C	14.0	14.1	12.6	18°C	13.5	13.1	8.8	18°C		
pH	6.5	6.50	6.02	6.0	6.61	5.70	6.21	6.5	6.1	4.4 - 7.8
Conductivity uS/cm	48	75	90	71.8	118	100	105	115	87	135
TP µg/L	303	287	70	225	140	124	23	555*	110	251
TSS mg/L	114.0	84.0	0.6	98	46.0	13.3	7.0	260*	25.8	72.0

Refer to Figure 3 for waterflow diagram

Some observations:

- The water was 2-4 degrees colder in the 1990's.
- The water entering the Biofilter in the 1990's was not dissimilar in WQ to the water entering the Biofilter now in Conductivity, TP, and TSS; the 3 major parameters.
- The WQ at the outlets was much improved over the inlets in the 1990's for all three major parameters.
- The contrast in WQ results show the deterioration of the Biofilter's effectiveness.
- While the 1990's results were sometimes over the compliance levels, the TP and TSS levels were not recorded to be over the max allowed.
- The Current results were well over the max allowed for both TP and TSS, by multiple factors.

The eastside of the Biofilter is captured in Table 6. The results were similar to the westside - the incoming stormwater concentrations were similar between the 1990's and the Current dataset, but the difference between the outgoing concentrations were considerable. The 1990's outlet parameters decreased for each whereas the Current outlet parameters markedly increased (x6 for TP and x13 for TSS).

Table 6. Eastside of Biofilter Comparison: Inlets vs. Outlets and Current vs. 1990's

	Inlets B1				Outlets at Compliance Point S4				Determined 1989-90 S4	
B1 ⇨ S4	10/03 1990	09/24 1992	09/22 1993	09/23 2020	10/03 1990	09/24 1992	09/22 1993	09/23 2020	Compliance levels	Max Level allowed
Water Temp °C	14.0	11.8	11.1	17 C	14.0	13.0	9.6	18 C		
pH	6.15	6.00	5.88	6.5	6.93	5.40	6.16	6.0	6.3	4.7 – 7.9
Conductivity uS/cm	66	93	74	83.5	58	83	72	105	63	97
TP µg/L	1200	129	84	145	121	99	88	976*	118	223
TSS mg/L	225	2.7	0.6	14	12.7	5.8	10.0	184*	19.4	51.6

Refer to Figure 3 for waterflow diagram

Like Table 5, Table 6 shows that in the 1990's, the water was similar to the Current stormwater coming into the Biofilter, and was again much cleaner exiting.

Note the 10/3/1990 dataset for TP. Even though inlet concentration was abnormally high (1200 µg/L), the Biofilter brought it down to 121µg/L, well below the max level, showing the power of an efficient biofilter system.

Because the only locations that were tested three times within the last two years were the outlet points L1 and L2, Tables 7 and 8 were created to compare those "Recent" results to the 1990's results, next to their upstream compliance levels.

Table 7. Historical Comparison: L1 Westside Biofilter Outlet to Lake

	5-yr Monitoring Program			City/Otak		Current	Upstream Standard	
L1	12/20/91	04/30/92	09/22/93	12/19/19	05/21/20	09/23/20	Compliance levels for S2	Max Level allowed S2
Water Temp °C	7.0	15.5	16.3	-	-	(18°C up-stream at S2)		
pH	5.78	6.14	6.55	7.2	7.4	(6.5 up-stream at S2)	6.1	4.4 - 7.8
Conductivity uS/cm	71	61	108	94	120	90.5	87	135
TP µg/L	74	68	42	270	71	319	110	251
TSS mg/L	7.0	11.0	10.8	140	11	140	25.8	72.0

Refer to Figure 3 for waterflow diagram

Table 7 shows that when comparing the recent datasets to the1990's datasets taken at the same time of the year, the water now is:

- hotter,
- pH is higher,
- the conductivity is generally higher (meaning there are now more dissolved solids in the water),
- TP is much higher (doubled, similar, and x8, respectively), and
- TSS is much higher (x20, same, x13, respectively).
- While there was one non-compliant reading in the 1990's dataset, there were no violations over the max allowed. The Current dataset has three non-compliant readings, two of which are also over the max allowed.
- The Dec 2019 dataset and the Current dataset are consistent with each other.

Both TP and TSS were above the upstream compliance levels (x3 and x5, respectively) and above the maximum levels (127% and 194% of those max levels, respectively)

The anomaly for L1 in the recent datasets is the May 2020 set, which looks more like the 1990's datasets than the recent ones. While it is shows a higher concentration for conductivity, it is lower than all other recent datasets for TP and TSS. This is likely due to being taken after 9 days of rain (Table 2b).[27]

When looking at Table 8, it is important to note that the swale/pond system was added sometime after 1993. Therefore, while the L2 results from the 1980's and 1990's were measuring only the Biofilter, the L2 from the recent datasets measured a mix of-storm-water from the Biofilter and a larger volume of stormwater from the swale/pond system.

Table 8. Historical Comparison: L2 Eastside Biofilter Outlet to Lake

	5-yr Monitoring Program			City/Otak		Current	Upstream Standard	
L2	**12/20/91**	**04/30/92**	**09/22/93**	**12/19/19**	**05/21/20**	**09/23/20**	**Compliance levels for S4**	**Max Level allowed S4**
Temp °C	5.0	14.9	14.7	-	-	(18°C up-stream at S4)		
pH	6.19	6.42	7.60	7.2	7.6	(6.0 up-stream at S4)	6.3	4.7-7.9
Conductivity uS/cm	71	57	83	Not Detected	79	84.8	63	97
TP µg/L	104	79	30	62	71	135	118	223
TSS mg/L	7.3	11.0	3.3	19	6.8	82	19.4	51.6

Refer to Figure 3 for waterflow diagram

[27] The City's May 2020 sampling day was on the 10th consecutive day of rain. While the May 2020 TP samples were not above the Biofilter's site-specific compliance levels of 110 µg/L and 188 µg/L, the west outlet result of 71 µg/L was above the EPA's recommended level of 50 µg/L as well as above the 2007 baseline levels for Lacamas Lake of 32-50 µg/L. Schnabel, Jeff and Hutton, Robert. "Monitoring Report: Lacamas Lake Annual Data Summary for 2007", *Clark County Public Resources.* June 2008. After 9 days of rain, a lower concentration should have been expected, closer the minimum levels recorded in Table 3.

The trends in Table 8 are in line with those in Table 7, i.e., the stormwater is still non-compliant for all three parameters. However, only TSS is found above the maximum level (160%), despite the upstream S4 compliance point concentrations being above maximum for all parameters. This is explained by visible dilution with the swale/pond system. In hindsight, the outlets from the swale/pond should have also been sampled to confirm this hypothesis.

Also different in Table 8 is that the Dec 2019 L2 result is not similar to the Current L2 result. It could be that since Dec 2019 had a high volume of rain, a higher volume coming from the swale/pond may have better diluted the S4 water before reaching the L2 outlet point. Note that for L2, the Current dataset is the most deviated from the other two recent datasets, although it is similar to the 1991 dataset in TP and conductivity.

The graphs in Figures 5-7 give a visual comparison of the 1990 datasets to the Current dataset for the eastside locations, showing how different the changes in stormwater WQ parameters are now between entry and exit of the Biofilter.

Figure 5. Comparative Stormwater TP Concentrations: 1990s vs. Current for Inlet, Compliance Outlet, and Lake Outlet

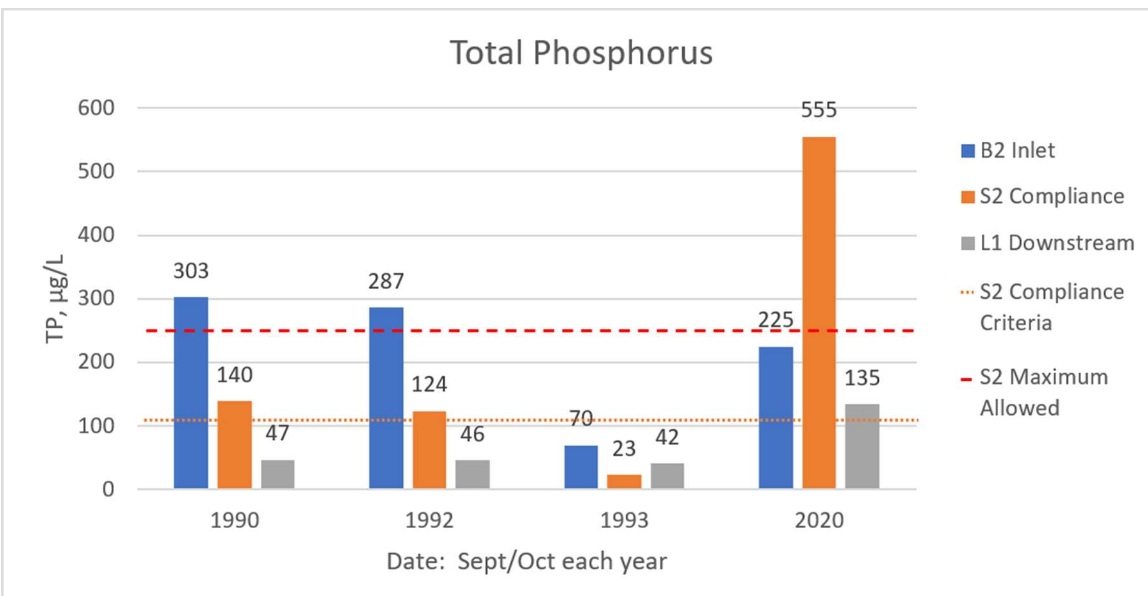


Fig. 5 shows the comparison between the Current dataset, where TP elevates significantly after traveling through the Biofilter, and the 1990's datasets, where TP drops, even when the stormwater is already relatively "clean". Note that the Current TP level is typical at the inlet compared to the inlets of the 1990's, i.e., the TP concentration is not higher now than it was recorded in the past. The Biofilter did not lower the same TP concentration in the Current stormwater that it had treated in the 1990's.

The results for TSS are similar (Fig. 6).

Figure 6. Comparative Stormwater TSS Concentrations:
1990s vs. Current for Inlet, Compliance Outlet, and Lake Outlet

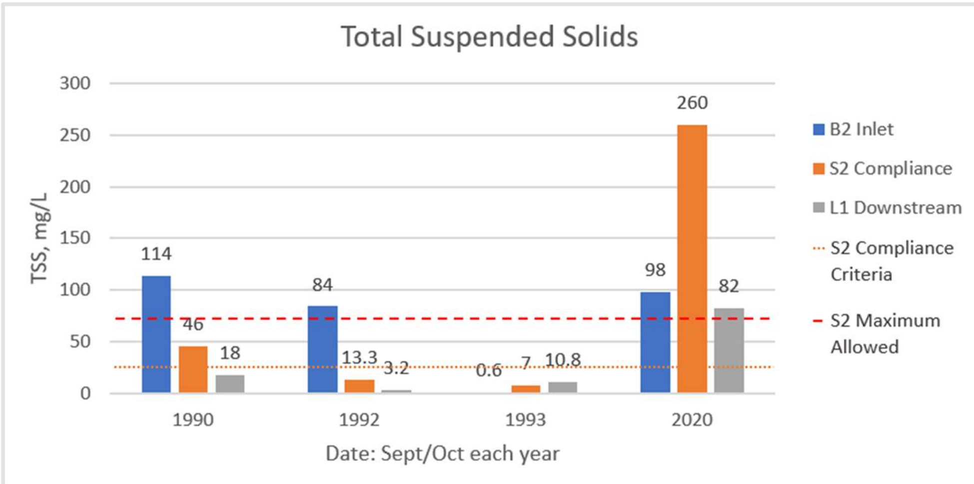
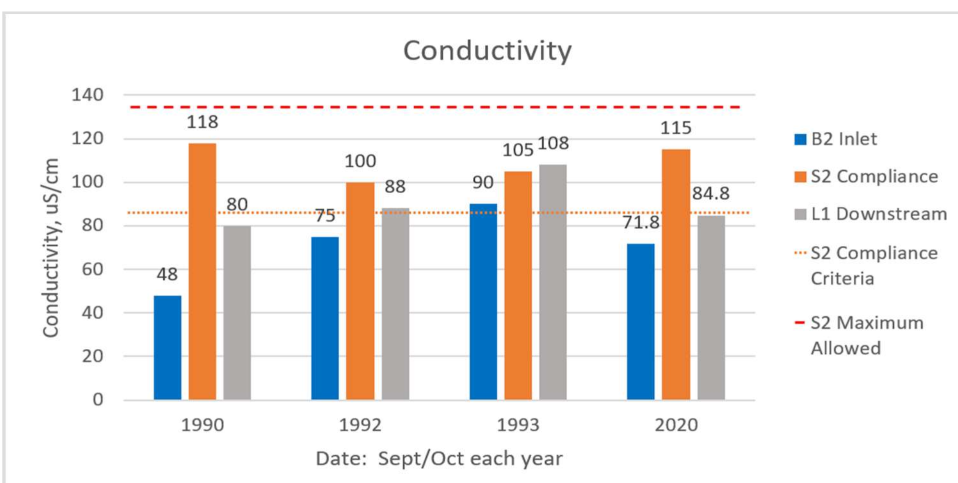


Figure 7 shows that the Biofilter does not appear effective to decrease conductivity, neither now nor in the 1990's. Instead, it increases conductivity in the stormwater. Conductivity only decreases for each dataset between the S and L locations, perhaps due to dilution.

Figure 7. Comparative Stormwater Conductivity Concentrations:
1990s vs. Current for Inlet, Compliance Outlet, and Lake Outlet



Discussion

The WQ of the stormwater going into the Biofilter for the Current dataset is above the compliance criteria set for the Biofilter. This is consistent with the 1990's datasets.

The Current dataset, similar to the Dec 2019 dataset, shows that the TP and TSS concentrations for the stormwater coming out of the Biofilter at the compliance locations were the highest ever recorded for those points.[28] Those results were more than 2x the maximum levels allowed for the Biofilter, as set by permit. This is divergent from the 1990 levels, which consistently decreased between Biofilter inlet versus outlet for all parameters, even the abnormally high ones.

All three WQ concentrations lowered after leaving the Biofilter (the compliance S locations) and before reaching the downstream L outlet points (tested by the City) in the shoreline wetlands. Though lowered, those concentrations were still higher than the maximum allowed for TP and TSS.

The reason for the decrease in concentrations on the eastside (from S4 to L2) is dilution with the swale/pond outlets. This is confirmed by visual observation of a large amount of stormwater coming from the swale/pond system merging with the relatively small stream from the Biofilter a few meters upstream of the L2 point. This difference indicates that the stormwater from the swale/pond system is relatively clean and therefore able to dilute the high pollutant concentrations coming from the Biofilter. This also indicates that the swale/pond system is working to clean stormwater coming from the 38.0 acres of the LSHOA's east-side properties.

The westside (S2 to L1) has no visible surface water dilution source to explain the decrease between the two points, so the reason for the change in concentrations is unclear. There is a 1.25m rocky rooted waterfall where a groundwater source could be entering the stream. Based on our available data, the difference could be due to dilution with groundwater, waterfall aeration or that the shoreline wetlands are acting as a second biofilter. Note that the latter is specifically what Ecology wanted to avoid by having stormwater treated with a filtration wetland - they did not want the shoreline wetlands exposed to pollutants.[29]

The Current dataset indicated that the WQ coming out of the Biofilter is worse than the WQ going into it. The Biofilter has violated the permit standards set for it. The TP load coming from the Biofilter is contributing to the total TP load for the Lake and feeding harmful algae blooms where they have been appearing with increasing frequency.

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[28] The Current and Dec 2019 TP readings are higher than the median TP levels for industrial land use of 171µg/L, i.e., the Biofilter is at times putting more TP in the stormwater than most industrial sites in western Washington. Hobbs, W., B. Lubliner, N. Kale, and E. Newell. 2015. "Western Washington NPDES Phase 1, Stormwater Permit: Final Data Characterization 2009-2013". Washington State Department of Ecology, Olympia, WA. Publication No. 15-03-001.

[29] Appendix K. "With this policy in mind, we want to see the resulting permit with conditions to provide additional protection to the shoreline environment." (p. 1) "The stormwater monitoring plan now includes contingencies to divert flows should this wetland show signs of stress from the increased water regime." p. 2.

Conclusions

1. The Current snapshot test results during the moderate to heavy rain, yielded Biofilter inlets concentrations for TP, TSS, and conductivity higher than the compliance standards.
2. The stormwater parameter concentrations increased between each inlet and its respective outlet, i.e., the Biofilter was adding TP, TSS and dissolved solids into the stormwater instead of filtering them out.
3. The concentrations for both compliance point outlets were higher than the maximum allowed via permit for TP and TSS.
4. The Biofilter “plumbing" leading to the bubbler pipes was overcapacity after minimal rain. Two weeks later, water looked like it was exiting from the bottom of the elevated B2 manhole, creating a channelized stream. This indicates that the bubbler may not be working properly to spread the stormwater.
5. Alternatives to handling the large amounts of flow, possibly due to additional hard surfaces of new neighborhoods/areas uphill of B2, should be investigated.
6. The erosional processes of the overflowing stormwater creating free-flowing streams through the Biofilter should be addressed.
7. The Biofilter's sediments have been trapping phosphates from prior stormwaters for years. Now, the stormwater is eroding and mixing those phosphate-heavy sediments back into the outflow. The sediments have become a vehicle for putting phosphates into the Lake.

The question then becomes, is the drainage part of the system broken or the filtering part of the system broken? It seems likely to be both. The water should not have been as visually fast flowing after 15-60 minutes of rain, nor should stormwater be channelized from the inlets all the way to the outlets. Even so, the combination of all stormwater exiting the Biofilter as surface water, both the channelized and dispersed, at either of the two outlet points (S2 and S4), should still have had lower concentrations of TP and TSS than was found. The age of the Biofilter, the length of time without maintenance, and the amount of accumulated sediment over the last 3 decades may be contributing to the inefficiency exhibited in this Biofilter.

The Biofilter, as it is currently configured, cannot handle the TP concentrations coming into it. Too much untreated stormwater runoff is reaching the Lake. In fact, the Lacamas Shores Biofilter is not doing the Lake any good at all at this time. Even if the stormwater runoff poured from the inlets directly into the lake, TP would still be too high according to the City permit standards. The Biofilter needs repair, restoration, and/or improvement in order to ensure that future stormwater WQ meets the compliance criteria set at the compliance locations and stops contributing to future harmful algae blooms.

Recommendations

While there are multiple ways to use the same Biofilter footprint to properly filter the stormwater coming into the Biofilter, the current situation is harmful to Lacamas Lake water quality and is, per City permit, not acceptable.   Options include:

- Returning the Biofilter to the original designed standard,
- Following the 1999 maintenance manual for the system,[30]
- Adding the "checkdams" proposed in the Monitoring Report,[31]
- Inclusion of the Biofilter inlets and outlets as part of any Lacamas Lake source assessment by the City or County.

[30] City of Camas. Lacamas Shores HOA Interim Trail, Open Space, Wetland and Storm Drainage Maintenance Manual. Camas, WA. (n.d.) This manual was written/commissioned by the City of Camas for the LSHOA sometime after 1998 with specific directions for maintenance. Many of those directives (such as removing debris, sediment buildup, dead vegetation, and trees that interfere with maintenance) do not appeared to have been followed.

[31] SRI/Shapiro. "5-year Stormwater Runoff and Wetland Biofilter Monitoring Program for the Lacamas Shores Residential Development Camas, WA - Fifth Year Report", p. 8. March 11, 1994. The 5th Annual report for the Monitoring Program suggested on page 8 that: "Small checkdams [AKA level spreaders] using downed logs could remedy the situation [of channelization]." Adding checkdams to the original Biofilter design would serve to slow and spread the stormwater, decreasing channelization and allowing for more infiltration. This action was not taken.

List of Appendices

A) 09/23/2020 Lacamas Shoes Biofilter Efficiency Monitoring – Map of Total Phosphorus

B) 09/23/2020 Lacamas Shoes Biofilter Efficiency Monitoring – Map of Total Suspended Solids

C) 09/23/2020 Lacamas Shoes Biofilter Efficiency Monitoring – Map of Conductivity

D) Columbia Laboratory Report #20-010257/D02.R01, Dated 10/07/2020.

E) 1998 Drainage Basin Map for the "Modifications to Lacamas Shores Stormwater Disposal System". This map shows the Q_2 capacity of the bubblers to be at 11.0 cfs for B2 and 5.0 cfs for B1. "Q_2" is the estimated design discharge (Q) capacity needed to handle a 2-year storm event, i.e., the type of storm that happens every two years.

F) Bautista, Mark F. and Geiger, N. Stan "Wetlands for Stormwater Treatment." *Water Environment & Technology*, July 1993, pp. 50-55. This national magazine article was written exclusively about the innovative design of the Biofilter, with maps and a chart of the "Compliance Criteria".

G) Bautista, Mark and Geiger, Stan (11 March 1994), Appendices to the Five-Year Stormwater Runoff and Wetland Biofilter Monitoring Program for the Lacamas Shores Development – Fifth Year Report. SRI/Shapiro, Lake Oswego, OR. Datasets are in Appendix A, Table 1 - "Lacamas Shores Water Quality Data, 1988-1993." The compliance standards are shown in Tables 12-15.

H) April 2018 COD Grab Sample Info Sheet

I) City 12/2019 Results: BSK Associates (1/13/2020). Certificate of Analysis for V9L0419. Samples submitted 12/19/2019.

J) City 05/2020 Results: BSK Associates (6/11/2020). Certificate of Analysis for VDE0400. Samples submitted 05/21/2020.

K) Jewett, Nora. Lacamas Shores Development Permit Additions. Received by Mel Avery. 22 June 1988. Washington Department of Ecology. Mel Avery was the Director of Public Works for the City of Camas.