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PUBLIC WORKS

SRI/SHAPIRO

March 11, 1994

Tom Shipler
3288 Hidden Valley Drive
Salem, Oregon 97304

Re: SRI/SHAPIRO Project Number 7885051

Dear Tom:

I'm pleased to enclose two copies of the fifth year monitoring report for the Lacamas Shores development. Copies of this report will also be sent to:

Duane Gahimer (IRC)
Adolf Hertrich (Vanport Manufacturing)
Art Larson (WDOE-EILS)
Luci Hise (J.D. White Co.)
Doug Quinn (City of Camas)
Richard Sposito (MacKay and Sposito)
Kim Van Zwalenburg (WDOE-Shorelands)

I have received brief comments from Kim Van Zwalenburg (March 2, 1994 letter) to which I have responded in the Discussion and Recommendations. She provided specific comments on three issues: winter nitrate-nitrogen concentrations, plant species composition and dominance, and nutrient and solids removal rates. Her letter has been included in the report as Appendix C.

Please contact us with any further comments or questions. It has been a pleasure working with you on this unique project.

Cordially,

Mark F. Bautista, Aquatic Ecologist

cc: Duane Gahimer
Adolf Hertrich
Art Larson
Luci Hise
Doug Quinn
Richard Sposito
Kim Van Zwalenburg

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FIVE-YEAR STORMWATER RUNOFF AND WETLAND BIOFILTER MONITORING PROGRAM FOR THE LACAMAS SHORES RESIDENTIAL DEVELOPMENT CAMAS, WASHINGTON - FIFTH YEAR REPORT

Prepared for

Tom Shipler
Salem, Oregon

Prepared by

SRI/SHAPIRO
Lake Oswego, Oregon

March 11, 1994

FIVE-YEAR STORMWATER RUNOFF AND WETLAND BIOFILTER MONITORING PROGRAM FOR THE LACAMAS SHORES RESIDENTIAL DEVELOPMENT CAMAS, WASHINGTON - FIFTH YEAR REPORT

Prepared for

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Project #7885051

March 11, 1994

EXECUTIVE SUMMARY

SRI/SHAPIRO has been retained by Tom Shipler to design and conduct a monitoring program for stormwater runoff and its treatment by a wetland biofilter at the Lacamas Shores development. The development is located on the southeast shore of Lacamas Lake, a lake that has received considerable attention because of impacts to its water quality from nutrient loading, principally phosphorus. The major source of those nutrients are from agricultural activity and septic systems in the watershed. This report presents the fifth and final year of monitoring results for the development's wetland stormwater treatment system.

REGULATORY PERSPECTIVE

As part of the permit approval process for the Lacamas Shores development, Mr. Shipler was required to monitor the stormwater collection and wetland treatment system of the residential development. The monitoring plan was designed by SRI/SHAPIRO with input from the Washington Department of Ecology (WDOE) and the City of Camas.

The purposes of the monitoring plan were to 1) obtain baseline water quality data for surface and ground water to and from the wetlands, 2) determine the effectiveness of the wetland system as a biofilter from stormwater runoff, and 3) establish criteria for implementing contingency plans. As a result of that plan, site-specific criteria for triggering contingencies were established based on the first two years of nutrient data.

The goals of the SRI monitoring effort are two-fold; determine whether the wetlands being used to treat stormwater runoff from the development protect the water quality of Lacamas Lake, and determine whether unacceptable impacts are occurring within the wetland as a result of stormwater runoff. A WDOE condition for allowing the use of the wetland system for stormwater treatment required the development of compliance levels for nutrients in runoff leaving the site. In the absence of any state- or locally-developed watershed loading limits, self-imposed water quality criteria were developed based on data collected at the site. To the best of our knowledge, no other development, residence, or business in the watershed is currently monitoring their loading to the lake.

DEVELOPMENT OF SITE-SPECIFIC CRITERIA

The first two years of study focused on obtaining baseline information for a range of water quality and vegetation parameters which provided a basis for evaluating future post-construction effects. A total of eleven complete sampling periods between October 1988 and October 1990 provided data from the wetland's surface water and groundwater, Lacamas Lake, and control creeks. Additional information on water table measurements, observations on vegetation health and composition, and pesticides/herbicides and heavy metals were made periodically during this period.

A set of site-specific criteria was proposed to define acceptable wetland performance and vegetative change resulting from stormwater treatment. In general, water quality values outside the range of *two standard deviations* from the baseline were considered of concern and warranting further investigation as to origin and impacts. The most important criteria were related to nutrients and vegetation changes. Additional threshold criteria for pesticides, herbicides, metals and biota (plant health and senescence) were also developed. These self-imposed criteria were to be used to evaluate the quality of the stormwater that passes through the wetlands before entering the lake during the subsequent three years of monitoring. Exceeding the criteria would 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.

SUMMARY OF MONITORING RESULTS

For the third, fourth, and fifth year, a general trend between the inflow and outflow concentrations was apparent. Primary parameters (total phosphorus, soluble phosphorus, and nitrate+nitrite-nitrogen) and total suspended solids measured at the outflows were less than the inflowing concentrations, indicating that the wetlands were effective at removing nutrients and solids from stormwater runoff.

Concentrations of TP were also monitored in three control creeks which drain other portions of the watershed. Dwyer Creek, designated Creek 1, drains land used for agricultural purposes, while two unnamed creeks (Creek 2 and Creek 3), drain relatively undisturbed forested land to the north of Lacamas Lake. Over the past four years of monitoring, TP concentrations in the three creeks have been consistently higher than concentrations in runoff from the Lacamas Shores wetlands.

The presence of elevated inflowing nitrate values during the 1992-3 winter appears to confirm the assertion of the fourth year report that increased levels of nitrates are entering the wetlands. Potential sources that have been suggested of the nitrate-nitrogen include runoff of commercially-applied fertilizers to residential lawns, and ground water which is contaminated upgradient of the development and eventually flows through the development and into the bubblers. The pattern of higher nitrate inputs during the winter appears to warrant an investigation to the source in the watershed. While the wetlands are able to reduce high nitrate levels to below compliance levels, unnecessary nutrient loading to the wetland may be avoided by source reduction in the watershed and thus increase the effective treatment life of the wetlands.

ESTIMATING PHOSPHORUS LOADING

The impact on lake water quality from stormwater passing through the wetlands is only partially explained by comparison of concentrations of the parameters of interest. Determination of the nutrient load defines the actual quantity of nutrients contributed by various input streams to Lacamas Lake. Using total phosphorus as an indicator of nutrient loading, calculations of the annual phosphorus contributions on a per unit-area basis for the past four monitoring years were made for the Lacamas Shores development and compared with inputs calculated from three control creeks. In all but one case, nutrient loading rate from the Lacamas Shores development is lower than from each of the three control creeks for the past four years, (1990 to 1993). Contributions by the creeks is generally from one to two orders of magnitude higher than the bubblers.

WETLAND SYSTEM PERFORMANCE

One of the original concerns of the use of the wetland for stormwater treatment was the ability of the system to reduce phosphorus loading to Lacamas Lake. All the evidence to date indicates that the bubbler systems are effective at reducing concentrations of phosphorus from the development to levels below site-specific criteria. An unanticipated consequence of sending stormwater to the treatment wetland has been the increased input of nitrate, with the site-specific criteria being exceeded during the winter months.

It is important to note here that the increased nitrate input to the lake during the winter months 1) is not in violation of state or local water quality standards, 2) is occurring at a time when the lake is well-flushed and there is reduced algal or plant growth, and 3) the lake's recreational use is limited primarily to viewing. The Beak/SRI 1985 study also indicated that the lake is a phosphorus-limited system during the winter time, so that an addition of nitrate-nitrogen would not have an adverse impact on the trophic level of the lake. Finally, in the absence of watershed loading limits for either nitrate or phosphorus, it is not possible to determine if the winter nitrate contribution from the development is of any significance to the lake nutrient budget as a whole.

Future compliance with criteria may entail alterations to the wetland to optimize treatment. Such contingencies could include alterations that would increase the amount of wetlands or increase the detention time of stormwater within the wetlands. A more direct approach to assuring future compliance would be to limit the sources of nutrients which eventually wash down to the wetland. A source control program which educates homeowners about proper lawn and garden practices and provides opportunities for reducing the amount of nutrients in stormwater runoff would be an important and vital component to the success and longevity of the treatment wetland system.

REFERENCES

Beak Consultants, Inc. and Scientific Resources, Inc. 1985. Lacamas-Round Lake Diagnostic and Restoration Analysis: Final Report and Appendix. July 31, 1985. Prepared for the Intergovernmental Resource Center, Vancouver, Washington.

TABLE OF CONTENTS

1.0 INTRODUCTION

This report characterizes results of the fifth of five years of monitoring of stormwater runoff quality above and below a wetland at a lake-side residential development north of Camas, Washington. The fifth-year monitoring program was from October 30, 1992 to November 17, 1993, and it is the third year in which the results of the monitoring program will be compared to site-specific criteria developed during the first two years of work at this site. The five-year program documents effects of diverting stormwater runoff through a dispersion system called a bubbler above the wetland. The project has been monitored by Scientific Resources, Inc. since fall of 1988.

1.1 Goals and Objectives

There are two goals of the monitoring program:

- Determine whether wetlands on the property which are being used to treat stormwater runoff from the development protect the water quality of Lacamas Lake.
- Determine whether unacceptable impacts are occurring within the wetland as a result of stormwater runoff.

The monitoring plan was designed with input from the Washington Department of Ecology (WDOE) and the City of Camas. The monitoring program was designed to address the following objectives:

1. Measure hydrologic conditions of the wetland to detect changes in wetland hydrology;
2. Document the quality of surface water and water moving through the soils and vegetation of the existing wetlands;
3. Document changes in the condition of vegetation in the wetland;
4. Develop a procedure for determining whether the water quality data indicate unacceptable polluting of the wetland and/or lake, thereby triggering contingencies;
5. Characterize the range of nutrient concentrations in stormwater runoff;
6. Sample outflows for nutrients from relatively undisturbed small streams entering Lacamas Lake for comparison with outflow from the treatment wetlands;
7. Test for evidence of herbicides, pesticides, and selected heavy metals.

1.2 Summary Results From the First Four Years

The first two years of study focused on obtaining baseline information for a range of water quality and vegetation parameters which provided a basis for evaluating future post-construction effects. A total of eleven complete sampling periods between October 1988 and October 1990 provided data from the wetland's surface water and groundwater, Lacamas Lake, and control creeks. Additional information on water table measurements, observations on vegetation health and composition, and pesticides/herbicides and heavy metals were made periodically during this period.

A set of criteria was proposed to define acceptable wetland performance and vegetative change resulting from stormwater treatment. In general, water quality values outside the range of two standard deviations from the baseline were considered of concern and warranting further investigation as to origin and impacts. The most important criteria were related to nutrients and vegetation changes (noted in the following table as *primary*). Additional threshold criteria for pesticides, herbicides, metals and biota (plant health and senescence) were also developed. Areal total phosphorus loading was also considered as a possible measure of acceptable runoff, but the absence of a watershed management framework to provide criteria limited the use of this measure. A summary of proposed criteria is outlined below:

Parameter	Relative Criterion
Water Quality	
nutrients (TP,SP, NO_3-N)	2 SD [primary]
pH , conductivity,	
sediment (TSS)	2 SD [secondary]
metals (e.g. Cu, Zn)	WA WQ Standards
organophosphate pesticides	detection limit
chlorinated herbicides	detection limit
chlorinated pesticides	detection limit
Biota	
species composition	25% Change [primary]
water depth	2 SD [secondary]
plant health	obvious stress
plant senescence	premature death

These criteria were used to evaluate the quality of the stormwater that passed through the wetlands before entering the lake during the third year of monitoring. Two general trends between the inflow and outflow concentrations were apparent. Primary parameters (total phosphorus, soluble phosphorus, and nitrate+nitrite-nitrogen) and total suspended solids measured at the outflows were less than the inflowing concentrations, indicating that the wetlands were effective at removing nutrients and solids from stormwater runoff. Secondly, pH increased and conductivity decreased across the wetlands, though these differences were small and likely not significant.

Compliance for primary criteria were exceeded on two of the six monitoring dates during the third year of monitoring. On December 17, 1990, the nitrate concentration at station S4 below bubbler/wetland 1 was 0.571 mg/l, slightly above the upper compliance level (0.565 mg/l). The soluble phosphorus and nitrate criteria were exceeded on February 21, 1991 at S2 and S4, respectively. These parameters were in compliance for the remainder of the monitoring season. The increased nitrate values during the winter warranted closer scrutiny during the fourth year of monitoring to see if the trend continued.

During the fourth year, concentrations at the wetland outflows for total phosphorus, soluble phosphorus, and the secondary parameters were always below the compliance levels. Compliance for nitrate-nitrogen was exceeded on two of the four monitoring dates during the fourth year. As in the third year, the levels were exceeded in the winter sampling months. On December 20, 1991, the nitrate concentration at station S4 was 0.962 mg/l and 0.665 mg/l at S2 (Table 12). The nitrate criterion was also exceeded on February 20, 1992 at S4 (0.620 mg/l, Table 13).

The increased nitrate values during the winter appear to be a consistent phenomenon. Possible sources of the nitrate-nitrogen may include runoff of commercially-applied fertilizers to residential lawns, and ground water that has been contaminated upgradient of the development.

2.0 STUDY AREA

2.1 Site Description

The Lacamas Shores development is located on the west shore of Lacamas Lake, near Camas, Washington (Fig. 1, pocket in Appendix B). The development is bordered on the south by Lake Road. The southern two-thirds of the site is occupied by residential home lots. The northern third is composed of wetlands and grassy areas. The area directly adjacent to the lake is a forested wetland between 50 and 100 feet in width (Fig. 1). From this forested area, areas of emergent wetlands extend southeasterly 400-600 feet. A wetland delineation was performed by Shapiro and Associates in 1987-1988 during the early site investigations. The defined wetland area is outlined and labelled in Figure 3.

There are a total of 159 lots at the site, which are to be developed in five phases. By February of 1993, 135 lots had been sold, with 77 homes completed and 6 under construction. The opportunity for additional housing is shown on Figure 1. Construction activity is seasonal, with low activity through the winter and increased activity in early spring and summer.

The development site is on fairly steep topography. Surface elevation drops from 350 feet (NGVD) at the south edge of the project to 190 feet at the lake shore. Prior to development, the area had five major surface drainage features (SRI 1989). As development on the site has occurred, stormwater runoff from paved surfaces and the flow in four streams has been collected by pipes and catch basins and discharged into French drains, called bubblers, located along the up-gradient edge of the wetlands (Fig. 2). The four northerly streams (streams 1 - 4) are spring-fed and often flow during dry weather periods. The fifth stream adjacent to the road to the boat ramp (on the south) is intermittent and only flows during periods of significant rainfall.

2.2 Drainage Features

The French drains, or bubblers, are designed to create a sheet flow a few inches deep which enters the up-gradient edge of the emergent wetlands (Fig. 2). These wetlands, in turn, "treat" this input stormwater prior to entering Lacamas Lake. The bubbler design at Lacamas Shores consists of a section of 12 inch pipe embedded in 2 inch gravel. The pipe has 0.5 inch holes that have been drilled at 0.5 foot intervals at mid-depth of the pipe (0.5 ft above pipe invert along both sides of the pipe). The gravel-filled trench is lined with filter cloth. At the surface of these bubblers, gravel covers the filter cloth above the perforated pipe. During 1990, sediment traps were installed upgradient from the bubblers to prevent them from becoming clogged and thereby limiting their performance.

Streams 1, 2, and 3 are now carried by the storm sewer system and discharged into bubbler 2 on the north (Figure 2). This bubbler will eventually receive surface runoff from the western third of the development. The catchment area and wetland area for bubbler 2 was initially estimated at 12.2 ha and 1.8 ha, respectively. Surface runoff from the middle third of the development along with stream 4 (catchment area approximately 9.5 ha) is carried to bubbler 1, which discharges into a 1.4 ha emergent wetland. Runoff from the southeastern portion of the Lacamas Shores development will not enter the benched wetland area.

As the site has been developed, specifically defined drainage basins for the two bubblers have been established. MacKay and Sposito (1991) have delineated these basins and they are presented in Fig. 3. The areas corresponding to Bubbler 1 and 2 are 4.1 and 8.8 ha, respectively.

3.0 MONITORING STRATEGY

3.1 Monitoring Plan

The monitoring program designed and executed by Scientific Resources Inc. focuses on characterizing ground and surface water quality changes resulting from diverting stormwater from the development to the wetland system. The stormwater is collected and distributed in such a way as to allow us to monitor the concentration of parameters of concern at specific points into and out of the wetlands. One unique feature of this project is having defined inputs and outputs that can be sampled during storm events.

The wetlands are viewed as essentially a black-box into which stormwater is introduced and the resulting water quality is measured. Transects were established to monitor water quality as it flowed through each of the wetlands. Distance downstream from the bubblers roughly translates to the length of time the water has been retained in the wetland. Sites were selected along the two transects for monitoring 1) ground water levels and water quality and 2) vegetative cover and composition to provide information on processes at specific points within the wetland. Data along each transect may also give some indication of how the water quality is affected as it flows over and through the wetland.

3.2 Surface Water Quality

Water quality parameters were measured in surface runoff from 1) the bubblers, 2) sites within the wetland, 3) the lake, and 4) three small off-site control creeks draining into the lake (see Fig. 3 for sampling locations). Runoff samples from the two sediment traps just upstream of the bubblers (B1 and B2) served as samples of the bubblers and were obtained by entering through sheet metal doors situated on the downstream side of each trap. Samples taken from station S3 represented water from bubbler 1 prior to its flow through the wetland. Stations S2 and S4 were established to sample surface water that had passed through each wetland area. The lake sampling sites (L1, L2) were situated to sample lake water just outside the mixing zone of each input channel from the wetlands.

The Lacamas Shores development wetland system has the advantage of having discrete points through which the water from the development passes as it flows to the lake. These points can be sampled during storm events to provide truly representative water quality measurements of water prior to and after its application to the wetland. Two transects were established to monitor surface and ground water as it passes through the wetland. Transect 1 includes the sampling points from B1 through S4 and terminates at L2, while transect 2 runs from B2 to S2 and terminates at L1 (Fig. 3).

To provide background information on the quality and quantity of surface water runoff, three creeks were also sampled (Figure 4). Creek 1 (Dwyer Creek) empties into lower Lacamas Creek above the lake, north of the development. Two unnamed creeks on the east shore (Creeks 2, 3) were also sampled and represent contributions from smaller watersheds.

Sampling consisted of field measurements for temperature, conductivity, pH and groundwater depths. Analyses of plant nutrient concentrations (total phosphorus, soluble phosphorus, nitrate+nitrite-nitrogen) and total suspended solids (TSS) in water samples were performed. Samples from selected stations were analyzed for organophosphate pesticides (EPA method 614), chlorinated herbicides (EPA method 615), and organochlorine pesticides (EPA method 608), as well as dissolved metals (chromium, copper, lead, zinc). Oil and grease and hardness were analyzed in samples collected during the first flush sampling. The detection limits for the herbicide, pesticide, and metals analyses are provided in Tables 5 - 8 in Appendix A.

Sample dates were selected to include a range of high and low flow periods, the "first flush" episode following the summer dry season, and an early winter sampling after the fall first flush to detect the presence and extent of any decrease in water quality levels. During each of the sample periods, the wetland areas between the bubblers and the outflow streams (S2 and S4) were inspected for channelization.

3.3 Estimating Phosphorus Loading to Lacamas Lake

Phosphorus nutrient loading from water receiving wetland treatment at the Lacamas Shores development and from control creeks was determined from estimates of average annual flow (USACE Portland District, Lystrom, 1970), and the average annual total phosphorus concentrations for each of the sampling sites downstream of the wetlands (S2 and S4) gathered during the 1992 monitoring year. The USACE equation predicts annual average flow as follows:

$$Q_A = 0.0187 \text{ X } A^{1.004} \text{ X } NAP^{1.231}$$

Where:

	Q_A	=	average annual runoff in cubic feet per second
	A	=	drainage basin area in square miles
	NAP	=	normal annual precipitation in inches (30 yr average)

Nutrient loading is determined as follows:

$$NL = 892.975 \text{ X } Q_A \text{ X } TP/A$$

Where:

	NL	=	total phosphorus in kg/ha/year
	Q_A	=	average annual runoff in cubic ft/sec
	TP	=	average total phosphorus concentration in mg/l
	A	=	hectares

3.4 Ground Water Quality

Eight shallow (3 feet deep) wells were installed at various locations on the site (Figure 3). The wells were monitored for 1) subsurface soil water quality parameters (pH, conductivity, temperature, total phosphorus, soluble phosphorus, and nitrate+nitrite-nitrogen, total suspended solids), and 2) ground water levels for wetland hydrology. Shallow wells in transect 1 were placed down-gradient from bubbler B1 (wells G4, G5, G6, G7, G11). Other shallow wells (G1, G2, G3) were installed in a similar fashion down-gradient from bubbler B2 (Fig. 3) and are located in transect 2. All wells were purged prior to sampling.

Changes in the design of the stormwater delivery system which eliminated bubbler 3 also eliminated the need for sampling several wells previously sampled in the first year monitoring (wells G8, G9, G10).

3.5 Vegetation

Two permanent vegetation transects were established below bubblers 1 and 2 during the 1990 field season to document changes in vegetation resulting from stormwater additions (Figure 3). Five permanent plots were placed along each transect near the ground water wells to sample species abundance present within each plot. Sampling consisted of determining plant species and species percent cover within each plot. Species shifts due to stormwater additions were determined by the wetland indicator status of species within each plot (US Fish and Wildlife Service 1988). The following cover class values were used:

Code		Cover range	Midpoint of cover range
1	=	0-1	0.5
2	=	2-5	3.5
3	=	6-10	7.5
4	=	11-20	15.0
5	=	21-35	27.5
6	=	36-50	42.5
7	=	51-65	57.5
8	=	66-85	75.0
9	=	85-100	92.5

During the 1991 monitoring season, four of the original plots (1.4, 1.5, 2.1, and 2.2) could not be located due to heavy vegetation cover. Four replacement plots were situated near the obscured plots. As vegetation died back through the 1991 season, all but one of the original plots were discovered, reestablished, and surveyed in the 1992 season. Plot 1.4 appears to have been removed during mowing and the corresponding replacement plot will be monitored instead.

3.6 Wetland Performance

The effect of the wetlands on stormwater from the site flowing to the lake was compared with water quality values gathered from three control creeks and Lacamas Lake. Data for surface and ground water samples were analyzed along transects running from the bubblers to the lake to evaluate water quality changes due to processes operating within the wetland. Table 1 (Appendix A) provides a summary of sample sites and dates for each transect evaluated from the start of the monitoring in 1988 through November 17, 1993.

4.0 RESULTS

4.1 Sampling Dates and Rainfall

The performance of the treatment wetland to improve stormwater runoff was monitored four times during the fifth year of monitoring (October 30, 1992, March 3, September 22, and November 17, 1993). The first date represents an early winter sampling after the 1992 first flush (September 24). The other dates represent a range of flow periods and the worst case or "first flush" episode following the 1993 summer dry season. Rainfall (in inches) for the six days preceding and including the day of sampling was 1.83 for October 30, 1992, 0.87 for March 3, 0.00 for September 22, and 0.30 for November 17, 1993 (see Table 2 of Appendix A). The November 17 sampling represented the first flush episode for fall of 1993.

The 1993 season continued the dry trend, with total calendar precipitation at 44.26 inches, 9.65 inches below the 37 year average (R. Bafus 1993). The year began with drier and cooler weather than average, with only 1.0 inch of rain in February. This was 4.79 inches below the average and a 37-year low for that location. Precipitation picked up in March (just 0.33 inches below normal) and it was the wettest April on record at 8.71 inches. That was over twice the average of 4.31 inches. Higher than normal precipitation continued through July and then decreased for the rest of the year, including a near-record minimum for November (second driest in 37 years).

During each of the sampling periods the wetland areas below each of the bubblers was inspected for signs of channelization. Some channels, which probably represent the pre-development stream channels, do persist, however sheet flow of the stormwater was observed from the bubblers during each sampling visit, as well as within the wetlands. A defined channel was observed beginning in March in bubbler/wetland 1 just southeast of groundwater well G2. Small checkdams using downed logs could be used remedy the situation. The checkdams would divert water out of the channel, and cause it to pond and disperse in a sheet flow. The development of channels could result in short-circuiting the flow through the wetland and decrease the detention time, and thus treatment, of the stormwater in the wetland.

4.2 Bubbler/Wetland 1 Results

Figures 5 and 6 provide a representation of average **surface water quality** values along transect 1 below bubbler 1. Overall, average total suspended solids concentrations were within the range of results for the previous years of monitoring. Elevated TSS values were not observed this season at the 25.1 meter location (S3). The TSS levels at the wetland outflow (S4 at 59.2 m) were lower on average than the lake and only slight higher than the control creeks.

Total and soluble phosphorus values were on average less than 0.20 mg/l at all sampling sites, just as they were during the third and fourth years of sampling. In a reversal of trends observed in 1991 and 1992, average nitrate concentrations entering the wetland (B1), within the wetland (S3), and in the lake (L2) during 1993 were lower than 1992 levels and more similar to 1991 levels, while the average nitrate levels in the three control creeks were 174% higher than the fourth year (1992) average. Nitrate concentrations were reduced on average by 40% as water passed through wetland transect 1. Average water temperatures continued to decrease from the previous year. Other water quality parameters, such as pH and conductivity, showed no discernible trends due to wetland treatment. Control creek conductivities increased from 82 to 134 umhos/cm from the previous year.

Ground water quality (Figure 7) shows overall reductions in total phosphorus, nitrate, and total suspended solids with distance through the wetland below bubbler 1. Total phosphorus concentrations at the three shallow ground water wells (G5, G6, and G7) continue to decrease from the 1991 and 1992 concentrations (Scientific Resources, Inc., 1992, 1993). The decrease in surface water nitrate concentrations to the wetland was evident by the decrease in average groundwater concentrations (from 0.283 to 0.061 mg/l) at 5.0 m (G5) as compared to 1992.

4.3 Bubbler/Wetland 2 Results

Average **surface water quality** (Figures 8 - 9) along transect 2 below bubbler 2 shows similar trends to transect 1. Fifth year total suspended solids average values continued to decrease from 1991 and 1992, and while there was an increase in TSS from the bubbler (B2) to 117 meters (S2) (4.5 to 8.3 mg/l), B2 concentration was nearly ten time lower than the upper compliance level of 72 mg/l. Reduction of nitrate concentrations was a notable observation, from 0.884 to 0.178 mg/l. In all cases, nutrient concentrations at the 117 meter mark were below control creek values. Temperature, pH, and conductivity show no discernible trends due to wetland treatment.

Table 3 provides the inflowing concentration and percent reduction of nutrients and TSS for both transects (wetland/bubbler 1 and 2) for the third, fourth, and fifth monitoring years. Inflowing concentrations of TP decreased again in 1993 and nitrate concentrations also decreased from 1992, although they remained higher than 1991. While TP concentrations appeared to have increased slightly (though probably not significantly) across the wetland transects, outflowing concentrations at S4 and S2 are still twice and four times lower, respectively, than the upper TP criteria.

Ground water quality trends for transect 2 are presented in Figure 10. Except for nitrate, all parameters are lowest at the middle well (G2) at 53.5 meters. Overall, nutrient concentrations in the fifth year's monitoring are consistent with results of the past two years.

4.4 Ground Water Comparisons by Sample Date

Comparisons of ground water values (pH, conductivity, total suspended solids, total and soluble phosphorus and nitrate) by sampling date along the two transects are provided in Figures 11 - 16. The fourth year first flush data (September 24, 1992) is included to provide a comparison between the fourth and fifth years' data. Data for G5 through G7 are presented for transect 1, and G1 through G3 for transect 2. No data is presented for

G5 for the November 17, 1993 sampling date because the well was dry. The following discussion compares the fifth year results with those presented in the third and fourth years' report (Scientific Resources, Inc., 1992, 1993).

Conductivity and pH continue to act conservatively (Figures 11 and 12). The fifth year pH values (Figure 11) were consistent over the four sampling periods, with most values falling within a one standard unit range (5.0 to 6.0). Conductivity values were similar to the results of the third and fourth year monitoring (Figure 12).

Except for the March 3, 1993 sample at G5, total suspended solids concentrations were less than 100 mg/l for the fourth year first flush sample as well as all of the fifth year period. There were slight decreases in TSS at the upstream wells (G1 and G5) of each transect after the first flush event. Otherwise, TSS values varied little over the season.

Samples for oil and grease were only collected during first flush episodes for 1992 and 1993. Overall, oil and grease concentrations from both surface and groundwater sample sites are one to two orders of magnitude lower than the corresponding first flush sampling in 1991 on October 25 (Table 1). Inflowing concentrations at B1 and B2 dropped from 10.1 and 10.3 mg/l, respectively, in 1991, to 0.4 and 0.2 mg/l, respectively, for 1992, and 0.5 and 0.3 mg/l, respectively, for 1993.

Nutrient concentrations in ground water samples from 1990 to 1993 were generally less than 0.60 mg/l (Figures 14 - 16). Total phosphorus levels generally dropped after the 1992 first flush samples. No significant patterns in 1993 soluble phosphorus levels are evident (Figure 15) and except for higher nitrate-nitrogen concentrations in two wells during the first flush (G5 and G7), levels are uniformly low (<0.10 mg/l). The winter increase in nitrate-nitrogen was not observed in 1993.

4.5 Surface Water Comparisons by Date

The parameter values for the surface water downstream sampling stations at Lacamas Shores (bubbler/wetland 2 [S2] and bubbler/wetland 1 [S4]) are compared with the three control creeks and Lacamas Lake at the shore of the project (average of L1 and L2) in Figures 17 - 22. Like the discussion above, results of 1993 will be compared to those from 1991 and 1992.

Levels of pH changed little for all surface water sites from the 1992 first flush sampling to October 30, 1992. Values for pH were similar to results from 1992 (Figure 17), with the range of pH measured during each sample period generally within 1.5 standard units (SU). Conductivities in the three control creeks increased slightly after the 1992 first flush sampling (Figure 18), decreased in the spring and rose again at the summer and 1993 first flush sample. Conductivities remained relatively consistent in the wetlands and lake.

Except for an increase on October 30, 1992 at C1 (Dwyer Creek), total suspended solids concentrations remained less than 20 mg/l for the 1993 season and generally increased during the first flush sampling (Figure 19). As far as nutrients are concerned, the creeks show the most variation over time, with higher concentrations in the winter and fall, and lower concentrations in the spring. Concentrations in the wetlands and lake remain low and do not fluctuate as much. Nutrient concentrations tended to increase slightly during the 1993 first flush sampling period.

In order to compare relative inputs to the wetlands and discharge from the wetlands, TSS and nutrients for samples taken from the sedimentation traps and the outflowing streams are presented along with the lake data in Figures 23 - 26. Included on the line graphs are the upper compliance values derived from the first two years of monitoring. Generally, parameter values for these sample sites were below the established compliance levels for each transect. The only sample above the compliance level was at S4 for nitrate on October 30, 1992. Nitrate at this sample site was well below compliance levels for the rest of 1993.

Input nitrate-nitrogen values at both B1 and B2 exceeded the upper compliance levels during the first three sample periods of the fourth monitoring year. High input concentrations of nitrate-nitrogen were also observed during the winter months of the third year. High nitrate inflow levels were observed only once (October 30, 1992) during the fifth year monitoring period. The pattern of higher nitrate inputs during the winter is still occurring, and investigations as to the source in the watershed above the wetlands would appear to be warranted. While the wetlands are able to reduce high nitrate levels to below compliance levels (see Figure 26, data for B2 and S2 of transect 2), unnecessary nutrient loading to the wetland may be avoided by source reduction in the watershed and thus increase the effective treatment life of the wetlands.

4.6 Phosphorus Loading to Lake

The impact on lake water quality from stormwater passing through the wetlands is only partially explained by comparison of concentrations of the parameters of interest. Determination of the nutrient load defines the actual quantity of nutrients contributed by various input streams to Lacamas Lake. Using total phosphorus as an indicator of nutrient loading, calculations of the annual phosphorus contributions on a per unit-area basis for the 1992-3 monitoring year were made for the Lacamas Shores development and compared with inputs calculated from control creeks 1-3.

The USACE equation in Section 3.3 was used, where NAP equals the total precipitation for the 1993 water year. Values for normal annual precipitation (NAP, usually 30-year average) were originally used for each years' loading calculations. In the fourth year report, it was suggested that loading rates be recalculated using the corresponding precipitation amount for each water year (October 1 through September 31). These loading rates were felt to be more representative of the year to year variation in loading. The resulting rates (presented as shaded values in Table 4 of the fourth year report) were lower than rates based on corresponding NAPs, emphasizing the effect that lower-than-normal annual rainfall amounts had on actual loading to the lake.

The average 1993 total phosphorus concentrations at the wetland outlet streams (S4, S2) and the three control creeks (C1, C2, C3) were used for TP in the USACE equation. The drainage basin areas originally used for the bubbler/wetlands were derived from predevelopment mapping information. MacKay and Sposito (engineering design firm for

Lacamas Shores) determined these areas from construction drawings showing the actual drainage areas created by the stormwater sewer system. These new areas were used in the fourth year report and will be used for the 1993 data as well. The MacKay and Sposito areas are smaller, but do not have a substantial effect on the loading rate calculations.

Watershed areas and total loading values from the Lacamas Shores development (bubbler/wetland 1 and bubbler/wetland 2) are compared with values from the control creeks 1-3 for the past four years in Table 4 (Appendix A). For 1993, nutrient loading from transect 2 of the Lacamas Shores development is the lowest of the past four years, and is lower than loading from three control creeks. Loading from transect 1 is higher than from unnamed creek 2, owing mainly to the lowest-ever average TP concentration at the creek. Creeks 1 and 3 had higher loading rates than transect 1.

For 1993, Creek 1 (Dwyer Cr.) continued to have the highest total phosphorus loading at 2.089 kg/ha/yr followed by Creek 3 (1.120 kg/ha/yr), and Creek 2, (0.576 kg/ha/yr). In comparison, bubbler/wetlands 1 and 2, originating within the development, contributed 0.902 and 0.504 kg/ha/yr, respectively.

4.7 Pesticides, Herbicides, and Heavy Metals

The "first flush" sampling for 1993 occurred on November 17. The first heavy rain of autumn washes the road and land surfaces of the accumulated sediment and pollutants, and the highest water quality values for the year are expected during this period. Water samples were collected at all of the monitoring stations and analyzed for the regular suite of parameters. In addition, samples from selected sites were collected for analysis of pesticides, herbicides, and heavy metals.

Pesticides and herbicides were monitored in surface first-flush water samples taken at the sedimentation facilities (B1 and B2) and from the streams flowing out of each wetland (S2 and S4). The results provided in Tables 5 - 7 (Appendix A) indicated no organochlorine pesticides, organophosphate pesticides, or chlorinated herbicides were detected at these sites.

Results for the metals analyses are presented in Table 8. If any of the analytes were detected, the Washington surface water quality criteria were calculated (WAC 173-201-047). The EPA limit for metals in drinking water are also included in the table. Levels of zinc were above the Washington limits at B1 (0.05 mg/l), but were well below the EPA limit of 5.0 mg/l (note that the laboratory detection limit for zinc is also greater than the calculated water criteria). The range of compliance values varies because they are calculated based on the hardness of the sample. Water samples ranged in hardness from 34 to 137 mg/l.

4.8 Hydrology

As mentioned in previous reports, the water table levels measured in the ground water wells relate more to the presence or absence of wetland rather than to detecting changes in ground water hydrology. Table 9 gives well elevations in relation to ground level for

1988 through 1993 by season to provide the best comparison between years. Because sampling did not always occur at the same time each year, three seasons were arbitrary defined (winter, spring, early/late summer, early fall) and the ground water elevations may either represent a single month's data, or may be the mean of several months observations. Complete water elevations for the past four years are presented in Table 1.

Wetland hydrologic conditions continue to persist in the two wetlands, despite lower than average precipitation levels for 1990 (2.44" below average), 1991 (5.3" below average), 1992 (10.66" below average), and 1993 (3.89" below average, based on the water year 10/92 to 10/93 36-year average; data courtesy of Reuben Bafus). Higher ground water levels were generally observed during the winter months.

Annual averages had shown that ground water levels were rising as stormwater is diverted to the wetlands, however average levels did drop in all but one well (G3) in the 1993 season, due to drier weather. The observation of rising water levels may be biased due to the measurement method. Ground water levels are only measured during sampling periods, and sampling coincides with storm events. Provision has not been made in the sampling program to obtain water levels during dry weather (low flow) periods, and the four to six sample periods per year does not provide the frequency of sampling required to adequately monitor water levels. Consequently, we have relied on the vegetation surveys as an indicator of wetland persistence and extent.

4.9 Vegetation

The diversity and abundance of vegetation cover types are useful indicators of environmental conditions prevailing at the project site. Since groundwater sampling cannot always be coordinated with stormwater surges into the wetland, vegetative responses to seasonal water regimes is considered a more reliable indicator of hydrologic trends.

The ten permanent sample plots (five per transect) established in 1990 were surveyed in 1991, 1992, and 1993 for species abundance and diversity, with the 1993 results presented in Table 10. In addition to areal percent cover for each sample plot, each species' wetland indicator status is provided as well. Comparisons between the yearly vegetation surveys provide information on the development and response of the wetland to the addition of stormwater from the development.

As mentioned in the Monitoring Strategy (Sec. 3), four plots (obscured by heavy vegetation) had to be replaced during the 1991 season. As a result, direct correlations of observations from 1992 and 1993 cannot be made with the previous year's results for these replacement sites. Nevertheless, comparisons of vegetation cover in the same vicinity for both the 1991 and 1992 seasons indicated a transition toward upland (drier) conditions in some of the marginal areas of the wetland.

Lush growth of both wetland and marginal wetland species was observed due to the wet, mild growing conditions during 1993. Himalayan blackberry (*Rubus discolor*) (FACU-) continued to expand in coverage and dominate in some areas. It appears to expand into wet areas with some success, belying its supposed facultative upland-minus status.

Himalayan blackberry is strongly competitive to the point of smothering adjacent species. Coverage by common cattail *(Typha latifolia)* (OBL) has expanded in the wet areas (especially in transect 1) almost to the exclusion of other species.

Overall, the plant community has responded to wet conditions by favoring high biomass production in certain highly competitive species, especially common cattail, reed canarygrass, and Himalayan blackberry. The expansion of the range of some of these species is not, however, adequately reflected by the sample plots. In general, areas that are consistently wet or dry have become less diverse despite the increase in productivity.

Table 11 shows trends in species dominance for each transect during the 1990, 1991, 1992, and 1993 monitoring seasons. In this analysis, species are considered dominant if they are present in one of the five sample plots at greater than 20% real cover. One caveat to this type of data presentation is that visual estimations of dominance are subjective and some species may be close to 20% cover and still not be included in the table. Consequently, the appearance of a species on the chart does not necessarily reflect a newly arrived plant or population. The species may have simply reached an observable level of dominance over its competition.

A few broad trends can be observed regarding changes to cover at the sample sites. Certain species continue to expand their ranges within areas most favorable to their growth. These are notably common cattail, reed canarygrass (*Phalaris arundinacea*) (FACW), and Himalayan blackberry. The drier transitional areas are favoring the alder, blackberries, and snowberry, while permanently saturated areas are favoring the highly competitive cattail and reed canarygrass. Two notable additions to dominant species in transect 2 are field horsetail (*Equisetum arvense*) and tall manna grass (*Glyceria elata*).

Stormwater runoff has maintained a core of obligate wetland and facultative wetland species in patches downslope from each bubbler, and there does not appear to be any negative impact on the wetland vegetation due to any deleterious substances contained in the stormwater runoff. No measurable amounts of herbicides or metals which may harm the foliage have been detected in water flowing to the wetlands (Sec. 4.7). Higher nitrate concentrations in the inflowing water may account for the lush growth of vegetation below the bubblers.

4.10 Adherence to Compliance Criteria

The compliance results for the two bubbler/wetland transects are presented in Tables 12 to 15. Results at the sedimentation facilities (B1 and B2) are included with the outflowing streams (S2 and S4) from the wetlands so that inflow and outflow concentrations can be compared. Concentrations at the wetland outflows for total phosphorus, soluble phosphorus, and the secondary parameters were always below the compliance levels, indicating that the wetlands were effective at removing these parameters from stormwater runoff. There was no apparent pattern of effect on pH or conductivity values in water passing through the wetlands.

Compliance for nitrate-nitrogen was exceeded on one of the four monitoring dates during the fifth year. As in the third and fourth monitoring years, levels were exceeded in winter sampling months. On October 30, 1992, the nitrate concentration at station S4 below bubbler/wetland 1 was 0.801 mg/l (Table 12). The nitrate values for the two transects were in compliance for the remainder of the monitoring season.

The presence of elevated inflowing nitrate values during the 1992-3 winter appears to confirm the assertion of the fourth year report that increased levels of nitrates are entering the wetlands. Potential sources that have been suggested of the nitrate-nitrogen include runoff of commercially-applied fertilizers to residential lawns, and ground water which is contaminated upgradient of the development and eventually flows through the development and into the bubblers.

5.0 DISCUSSION AND RECOMMENDATIONS

As per last year's request from the Washington Department of Ecology (Nora Jewett), several graphs have been included to illustrate changes taking place at the site over time. Graphs are presented that show changes in 1) phosphorus loading rates from the wetland bubblers and the control creeks, 2) total annual phosphorus mass contributed to the lake from the bubblers and creeks, and 3) concentrations to and from the wetland bubbler systems for the past three years.

When phosphorus loading rates are compared for the past four years (Fig. 27), it is evident that rates for the creeks are greater than from the bubblers. Creek 1 (Dwyer Creek) has show the greatest increase in loading rate, with Creek 2 actually decreasing over time, mainly attributable to lower TP concentrations over the year. Figure 28 presents the total annual mass contributed on an annual basis to the lake from the bubblers and the creeks. The contribution by the creeks can be seen to be from one to two orders of magnitude higher than the bubblers. Because of its relative drainage basin size, Dwyer Creek adds from 325 to 675 kg TP/yr, while TP enters the lake from the wetlands at a rate of 3 to 8 kg/yr.

In Figures 29 and 30, annual mean concentrations at the inflow and outflow of Transects 1 and 2, respectively, are presented for the three years that the compliance levels have been in effect. With a few exceptions there has been a reduction in nutrients (TP, NO_3) and TSS in stormwater as it flows from the bubblers (B1, B2) to the outlet streams (S4, S2; also see Table 3). The concentrations of the outflowing means were also all below the established compliance levels for nutrients and TSS (see Tables 12 - 15 for compliance levels).

These two figures also illustrate the trend of phosphorus, nitrate, and total suspended solids concentrations entering the wetlands over the past three years. Total phosphorus and TSS concentrations going into the wetlands at B1 and B2 have consistently decreased from 1991 to 1993. Annual mean concentrations of nitrate-nitrogen increased from 1991 to 1992, but then decreased in 1993.

It is important to note that outflowing concentrations are the sum of treatment by the wetlands as well as natural uptake and release processes within the wetlands. Especially when inflowing concentrations are low (e.g., TP and TSS in transect 2, 1993), outflowing concentrations may exceed inflowing levels. It is unlikely that concentrations for nutrients and TSS would ever reach zero. Wetlands naturally release nutrients and solids with certain seasonal fluctuations as a function of their existence. It was the purpose of the first two years of this study to document those seasonal fluctuations in order to set up the site-specific criteria that are presently used. The low concentrations flowing out of the wetlands are a reflection of background conditions independent of the stormwater inputs.

Because of the overall reduction in inputs of TP and TSS to the wetlands, removal percentages appear to be smaller with time (see Table 3). As the discussion above illustrates, higher outflowing versus inflowing concentrations do not necessarily mean a reduction in wetland treatment capability. And because nitrate input levels have not decreased to pre-compliance levels (i.e. 1989 and 1990 data), percent removals have been relatively higher, and did increase for both transects from 1992 to 1993.

As stated in the fourth year report, one of the original concerns of the use of wetlands for stormwater treatment was the ability to reduce phosphorus loading to Lacamas Lake. All the evidence to date indicates that the bubbler systems are effective at reducing concentrations of phosphorus from the development to levels below site-specific criteria. An unanticipated consequence of sending stormwater to the treatment wetland has been the increased input of nitrate, with the site-specific criteria being exceeded during the winter months.

Future compliance with criteria may entail alterations to the wetland to optimize treatment. Opportunities do exist on-site to either modify the existing wetlands or add addition area. Limiting nutrient sources in the drainage basin has also been suggested as a direct method to reduce inputs, thus extending wetland treatment life and efficiency. A source control program which educates homeowners about proper lawn and garden practices and provides opportunities for reducing the amount of nutrients in stormwater runoff was identified as an important and vital component to the success and longevity of the treatment wetland system.

As required by the original shoreline permit, copies of the annual report are sent to the Washington Department of Ecology (WDOE) for review and comment. A brief review by Kim Van Zwalenberg (Shorelands and Coastal Zone Management Program 1994) is summarized below (see Appendix C for complete letter) and appropriate comments are included.

5.1 Nitrate-Nitrogen Levels

Continued concern was expressed regarding the apparent increase in nitrate-nitrogen levels in water flowing into the wetlands. The implementation of upstream control measures within the development was suggested to see if reduction of input could be observed. Suggested source control measures included minimizing lawn fertilizers, restricting nitrogen content in fertilizers, restricting application rates, and restricting fertilizer application to specific months.

Source control measures have been recommended in these monitoring reports in the past. The alternatives (pretreatment, increased wetland treatment area) are more costly and less proactive in treating the problem, rather than the symptoms.

5.2 Species Diversity and Dominance

The comment was made that the tables presented do not provide information regarding the changes in species diversity and dominance over time, thus making it difficult to analyze impacts on wetland vegetation over time. This observation appears to be unfounded, given the results presented in Table 11 (Dominant species for 1990 to 1993), and transect data presented in all four monitoring reports prepared for the site and included by reference in the fourth year report. The results are also discussed in appropriate sections of each report.

The letter goes on to state that a decrease in species diversity and/or an increase in more invasive species could indicate negative impacts resulting from changes in hydrology due to stormwater inputs. Variations in climatic regime (temperature, precipitation, cloud cover?) may also be contributing factors. The letter also notes that the expansion of reed canarygrass should be watched closely and that some sort of intervention may be needed. These observations have been noted in previous and the recent monitoring reports.

5.3 Removal Rates of Nutrients and Total Suspended Solids

The letter states that if the apparent trend in decreasing removal rates by the wetlands continues, it may be an indication that additional pretreatment and/or source controls may be needed prior to discharge of stormwater into the wetland. This issue has been addressed in the discussion above regarding trends of inflowing and outflowing concentrations. Because of the decreasing concentration of TP to the wetlands, there does not appear to be a need for additional pretreatment of stormwater. However, the winter time increases in nitrate may warrant source control measures within the development, as suggested earlier in the letter.

We would like to acknowledge the assistance and cooperation of Tom Shipler and Charles Cox of the Lacamas Shore development. We are especially grateful to Reuben Bafus, a long-time local resident, for the generous use of the precipitation and temperature data he has accumulated over the past thirty-seven years.

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