Benefit and Cost of Phosphorus-Reducing Activities in the Lake Whatcom Watershed

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Background and Purpose

Management of the Lake Whatcom drinking water reservoir is challenged by excessive nutrient loading that causes increased algal blooms that in turn results in reduced treatment capacity, increased treatment costs, and increased disinfection by-products at the City's Whatcom Falls Water Treatment Plant. In addition to the basic response needed to protect water supply delivery, a response is also required to the listing of Lake Whatcom as an impaired water body under the tenants of the Clean Water Act, the Total Maximum Daily Load (TMDL) listing for Total Phosphorus.

Lake Whatcom Management Program (LWMP) members, the City of Bellingham, Whatcom County, and Lake Whatcom Water and Sewer District, have researched, selected, and implemented several actions over the past 20 years to improve lake water quality. These actions have been described in work plans produced every five years that guide a multi-faceted response to many pollution issues. Although previous work plans have included many actions to reduce phosphorus loading, the current five year work plan (2010-2014 Work Plan) significantly increases the emphasis on phosphorus reduction actions. The reason for this emphasis is that phosphorous reduction was also the basis for the Summary Implementation Strategy (SIS), the first step in the TMDL response process. Even though the SIS is not yet completed, LWMP staff are beginning development of the next component of the TMDL response, the Detailed Implementation Plan (DIP) which requires identification of specific actions, costs of those actions, committed funding sources, and an implementation timeline for reducing the pollutant load (phosphorus) and thereby removing the lake from TMDL impaired status (delist).

The purpose of this study is to provide an initial comparison of several selected phosphorus-reducing and phosphorus-removal strategies that may inform policy decisions and the development of the DIP. To this end, the project team estimated phosphorus reduction and associated costs on a per-unit basis of specific in-watershed activities selected by City staff from the Lake Whatcom Management Program 2010-2014 Work Plan. The results of this work form an initial step in guiding further evaluation of activities and development of the DIP to comply with TMDL requirements.

Assumptions, Limitations, and Context

This work can inform the prioritization of watershed activities based on phosphorus reduction benefit. It can also guide and prioritize further evaluation of specific activities to assess their feasibility and effectiveness throughout the watershed for inclusion in the forthcoming DIP. It is understood that other factors beyond the computed phosphorous-reduction and associated unit costs presented herein also contribute to prioritization. These other factors may including: other studies, regulatory requirements, public expectations, political will, and others.

The following are assumptions and limitations upon which the estimates presented herein were based, including:

- The information upon which the estimates were based is from existing sources, where available and applicable, as well as information provided by the City. No new site-specific data was collected as part of this study. Additionally, anecdotal evidence of the phosphorous-reduction effectiveness is not incorporated into this work.

- The information provided in this summary memorandum is for planning-level purposes only to aid the City of Bellingham and Whatcom County in decision-making and/or prioritization and should not be used for design or construction.
- For this study, it was assumed each individual activity was independent of the others. Therefore, the phosphorus reduction estimates are for that activity only and don't include phosphorus reduction benefits of other activities.
- 'Benefit' only includes phosphorus reduction benefit, not a broader public benefit. Activities that may not be as cost-effective at reducing phosphorous may warrant consideration based on other factors. These other factors may include aesthetics, temperature reduction, public expectation, or other (non-phosphorus) water quality improvements.
- Costs are those that would primarily impact public entities (the City, County, and/or Water/Sewer District), not the cost to the private sector (such as cost to developers).
- Costs do not include the cost of land acquisition that might be required for implementation of activities such as bio-filtration swales or rain gardens.
- Costs do not include lost tax revenue to the County and City associated with changing the zoning ("down-zoning") of properties in the watershed to preclude development was not included in this work. In addition, the lost value to the property owner of down-zoning was not included in this work.
- Costs to property owners related to ordinance changes that govern development or changes related to forest practices were not included. In addition, costs associated with attempting to negotiate and implement such changes have not been included.
- Costs do not include annual operating and maintenance costs.
- The activities considered in this work were identified by members of the Lake Whatcom Management Program and do not represent all phosphorous-reducing activities that could be undertaken. Addressing the impact of Asian Clams was not included in this work because this issue came to light after this work was substantially complete.
- The extent to which each of the phosphorous reduction activities can be implemented in the watershed was not covered in this work. This, additional work task will be a key element of developing an effective DIP.

Watershed Activities

A working group consisting of staff from the City of Bellingham and Whatcom County prepared an initial draft of in-watershed activities based upon the Lake Whatcom Reservoir Management Program 2010-2014. CH2MHILL, the City, and the County collaboratively refined the list of activities, as presented in the summary list below:

1. Reducing development potential / developable land
2. Restoration of natural functions on acquisition properties
3. Bio-filtration: vegetated swales
4. Bioretention: rain gardens
5. Bio-filtration: street trees
6. Lawn replacement & landscaping: retrofit to provide bioretention
7. Infiltration: dry wells
8. Infiltration: trenches
9. Infiltration: pervious pavement
10. Infiltration: basin
11. Rainwater reuse
12. Onsite dispersion
13. Media filters
14. Sizing culverts to eliminate erosion

15. Street sweeping
16. Controlling erosion through streambank stabilization or restoring stream buffer vegetation
17. Regulations: Phosphorus fertilizer ban
18. Education: Watershed signs
19. Education: Mass mailings
20. Education: Online information
21. Education: Newspaper ads
22. Education: Video presentations
23. Education: Community events (public meetings)
24. Education: Onsite training/workshops
25. Education: Resident contact
26. Education: Project consultation
27. Incentives
28. Transition from Ecology Water Quality Assurances of Forest Practices to pre-development conditions
29. Design standards for new and retrofitted roads
30. Reconfigure roadside ditches
31. Reconfigure streets
32. Vehicle trips - reduce and redirect
33. Recreational facility design and use (Improving existing facilities)
34. Watershed-wide enforcement
35. Animal waste: wildlife (goose)
36. Septic system transition to sewer connection

Summary of Results

Exhibit 1 presents a graphical summary of the cost-benefit in terms of dollars per pound of phosphorus removed for each of the activities.

Exhibit 2 presents a tabular summary of the cost-benefit in terms of dollars per pound of phosphorus removed for each of the activities.

Exhibit 3 contains the detailed information which is the basis for phosphorus reduction estimates and costs contained in this memorandum. Exhibit 3 includes all of the 36 activities except for the education, incentives, and enforcement activities, which were separated out to allow for an off-line comparison. This was done to allow the City and County to compare education activities amongst themselves separate from the other activities.

Exhibit 4 contains a summary of information available in the literature about effectiveness of different education methods and also incentives and enforcement. This summary provides the City of Bellingham and Whatcom County with a planning tool to assist in prioritizing which type of education methods to implement.

Exhibits 1-4 are attached to this memorandum.

Benefit in Terms of Phosphorus Reduction

For this cost-benefit study, benefit is defined solely as phosphorus reduction. While each activity may have other benefits such as aiding in regulatory compliance or to addressing a public safety issue, the benefit described in this study is only phosphorus reduction. These activities may not lead to a measurable phosphorus reduction but may be a good idea for those other reasons. In the case of some of the activities, quantifying a phosphorus reduction was not possible. This was because information was not found in the literature.

Cost of Activities

These costs are estimates of capital costs. In some cases, where they were readily available, annual maintenance costs are also provided within Exhibit 3. Note that costs shown in Exhibit 3 only reflect public cost (that is, cost to the public agency) and not other costs such as cost to developers.

Attachments:

Exhibit 1 –Summary of Cost-Benefit

Exhibit 2 - Tabular Summary of Cost-Benefit

Exhibit 3 – Details of Cost-Benefit Analysis for Watershed Activities (except for education/incentives/enforcement)

Exhibit 4 - Education/Incentives/Enforcement Activities

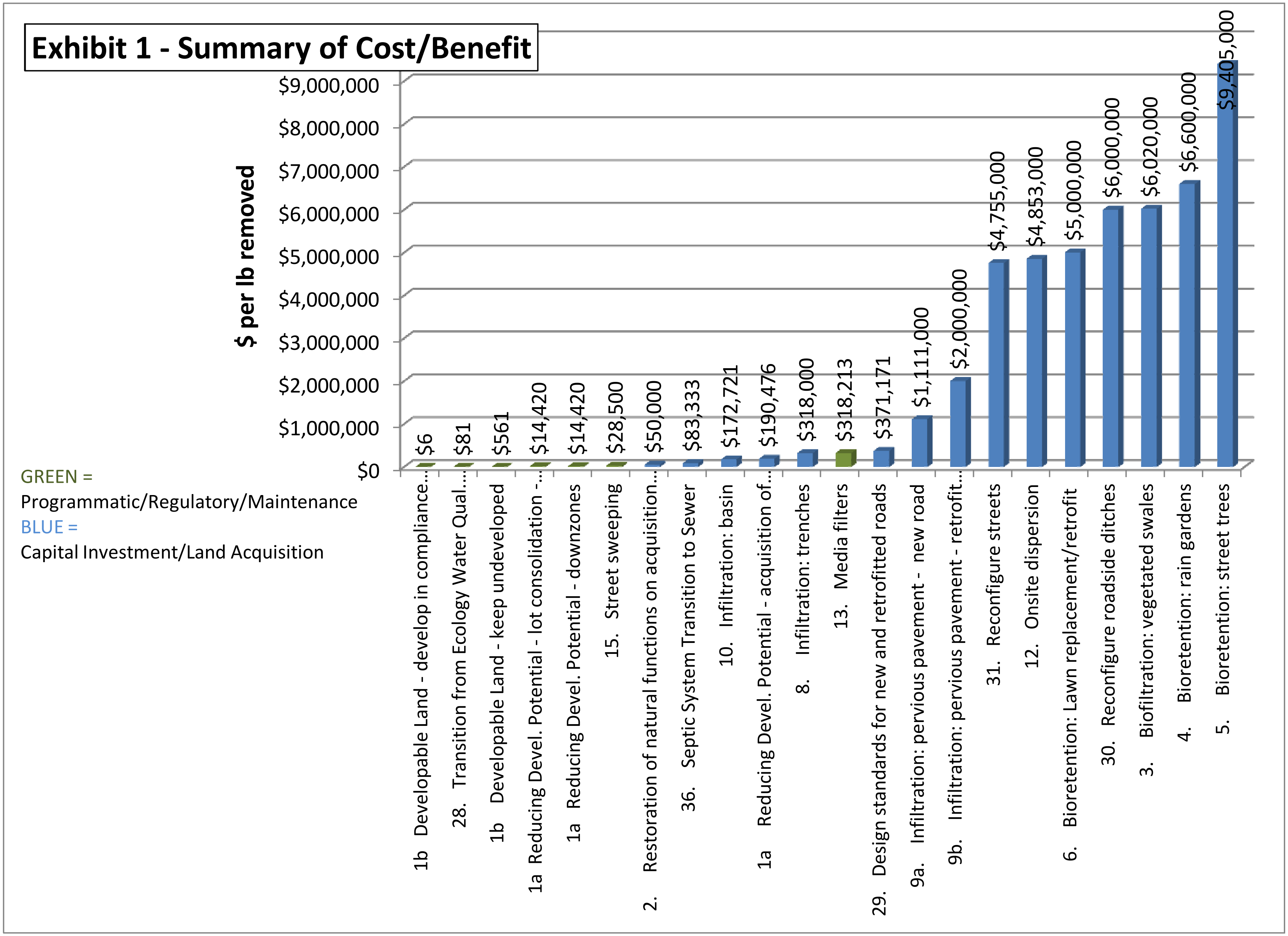

Exhibit 1 - Summary of Cost/Benefit
$ per lb removed
$9,000,000
$8,000,000
$7,000,000
$6,000,000
$5,000,000
$4,000,000
$3,000,000
$2,000,000
$1,000,000
$0
GREEN =
Programmatic/Regulatory/Maintenance
BLUE =
Capital Investment/Land Acquisition
$6
$81
$561
$14,420
$14,420
$28,500
$50,000
$83,333
$172,721
$190,476
$318,000
$318,213
$371,171
$1,111,000
$2,000,000
$4,755,000
$4,853,000
$5,000,000
$6,000,000
$6,020,000
$6,600,000
$9,405,000
1b Developable Land - develop in compliance…
28. Transition from Ecology Water Qual…
1b Developable Land - keep undeveloped
1a Reducing Devel. Potential - lot consolidation - …
1a Reducing Devel. Potential - downzones
15. Street sweeping
2. Restoration of natural functions on acquisition…
36. Septic System Transition to Sewer
10. Infiltration: basin
1a Reducing Devel. Potential - acquisition of…
8. Infiltration: trenches
13. Media filters
29. Design standards for new and retrofitted roads
9a. Infiltration: pervious pavement - new road
9b. Infiltration: pervious pavement - retrofit…
31. Reconfigure streets
12. Onsite dispersion
6. Bioretention: Lawn replacement/retrofit
30. Reconfigure roadside ditches
3. Biofiltration: vegetated swales
4. Bioretention: rain gardens
5. Bioretention: street trees

Exhibit 2: Tabular Summary of Cost-Benefit Evaluation

Activity	Benefit: Phosphorus Reduction	Benefit: Units	Cost: Initial Capital	Cost: Units	Cost/Benefit ($ / lb)
1. Reducing development potential / developable land					
Reducing Devel. Potential - acquisition of open space	1.05	lb/acre/year	$200,000	per acre	$190,476
Reducing Devel. Potential - lot consolidation - residential	minimal	lb/acre/year	$20,000	total	$14,420
Reducing Devel. Potential - downzones	minimal	lb/acre/year	$20,000	total	$14,420
Developable Land - develop in compliance with City ordinance [1]	2498	lb/yr for the watershed	$15,000	total	$6
Developable Land - keep undeveloped [1]	2775	lb/yr for the watershed	$1,402,000	total	$561
2. Restoration of natural functions on acquisition properties	1.0	lb/acre/year	$50,000	per acre	$50,000
3. Biofiltration: vegetated swales	20	%	$8	per sf of treated area	$6,020,000
4. Bioretention: rain gardens	50	%	$22	per sf of treated area	$6,600,000
5. Bioretention: street trees	40	%	$25	per sf of treated area	$9,405,000
6. Bioretention: Lawn replacement / retrofit	75	%	$25	per sf of treated area	$5,000,000
7. Infiltration: dry wells [2]	-	-	-	-	-
8. Infiltration: trenches	70	%	$1.48	per sf of treated area	$318,000
9a. Infiltration: pervious pavement - new road	60	%	$4.43	per sf of treated area	$1,111,000
9b. Infiltration: pervious pavement - retrofit existing	60	%	$8	per sf of treated area	$2,000,000
10. Infiltration: basin	100	%	$50,000	per acre of treated area	$172,721
11. Rainwater reuse [3]	minimal	lb/year	-	-	-
12. Onsite dispersion	40	%	$12.90	per sf of treated area	$4,853,000
13. Media filters [4]	52	%	$1.10	per sf of treated area	$318,213
14. Sizing ditches/culverts to eliminate erosion [3]	minimal	lb/year	-	-	-
15. Street sweeping [5]	60	%	$0.11	per sf swept	$28,500
16. Controlling erosion through streambank stabilization or restoring stream buffer vegetation [8]	moderate	lb/year	-	-	-
17. Regulations: Phosphorus fertilizer ban [6]	0.5	lb/acre/year	-	-	-
18. Education: Watershed signs [7]	-	-	-	-	-
19. Education: Mass mailings [7]	-	-	-	-	-
20. Education: Online information [7]	-	-	-	-	-
21. Education: Newspaper ads [7]	-	-	-	-	-
22. Education: Video presentations [7]	-	-	-	-	-
23. Education: Community events (public meetings) [7]	-	-	-	-	-
24. Education: Onsite training/workshops [7]	-	-	-	-	-
25. Education: Resident contact [7]	-	-	-	-	-
26. Education: Project consultation [7]	-	-	-	-	-
27. Incentives [7]	-	-	-	-	-
28. Transition from Ecology Water Qual. Assurances of Forest Practices to pre-development conditions	0.1	lb/acre/year	$200,000	total	$80.65
29. Design standards for new and retrofitted roads	60	%	$1.48	per sf of treated area	$371,171
30. Reconfigure roadside ditches	20	%	$8.00	per sf of treated area	$6,000,000
31. Reconfigure streets	30	%	$10.00	per sf of treated area	$4,755,000
32. Vehicle trips - reduce and redirect [3]	minimal	lb/year	-	-	-
33. Recreational facility design and use (improving existing facilities) [3]	minimal	lb/year	-	-	-
34. Watershed-wide enforcement [7]	-	-	-	-	-
35. Animal waste: wildlife (goose) [9]	0.3	lb/goose/year	-	-	-
36. Septic System Transition to Sewer	0.6	lb/septic system/yr	$50,000	per septic system	$83,333

Notes:

[1] As compared to developing conventionally

[2] At the direction of the City did not assess cost-benefit of this activity because activity is not feasible throughout most of the watershed (due to soil and groundwater conditions)

[3] Did not characterize cost or cost-benefit after determination of minimal direct phosphorus reduction benefit

[4] Evaluated several types of media filters; Phosphorus Reductions and Costs shown in this table are on conservative end of range

[5] $/lane mile swept to be determined

[6] no cost-benefit characterized because cost to implement ordinance already expended; assuming no cost for enforcement; enforcement/education/incentives covered on Table 2

[7] Activities 18 through 37 (education/incentives/enforcement) summarized on Table 2 of this deliverable and not summarized here

[8] stream buffer provides indirect phosphorus reduction benefit (by reducing velocities and promoting infiltration); stream channel stabilization could have significant phosphorus reduction benefit

[9] At the direction of the City did not assess cost-benefit of this activity because implementation of this activity is not acceptable

Exhibit 3. Lake Whatcom Phosphorus-Reduction: Cost-Benefit Analysis Detail

Activity Number	Activity	Units of Phosphorus (TP) Removal	Phosphorus Loading Removed	Cost	Cost/Benefit	Notes
1a	**Reducing development potential**					
1a(i)	Acquisition of existing open space	lb/acre/year	1.05	$200,000 per acre for land acquisition**	In the first year, $200,000/acre cost with a 1.05 lb/acre benefit = $190,476/lb	Acquisition does not include any land cover changes or site management. Phosphorus removal estimate is equal to the difference between developed land loading (blended pervious and impervious) and undeveloped land loading, per the Lake Whatcom TMDL study (Ecology 2008a). Developed pervious (82% of developed area): 1.24 lb/acre/year; Developed impervious (18% of developed area); The land use acreages indicated that 18 percent of the developed area is impervious. Therefore, the blended loading calculates to 1.20 lb/acre/year: 0.99 lb/acre/year (CDM 2008; Ecology 2008) Deciduous Forest: 0.14 lb/acre/year; Evergreen Forest: 0.16 lb/acre/year; Mixed Forest: 0.14 lb/acre/year; An overall total phosphorus loading of 0.15 lb/acre/year was assigned. 1.20 (Developed land loading) – 0.15 (Undeveloped land loading) = 1.05 lb/acre/year (developed land loading and undeveloped land loading from CDM 2008; Ecology 2008) Cost equals the sum of the current price of open space parcels and cost to process acquisition **Note that this study does not consider costs to the private sector (i.e. developers) only to the public sector (i.e. administrative costs to administer development). This is especially important to note for these items 1a and 1b.
1a(ii)	Lot consolidation - residential	lb/acre/year	*Minimal benefit*	$20,000 total, watershed wide**	'minimal benefit' estimated as 0.01 lb/acre/year; Assuming can implement on only 5% of developable land (5% of 2,774 acres or 138.7 acres); $20k / (138.7 * 0.01) = $14,420/lb for the first year	Phosphorus removal estimate would equal the difference between multi-family and single family residential phosphorus loading, which is not likely a significant difference. Furthermore, lot consolidation would occur as opportunities present themselves, not uniformly across the watershed. The actual phosphorus loading reduction is therefore expected to be relatively small. Cost to process lot consolidation – 2 FTEs for 1 month, assuming $100,000 per FTE for 1 year plus additional administration work
1a(iii)	Downzones	lb/acre/year	*Minimal benefit*	$20,000 total, watershed wide**	'minimal benefit' estimated as 0.01 lb/acre/year; Assuming can implement on only 5% of developable land (5% of 2,774 acres or 138.7 acres); $20k / (138.7 * 0.01) = $14,420/lb for the first year	Phosphorus loading reduction would result from reduced lot density (i.e., residential to public/recreational, commercial to public/recreational, commercial to residential). There are too few industrial zoned parcels in the watershed to include in this evaluation. Minton (2011) does not report a significant difference in phosphorus loading between single-family residential, multi-family residential, and commercial/industrial land. As with lot consolidation, downzoning would occur as opportunities present themselves, not uniformly across the watershed. The actual phosphorus loading reduction is therefore expected to be relatively small. Cost to process downzone – 2 FTEs for 1 month, assuming $100,000 per FTE for 1 year plus additional administration work

Exhibit 3. Lake Whatcom Phosphorus-Reduction: Cost-Benefit Analysis Detail

Activity Number	Activity	Units of Phosphorus (TP) Removal	Phosphorus Loading Removed	Cost	Cost/Benefit	Notes
1b	**Developable land**					Assumes 2,774 acres of developable land in the watershed. This represents the difference between developed land under the “full buildout” and the “base scenarios” in the Lake Whatcom TMDL Study (Ecology 2008a). Phosphorus loading rate assumptions used: • 0.20 lb/acre/year from undeveloped land (see item 1a, reference: CDM 2008; Ecology 2008) • 0.3 lb/acre/year (City-estimated) from land developed in compliance with City’s LID standards • 1.20 lb/acre/year from conventionally developed land (reference: CDM 2008; Ecology 2008) Assumes that the “baseline” condition is conventional development of all 2,774 acres of developable land in the watershed. (1.20 lb/acre/year developed land loading)(2,774 acres of developable land) = 3,330 lb/year (0.3 lb/acre/year developed land loading)(2,774 acres of developable land) = 832 lb/year 3,330 – 832 = 2,498 lb/year (Cost equal to the permitting and processing cost for developing a 1) SFR residential and 2) commercial in compliance with City LID standards, administrative costs only estimated at 1 FTE for 2 months, assuming $100k per FTE per year.) (1.20 lb/acre/year developed land loading)(2,774 acres of developable land) = 3,330 lb/year (0.2 lb/acre/year undeveloped land loading)(2,774 acres of developable land) = 555 lb/year 3,330 – 555 = 2,775 lb/year (Cost equal to the building department revenue that would have been generated from a 1) SFR residential and 2) commercial) PLUS the administrative costs as determined above)
1b(i)	Benefit of developing all conventionally	lb/year (watershed-wide)	0 *(as baseline for other options under item 1b)*	$0 *(as baseline for other options under item 1b)*	--	
1b(ii)	Benefit of developing all land in compliance with City ordinance *as compared to* developing all of conventionally	lb/year (watershed-wide)	2,498	$15,000 **	for the first year: $15,000 / 2,498lbs/yr = $6/lb	
1b(iii)	Benefit of keeping developable land undeveloped *as compared to* developing all of it conventionally	lb/year (watershed-wide)	2,775	$15,000 + $500/acre (estimated same as above PLUS $500/acre) **	for the first year: ($15,000 +$500/acre * 2,774 acres) / 2,498lbs/yr = $561/lb	
2	**Restoration of natural functions on acquisition properties**	lb/acre/year	1.0	$50,000 / acre **	In the first year, $50,000/acre cost with a 1.0 lb/acre benefit = $50,000/lb	Assumes restoration is to forested conditions. This would take several years to achieve. The phosphorus loading under restored conditions would be expected to be lower than that for land developed in compliance with City LID standards (see item #1a). The phosphorus loading benefit would be the difference between developed and restored land loading rates: 1.20 – 0.20 lb/acre/year = 1.0 lb/acre/year TP removed by restoring land to forested conditions. See also notes for item #1. Continued access and limited use of restored lands would probably occur to a higher degree than in the case of natural land preservation. Cost equal to the total cost for planning, design, construction and planting, and maintenance until the site is self-sufficient, estimated at $50,000 per acre. **Note that this study does not consider costs to the private sector (i.e. developers) only to the public sector (i.e. administrative costs to administer development). This is especially important to note for these items 1a and 1b.

Exhibit 3. Lake Whatcom Phosphorus-Reduction: Cost-Benefit Analysis Detail

Activity Number	Activity	Units of Phosphorus (TP) Removal	Phosphorus Loading Removed	Cost	Cost/Benefit	Notes
3	**Biofiltration: vegetated swales[1]**	%	20	Construction: $8/sf of area treated	Assuming 20% removal of phosphorus at $8 per square foot of treated area = $6,020,000/lb (*Example calculation, which applies to all other cost-benefit calculations in this study: 8,974 lb/year total Phosphorus loading watershed-wide, with 31,000 acres in the watershed equates to an average of 0.29 lb/year per acre; 20% removal yields a 0.06 lb of phosphorus removed per acre per year. At $8/sf of treated area, and 43,560 sf in an acre, the cost to treat one acre is $348,480. $348,480 to remove 0.06 lb of phosphorus equates to $6,020,000 per lb of Phosphorus removed. Note that the results of this calculation are independent of the scale on which it is based. i.e. yields the same answer regardless of 1 acre, 10 acres, or 100 acres, or watershed-wide implementation*)	Assumes no infiltration. CWP (2008) reports 10-20% flow reduction plus an additional 20-40% reduction of TP in the surface flow. Geosyntec (2008) reports 36% reduction. The "Dayton" swale in Seattle in the NPDES BMP database reported no TP removal (inflow concentration of 0.18 mg/l, outflow concentration of 0.19 mg/l). Other literature reports only limited TP removal for biofiltration swales.
		%	77-100			"Geneva Swales" testing results (provided by Whatcom County via email, 10/3/2011).
		lb/swale/year	0.02 – 6.71 Avg: 0.86			2010 City data – range of phosphorus removal of all 11 facilities listed as swales: 0.02 – 6.71 lbs (Bellingham 2011). 2009 City data – range of phosphorus removal: 0.07 – 2.65 lbs Cost - Silver Beach Creek Outreach Program cited a cost for the Lahti Drive bio-infiltration swale (design, survey, and permitting): $24,356.04; OR Total cost (including design, survey, permitting, construction, and annual maintenance) of at least 5 of the 10 swales included in the Detailed Phosphorus analysis.
4	**Bioretention: rain gardens[1]**	%	50	Construction: $18.90 - $32.80/sf of treated area	Assuming 50% removal of phosphorus at $22 per square foot of treated area = $6,600,000/lb	CWP (2008) reports 80% flow reduction (40% if there are underdrains) plus an additional 25-50% reduction of TP in overflow. Tetra Tech (2008) reports overall 70 % reduction. Given limited infiltration capability of the soils in the watershed, assume a 50% TP reduction credit.
		mg/L TP	+0.04			NPDES Urban BMP Performance Tool - University of Connecticut 2005; higher outflow concentration; no volume data available.
		lb/rain garden/year	0.04-5.90			2009/2010 City data: Bloedel Raingarden 1 – 5.51 acres treated, 100% treatment efficiency; BloedelRaingarden 2 – 0.34 acres treated, 10% treatment efficiency Net phosphorus removal requires that rain gardens are sized correctly. The City has indicated that monitoring found one of its rain gardens exports phosphorus. Total cost (including design, survey, permitting, construction, and annual maintenance) of the Bloedel rain gardens.
		lb/year (watershed-wide)	423			An estimated 30% of the developed basin can accommodate rain gardens; 50% TP removal efficiency assumed; 2,352 acres of developed land in the watershed (Ecology 2008a); loading rate from developed land assumed to be 1.20 lb/acre/year (see item #1). Cost: Estimate number of rain gardens needed to treat the full 30% of the developed basin that can accommodate it. Multiply the number of rain gardens by the cost estimated from the above Bloedel rain gardens (the result will likely be a cost range).

Exhibit 3. Lake Whatcom Phosphorus-Reduction: Cost-Benefit Analysis Detail

Activity Number	Activity	Units of Phosphorus (TP) Removal	Phosphorus Loading Removed	Cost	Cost/Benefit	Notes
5	**Bioretention: street trees[1]**	%	15	No quote provided by Filterra Systems (as surrogate, use $18.90 - $32.80/sf of treated area)	Assuming 40% removal of phosphorus at $25 per square foot of treated area = $9,405,000/lb	Center for Watershed Protection (CWP 2008) reports a 15% flow reduction; but gives no further credit for reduction of TP in the remaining surface flow. Washington Department of Ecology (Ecology) TAPE Program (Ecology 2011) made a preliminary determination that Filterra has poor phosphorus reduction and does not meet phosphorus treatment criteria of 50% removal.
		lb/tree/year	0.0014			Assumes 0.36 mg/L TP in runoff (Minton 2011); 845 gal/tree stormwater runoff reduction (McPherson et al. 1999); Filterra's whitepaper reports 56.5% TP removal efficiency in a Bellingham study. Cost: Quotes for Filterra system
		%	74			Charles River Watershed Association (CRWA) 2009 reports 74% TP removal from street trees.
6	**Lawn replacement & landscaping: retrofit to provide bioretention[1]**	%	75	As a surrogate, use item 4 above: Construction: $18.90 - $32.80/sf of treated area	Assuming 75% removal of phosphorus at $25 per square foot of treated area = $5,000,000/lb	Lawns often sit atop poorly draining subsoils, resulting in limited infiltration of rainfall and extensive runoff. The subsoils can be amended with compost, greatly increasing infiltration capacity. The amended soils can then be replanted either with native plants or reseeded in grass. CWP (2008) reports a 75% flow reduction attributable to amended soils. No treatment for TP is credited for surface runoff. Therefore assign a 75% TP reduction credit for the replaced lawn area. Assumes fertilizer restriction is enforced.
7	**Infiltration: dry wells[1]**	n/a	n/a	--	--	Phophorus removal is likely similar to rain gardens or infiltration trenches. New dry wells are not likely an option in the Lake Whatcom watershed, because Ecology requires them to be located in cobble areas, which are not naturally present in the watershed. Therefore, this item was not evaluated further.
8	**Infiltration: trenches[1]**	%	(-)100 - 65	$1.48 per sf of treated impervious surface.	Assuming 70% removal of phosphorus at $1.48 per square foot of treated area = $318,000/lb	NPRPD 2007 – Infiltration

Exhibit 3. Lake Whatcom Phosphorus-Reduction: Cost-Benefit Analysis Detail

Activity Number	Activity	Units of Phosphorus (TP) Removal	Phosphorus Loading Removed	Cost	Cost/Benefit	Notes
9a	**9a - Infiltration: pervious pavement (new road)** [1]	%	60	$4.43 per sf of treated impervious surface.	Assuming 60% removal of phosphorus at $4.43 per square foot of treated area = $1,111,000/lb	CWP (2008) reports 45% flow reduction (no underdrains) plus an additional 25% reduction of TP in the underflow. Tetra Tech (2008) reports overall 67% reduction. Assign a 60% TP reduction credit (for the pervious pavement area, only). This estimate addresses the TP removal from the retrofitted road surface only. There would be a lower % removal of TP on a watershed-wide basis. Cost for new road (from SPU); Retrofitting existing road would be more expensive, as it would include the breakup and removal of the existing road surface and road bed. The difference between the $8/sf for the retrofit and the $4.43/sf for the new is to remove the existing road and roadbed to make way for the new pervious pavement.
9b	**9b - Infiltration: pervious pavement (retrofit existing road)** [1]	%	60	$8 per sf of treated impervious surface.	Assuming 60% removal of phosphorus at $8 per square foot of treated area = $2,000,000/lb	
10	**Infiltration: basin** [1]	%	100	$6/sf of infiltration basin ($100,000 for an infiltration basin treating approx. 2 acres)	Assuming 100% removal of phosphorus at $50,000 per acre of treated area = $172,721/lb	Assumes 100% infiltration to groundwater, with no discharge to surface runoff. This item was formerly listed as "Sand filter" – see also item #13, Media Filters Cost: based upon recent experience on M Street project for City of Auburn (infiltration pond as stormwater management)
11	**Rainwater reuse**	lb/L water	*Minimal benefit*	--	--	Roof runoff presumably contributes a minimal fraction of the total phosphorus load, as rooftop runoff does not contain significant phosphorus concentrations. However, it likely contributes to phosphorus loading reductions when combined with other residential BMPs such as bioretention (i.e., lawn replacement) and if used widely throughout the watershed. Also note that phosphorus concentrations in rooftop runoff can vary seasonally, with a presumed high loading from leaf litter in the fall season. However, since no documentation is available, did not include this within the context of this study. CWP (2008) reports 40% flow reduction. A Bellingham study of the Rain Barrel Program concluded that 24% of captured roof runoff was infiltrated and the remainder dispersed into landscaped areas.
12	**Onsite dispersion**	%	40	$12.90/SF	Assuming 40% removal of phosphorus at $12.90 per square foot of treated area = $4,853,000/lb	Evaluated as a stand-alone activity. CWP (2008) reports 50-75% flow reduction but gives no further credit for reduction of TP in the remaining surface flow. Given limited infiltration capability of the soils in the watershed, assign a 40% TP reduction credit.

Exhibit 3. Lake Whatcom Phosphorus-Reduction: Cost-Benefit Analysis Detail

Activity Number	Activity	Units of Phosphorus (TP) Removal	Phosphorus Loading Removed	Cost	Cost/Benefit	Notes
13	**Media filters**	%	50-90	Aquip: Construction cost= $0.81 to 1.8/sf of treated impervious surface Annual Maintenance cost = $0.29 to $0.80 per sf of treated surface. BaySaver: Construction Cost = 0.34 to 0.91 per sf of treated impervious, Maintenance cost = $0.06 to $0.17 per sf of treated impervious surface area.	8974 lb/year P loading watershed-wide, assuming 70% removal of phosphorus; Watershed-wide implementation reduces phosphorus by 6,281 lbs and costs $1,620,000,000 at $1.20/sf, for a cost/benefit for the first year only of approximately $257,957/lb	The TAPE website (Ecology 2011) identifies the following six proprietary devices certified by Ecology as effective for stormwater phosphorus treatment, reducing total phosphorus by at least 50%. The percentage removals shown for Pilot and Conditional Uses are preliminary. Aquip Enhance Stormwater Filtration System: 60-90% TP reduction (Conditional Use) Americast Filterra System: less than 50% TP removal (Conditional Use) FloGard Perk Filter: 62% TP removal (General Use) Request quote from BaySaver Technologies BayFilter: 55% TP removal (Conditional Use) Aquashield AquaFilter: No TP removal % identified (Pilot Use) WSDOT Media Filter Drain: 86% TP removal (General Use) Cost: from Manufacturers
	Sand Filters	%	50	Construction cost= $1.00 sf of treated impervious surface	8974 lb/year P loading watershed-wide, assuming 50% removal of phosphorus; Watershed-wide implementation reduces phosphorus by 4,487 lbs and costs $1,350,000,000 at $1.00/sf, for a cost/benefit for the first year only of approximately $300,949/lb	Sand filters: CWP (2008) credits a 59% reduction of TP. Geosyntec (2008) reports 30%. WA Dept. of Ecology bestows a 50% phosphorus removal credit for this BMP (i.e., a minimum 50% P removal). Assign a 50% TP reduction credit. Assumes all treated water is discharged to surface runoff.
		lb/filter/year	4.77 – 34.84 Avg: 14.91			2009/2010 City data – "Sandfilter" and "Sandfilter/Infiltration" (Bellingham 2011). Does not include the Electric Ave Sandfilter.
	StormFilter® with PhosphoSorb ™	lb/acre/year	0.80	Construction Cost: $0.52 to 1.31 per sf of treated impervious. Maintenance Cost: $0.06 to $0.25 per year per sf of treated impervious surface area.	8974 lb/year P loading watershed-wide, assuming 52% removal of phosphorus; Watershed-wide implementation reduces phosphorus by 4,666 lbs and costs $1,350,000,000 at $1.10/sf, for a cost/benefit for the first year only of approximately $318,312/lb	Contech StormFilter® with PhosphoSorb ™ (www.contech-cpi.com) reports: Influent: 0.02 – 0.49 mg/L; Effluent: 0.025-0.083 mg/L (these values reflect manufacturer's field testing at Cable Street, Whatcom County). Phosphorus removal rate of 67% is reported for influent TP concentrations greater than 0.1 mg/l (CONTECH 2010). Loading rate of 1.20 lb/acre treated/year assumed (see item #1). Cost: Request quotes from manufacturers
		%	21-83 Avg: 52			PhosphoSorb Media – testing at Cable Street StormFilter (total phosphorus).

Exhibit 3. Lake Whatcom Phosphorus-Reduction: Cost-Benefit Analysis Detail

Activity Number	Activity	Units of Phosphorus (TP) Removal	Phosphorus Loading Removed	Cost	Cost/Benefit	Notes
	StormFilter® with ZPG media	%	-24-79 Avg: 28	Construction Cost: $0.52 to 1.31 per sf of treated impervious. Maintenance Cost: $0.06 to $0.25 per year per sf of treated impervious surface area.	8974 lb/year P loading watershed-wide, assuming 28% removal of phosphorus; Watershed-wide implementation reduces phosphorus by 2,812lbs and costs $1,350,000,000 at $1.10/sf, for a cost/benefit for the first year only of approximately $591,151/lb	ZPG Media – testing at Cable Street StormFilter (total phosphorus). Cost: Request quotes from manufacturers
		lb/filter/year	0.02 – 3.16 Avg: 1.04			2009/2010 City data: “Filter” (11 total) (Bellingham 2011).
		lb/filter/year	0.02 – 1.47 Avg: 0.49			2009/2010 City data: “Stormfilter” (subset of “Filter” – 4 total) (Bellingham 2011). Electric Ave (two values reported), Poplar (WQF 132), Poplar (WQF 133)
		lb/filter/year	0.00 – 4.69 Avg: 1.11			2009/2010 City data: “Enhanced Filter” (4 total) (Bellingham 2011). E. Beachview, Silvern Lane, Alabama Vault, Lakeside Vault.
	StormCeptor with Imbrium	lb/acre/year	0.21	Construction Cost: $1.50 per sf of treated impervious. Maintenance Cost: $0.25 per year sf of treated impervious surface area.	For the first year, 0.21 lb/acre removed with $1.50/sf ($65,340/acre) is $311,142/lb	Enhanced settling technology: Imbrium – Stormcepter: 20% removal efficiency and 1.07 lb/acre treated/year pre-treatment loading assumed. The Imbrium testing reports: “The Stormceptor can remove approximately 20-30% of the Total Phosphorus from influent stormwater (Madison, Wisconsin study; Como Park, Minnesota study).” Cost: Request quotes from manufacturers
14	**Sizing ditches and culverts to eliminate erosion**	lb/culvert/year	*Minimal*	--	--	Standard circular culverts replaced with flat bottom culverts to eliminate exit scour (erosion at the culvert outlet). Very little literature exists quantifying the TP reduction attributable to stream channel stabilization. Long-term studies performed at Lake Tahoe indicate that shoreline disturbance contributes 4% of the lake’s phosphorus load while stream channel erosion of stream channels draining to the lake contribute 2% of the lake’s phosphorus load (California Regional Water Quality Control Board 2010). Thus non-urban erosion at Lake Tahoe contributes only a minor portion of the phosphorus load. It should be pointed out that Lake Tahoe has a considerably different soils and geology regime than Lake Whatcom, making a direct comparison tentative. Therefore, it is estimated that a minimal to moderate phosphorus loading benefit from this activity could be expected only if this is applied consistently over the entire watershed.
15	**Street sweeping**	%	60 (street) 10 (basin)	$6,000 per lane mile (per year)	$6000 per lane mile = $0.11 per sf;	Shoemaker (2000) states that 40-75% of street-related TP can be collected by mechanical and vacuum-assisted sweepers, respectively. However, on a watershed basis, USGS (2002) reports a TP reduction of 5-14% while Northern Virginia Planning District Commission reports a 9-11% reduction. The City of Seattle conducted extensive street sweeper testing (Seattle Public Utilities and Herrera Consultants 2009) but did not report phosphorus data. The City of Bellingham conducted a single analysis of phosphorus content of sweepings but the data was insufficient to allow calculation of removal rate. Assign the following TP reduction credit: 60% for the street area; 10% on a basin-wide basis. Cost: *City provided $6,000 per lane mile per year*

Exhibit 3. Lake Whatcom Phosphorus-Reduction: Cost-Benefit Analysis Detail

Activity Number	Activity	Units of Phosphorus (TP) Removal	Phosphorus Loading Removed	Cost	Cost/Benefit	Notes
16	**Controlling erosion through 1) streambank improvements and 2) restoring stream buffer vegetation**		*Moderate benefit*	--	--	The benefit to phosphorus load reductions from stream buffer protection is attributed to erosion control; however, stream buffer vegetation also contributes phosphorus by export of organic material. Note: Phosphorus loading associated with streambank erosion depends on the TSS/TP correlation (soil composition) and local hydrology regime. Restoring and preserving the stream buffer's vegetation would involve enforcement of the City's designated stream buffer widths. As with item #14 (culvert sizing to control erosion), the maximum phosphorus loading benefit from this activity could be expected only if this is applied consistently over the entire watershed. Available for farming land, but limited data available for urban areas. See notes for item #14. Excerpt from literature: "Although buffer zone vegetation reduces erosion, it is not considered effective for the removal of phosphorus over the long term because phosphorus retained by plants in the spring and summer is released with plant senescence in the fall. Therefore, lakeside residents have been asked to circumvent this natural recycling by collecting beach debris and cutting, harvesting, and removing excess buffer zone vegetation two to three times per year as suggested by Dillaha et al. _1986_. Measurements indicate that typical shoreline debris material has a water content of about 75% and contains about 0.25% phosphorus by dry weight. Therefore, a total phosphorus loading reduction of about 70 kg/year could be attained if each lakeside property owner removed 225 kg of vegetative litter and beach debris _wet weight_ from their property per year." (Canale, RP; Redder, T; Swiecki; W, Whelan, G. Phosphorus Budget and Remediation Plan for Big Platte Lake, Michigan. *Journal of Water Resources Planning and Management.* 2010, 136 (5), 576-586). Cost: Cost would be equal to the total cost of planning, design, construction and planting, and maintenance until the site is self-sufficient, based on research results (reference in the region).
17	**Regulations: Phosphorus fertilizer ban**	lb/acre/year	0.5	$0	--	A number of articles review general lawn phosphorus contribution but none of them identify numeric contributions. Vadas (2008) documents very high phosphorus losses if heavy rainfall occurs within a few days of fertilization. Lehman (2009) documents a 28% reduction in TP concentrations in a river following a ban on fertilizers. Gross (1990) and Erickson et al. (2005) measured measured phosphorus losses due to leaching caused by infiltrating rainfall from grassed areas. Both reported minimal phosphorus losses due to surface runoff because the sandy soils used in these studies had very high rates of infiltration and produced very little surface runoff. Easton (2004) also reported that the majority of phosphorus loss observed from lawn plots was due to leaching. However, his study also reported substantial surface runoff from the lawn plots and an associated phosphorus loss of 0.5-1.0 kg/ha/yr (0.5-0.9 lbs/acre/year). Unfertilized lawns can also contribute soil-bound phosphorus to surface runoff. Given the uncertainty of the contribution of soil-associated phosphorus in the Lake Whatcom Watershed and the very limited data on lawn-generated phosphorus loadings, a unit-load reduction due to the fertilizer ban cannot be reliably estimated at this time. A conservative estimate of 0.5 lbs TP/acre/yr of lawn area may be justified. Cost: assumes no cost for annual enforcement.

Exhibit 3. Lake Whatcom Phosphorus-Reduction: Cost-Benefit Analysis Detail

Activity Number	Activity	Units of Phosphorus (TP) Removal	Phosphorus Loading Removed	Cost	Cost/Benefit	Notes
18	**Education: Watershed signs**	-	-	-	-	See Exhibit 4: Education, Incentives and Enforcement Matrix.
19	**Education: Mass mailings**	-	-	-	-	
20	**Education: Online information**	-	-	-	-	
21	**Education: Newspaper ads**	-	-	-	-	
22	**Education: Video presentations**	-	-	-	-	
23	**Education: Community events (public meetings)**	-	-	-	-	
24	**Education: Onsite training/workshops**	-	-	-	-	
25	**Education: Resident contact**	-	-	-	-	
26	**Education: Project consultation**	-	-	-	-	
27	**Incentives**	-	-	-	-	
28	**Transition from Department of Ecology Water Quality Assurances of Forest Practices to 'Pristine', pre-development conditions**	lb/acre/year	0.10	$200,000 (Administrative only, no capital)	For the first year, 2,480 lbs reduction for $200,000 is $80.65/lb	Phosphorus reduction is equal to the difference between loading from pristine forested land and forested land that meets forest practice conditions. Forest loading is 0.15 lbs/acre/year (see item #1). 'Pristine' forest loading assumed to be 0.05 lbs/acre/year, so the benefit is 0.15-0.05 = 0.10 lbs/acre/yr. At base (2003) conditions, 88% of 31,183.9 acre watershed is in wetland or forest cover, so the total (watershed-wide) net benefit is 2,480 lbs. (note: TP removal stated as lb/acre/year applies only to acres under forest/wetland land uses). Assume 2 FTEs for 1 year, with 1 FTE per year at $100,000
29	**Design standards for new and retrofitted roads**	%	60	$1.48 per sf of treated impervious surface.	8974 lb/year P loading watershed-wide, assuming 60% removal of phosphorus; Watershed-wide implementation reduces phosphorus by 5,384 lbs and costs $1,350,000,000 at $1.48/sf, for a cost/benefit for the first year only of approximately $371,171/lb	Narrower roads constructed under new design standards would produce less runoff than conventional road widths, but it is not clear that reduced runoff would result in reduced TP loads. Use of pervious pavement for new and retrofitted roads could reduce TP by that shown in item #9: 60% TP reduction credit (pervious pavement area, only). Pervious-paved parking lanes might achieve a similar reduction if travel lane runoff was directed across the parking lanes.
30	**Reconfigure roadside ditches**	%	20	$8 /sf of swale	8974 lb/year P loading watershed-wide, assuming 20% removal of phosphorus; Watershed-wide implementation reduces phosphorus by 1,795 lbs and costs $10,802,880,000 at $8/sf, for a cost/benefit for the first year only of approximately $6,000,000/lb	Most roadside ditches could likely be reconstructed into biofiltration swales. This could reduce TP by that shown in item #3 (Biofiltration Swales): 20% TP reduction credit. Cost: see item #3 (Biofiltration Swales). Cost assumed similar

Exhibit 3. Lake Whatcom Phosphorus-Reduction: Cost-Benefit Analysis Detail

Activity Number	Activity	Units of Phosphorus (TP) Removal	Phosphorus Loading Removed	Cost	Cost/Benefit	Notes
31	**Reconfigure streets**	%	20-40	$10/sf of street	8974 lb/year P loading watershed-wide, assuming 30% removal of phosphorus; Watershed-wide implementation reduces phosphorus by 2,692 lbs and costs $12,801,000,000 at $9.48/sf, for a cost/benefit for the first year only of approximately $4,755,000/lb	This approach would result in narrow paved streets, on the order of 22-26 feet in width. The remainder of the street ROW would be largely devoted to bioretention for street slopes less than 3%. For streets with slopes ranging from 3-10%, biofiltration swales with check dams and other measures would be installed to enhance infiltration. The City of Seattle has more than 10 years of experience with this approach through its nationally-known SEA Streets Project and subsequent street edge projects (Seattle Public Utilities 2011). The enhanced biofiltration swales on the moderately-sloped streets could be expected to readily achieve the phosphorus reduction identified under Reduction Measure #3: Biofiltration Swales – 20%. The bioretention areas installed along the gently sloped streets would likely experience relatively higher runoffs than the typical bioretention facilities discussed under Reduction Measure #4: Bioretention. Therefore the assigned TP reduction credit is reduced from 50% to 40% for street bioretention. Prior to installing bioretention areas in a public ROW, it is important that the infiltration rates and water table conditions of the local subsoils be documented. Otherwise seasonally high water table levels could result in undesirable ponding or local seepage onto adjacent properties. Cost: equal to the sum of the costs of items #3 and #29
32	**Vehicle trips - reduce and redirect**	n/a	Minimal direct benefit	--	--	Vehicle trip reduction via increased transit and bike. Vehicles by themselves are not expected to contribute a substantial amount of phosphorus loading to runoff. Therefore, this item will be characterized in the main text rather than quantified.
33	**Recreational facility design and use (Improving existing facilities)**	lb/acre/year	Minimal direct benefit	--	--	Assumes there would be a net phosphorus decrease from reduction of shoreline erosion and elimination of fertilizer. However, no numeric estimate is made of phosphorus reduction or avoidance for this reduction measure. Of the four recreational facilities with Lake Whatcom shoreline, Bloedel-Donovan Park has the most developed land area and supports the most intensive shoreline recreation. The remaining three parks have limited road and trail access to the lake shore but no shoreline development, are mostly forested, and could be expected to contribute minimal TP loading. See Item #33 – Figure 1.
34	**Watershed-wide enforcement**	-	-	-	-	See Exhibit 4: Education, Incentives and Enforcement Matrix.
35	**Animal waste: wildlife (goose)**	lb/goose/year	0.25	--	--	Unit estimates of TP production (lb TP/goose/year): Sherer et al. (1995): 1.2 Manny (1975): 0.35 Kear (1963): 1.4 The middle value of 1.2 lb TP/goose/year is assigned. For resident goose, the majority of the food eaten by a goose is likely to come directly from the watershed. Therefore the net new phosphorus produced by a goose is assumed to be 20%. Thus the TP contribution of is assumed to be 0.2 x 1.2 = 0.25 lb TP/goose/year. No estimate of the Lake Whatcom goose population has been found. Cost: an order-of-magnitude estimate may be available by researching other jurisdictions with goose control programs (or restoration sites and treatment wetland facilities with such a program). Cost estimate would be a general, annual programmatic cost.

Exhibit 3. Lake Whatcom Phosphorus-Reduction: Cost-Benefit Analysis Detail

Activity Number	Activity	Units of Phosphorus (TP) Removal	Phosphorus Loading Removed	Cost	Cost/Benefit	Notes
36	**Septic system transition to sewer connection**	lb/septic system/year	0.6	$50,000 per septic system ($50,000 x 92 septic systems = $4,600,000)	0.6 lb/septic system x 92 septic systems = 55 lb total at $4,600,000 is $83,333/lb (for the first year)	Table 12 of the Soil Conservation Service report for Whatcom County indicated that virtually all of the shoreline soils had severe limitations for septic systems. The subset of soils used for this analysis was limited to those soils that were identified as having a shallow (three feet or less) depth to seasonal bedrock, hardpan or water table, or as being subject to seasonal flooding. These are the conditions that would promote phosphorus migration. According to a visual inspection of the known septic systems mapped in the Lake Whatcom 2008 Stormwater Comprehensive Plan (CH2M HILL 2008), there are approximately 92 septic systems within 150 feet of the lake shoreline located in soils susceptible to phosphorus leaching. These were assumed to be capable of leaching TP to Lake Whatcom. Data from EPA (2002) indicate that for the typical septic systems 0.8 lb TP/person/year reaches the leach field. Assuming three persons per house, leach field phosphorus was calculated to be 3 x 0.8 = 2.4 lbs/house/year. Using a midpoint value of leaching phosphorus from Dudley and May (2007) of 25%, it is assumed that one-quarter of leach field phosphorus reaches the lake. 0.25 x 2.4 yields an estimate of 0.6 lb/year of phosphorus loading to the lake for each of the 92 identified houses. The total estimated phosphorus loading benefit from converting these homes to sewered is therefore equal to 92 septic systems x 0.6 lb/septic system/year. This loading estimate is somewhat speculative but it provides an order of magnitude of the potential lake phosphorus loading attributable to septic systems. [a] Cost (lb/septic/year): research with other jurisdictions the total administrative and capital cost to transition one SFR from septic to sewer. Cost estimate not to include annual sewer operations. [b] Cost: equal to the cost estimate in ([a]) multiplied by 92 septic systems.
		lb/year (watershed-wide)	55.2			

Notes:

[1]definitions of the terms biofiltration, bioretention, and infiltration, in the context of this study:

Infiltration: water percolates into the ground and does not re-enter the surface water flows; mechanism of phosphorus reduction is stormwater volume reduction (activities in this study: dry wells, infiltration trenches, pervious pavement, and infiltration basin (activities 7, 8, 9, and 10, respectively)

Biofiltration: Mechanism of phosphorus reduction is plant uptake of pollutants, assumes no infiltration (activities in this study: vegetated swales (activity 3))

Bioretention: Mechanisms of phosphorus reduction are both plant uptake of pollutants and some infiltration (activities in this study: rain gardens (activity 4), street trees (activity 5), and lawn replacement (activity 6))

Exhibit 4. Education, Incentives and Enforcement Matrix

		Reference																Relative Estimated Effectiveness (by Category)				
	Activity	a	a	a	b	c	d	e	f	g	h	h	i	j	k	l	Average % [1]	Pet Waste	Fertilizer	Car Washing	SW Mgmt on Private Property	Septic System Maintenance
Category	Performance Measure	% effectiveness	% would change behavior	% followed advice of	% in favor	% in favor	% noticed	% noticed	% noticed	% influenced by	% supportive of	% motivated by	% interested	% interested	% made changes to yard care habits	% very or somewhat						
EDUCATION	Watershed interpretive signs					2	4					1					2	Very Low	Very Low	Very Low	Very Low	Very Low
	Mass mailings	55		50	10	31			4	55	49	12	23	46			34	Moderate	Moderate	Moderate	Moderate	Moderate
	Online information (website)	45			13		3						8				17	Low	Low	Low	Low	Low
	Newspaper ads	56				15	33		38	46	66	36	12				38	Moderate	Moderate	Moderate	Moderate	Moderate
	Video presentations (or TV ads)	56.9	19			19	71	66	28	43		27	15		52.4		40	Moderate	Moderate	Moderate	Moderate	Moderate
	Community events (public meetings)					2	0				75	4		26			21	Low	Low	Low	Low	Low
	Resident contact (home visit)										49			18			34	Moderate	Moderate	Moderate	Moderate	Moderate
	Onsite training/workshops	39								49					23.5	35	37	n/a	Moderate	n/a	Moderate	Moderate
	Technical assistance	45									67						56	n/a	High	n/a	High	High
INCENTIVES	Convenient disposal		17														17	Low	n/a	n/a	n/a	n/a
	Store coupons										82			54			68	n/a	High	n/a	High	n/a
	Yard waste pickup													48			48	n/a	Moderate	n/a	Moderate	n/a
	Rain barrel													44			44	n/a	Moderate	n/a	Moderate	n/a
	Food waste pickup													37			37	n/a	Moderate	n/a	Moderate	n/a
	Compost bin													28			28	n/a	Low	n/a	Low	n/a
ENFORCEMENT	Watershed-wide		7								58						33	Moderate	Moderate (*Note: No literature found on effectiveness of enforcement actions on fertilizer use. 'Moderate' effectiveness based on surrogate described below.*)	Moderate	Moderate	Moderate
																		Notes for this Category: ***0.3 lb TP/dog/year;*** *A dog averages 1/3 pound of waste per day with a phosphorus content of 1% (Carrasco 2003). A dog therefore produces up to 1.2 pounds of phosphorus per year. Conservatively assume that all waste remains on the ground and that up to 25% of the phosphorus reaches the lake via surface runoff. Thus, 1.2 lb/dog/year x 25% = 0.3 lb/dog/year TP reduction benefit with pet waste elimination. An estimate of the number of dogs in the watershed could yield an estimate for the whole watershed.*	Notes for this Category: ***0.5 lb/acre/year*** *- See Table 1 'phosphorus fertilizer ban' - estimate of loading from fertilizer use. A moderate estimated effectiveness is assumed based on available literature reviewed to-date.*	Notes for this Category: *No information found in the literature on P-loading from car washes. Phosphorus may be phased out of detergents and car wash soaps. Effective enforcement is not likely to be feasible; incentives such as car wash coupons have been found somewhat popular, and are likely to be more effective than education alone because cost is a main reason cited by survey participants (Silver Beach Creek - reference j) as the reason for washing vehicles at home instead of a commercial car wash.*	Notes for this Category: ***0.62 lb/acre/year;*** *Assumes a loading rate from conventionally-developed SFRs of 1.24 lb/acre/year, and 50% TP removal from retrofits (see Table 1, Bioretention). Thus, the TP reduction benefit is equal to 0.62 lb/acre/year. Could assume that 30% of the developed area would potentially be retro-fitted to compliance with City LID standards.*	Notes for this Category: *To calculate the TP reduction benefit, need a loading rate from failing septics - not found in the literature to-date. The loading rate from properly maintained septics within 150 feet of the lake shoreline is estimated to be* ***0.6 lb/septic system/year*** *(see Table 1, Septic System Transition to Sewer).*

[1] These results are intended to be used for discussion only due to the widely varying nature and purpose of the supporting studies/references.

Reference	
a	Center for Watershed Protection. 1999. A Survey of Residential Nutrient Behavior in the Chesapeake Bay. Ellicott City, Maryland. July 1999.
b	Cascadia Consulting Group, Inc. 2009. Evaluation of Seattle Public Utilities' Public Involvement and Education Programs. Prepared for Seattle Public Utilities. Seattle, Washington. February 2009.
c	Fairbank, Maslin, Maullin & Associates. 2001. San Mateo Countywide Stormwater Pollution Prevention Program: 2001 Residential Survey. June 2001.
d	Pelegrin Research. 2004. Storm Water Public Education Program: Resident Population Telephone Survey – 2004 Evaluation and Next Steps. Prepared for [California] State Water Resources Control Board and Rogers and Associates. Los Angeles, California. October 2004.
e	Maine Department of Environmental Protection. 2005. Assessment of Maine's Stormwater Phase II & NPS Outreach Campaign: 2003/2004. February 2005.
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g	Rockwood Research, University of Minnesota Extension Service. 1999. Evaluation of Spring 1999 Stormwater Media Outreach: Think Clean Water Campaign. Twin Cities, Minnesota.
h	Riley Research Associates. 2002. Do Clean Rivers Begin at Home? Exploring the Obstacles and Motivations of Homeowner Behavior: A Survey of Public Habits in Oregon's Tualatin River Watershed. Prepared for Oregon Clean Water Services and Tualatin Basin Public Awareness Committee.
i	Gilmore Research Group. 2005. Surface Water Study [telephone survey of Bellevue, Redmond, and Shoreline residents].
j	Silver Beach Creek Outreach Program. Final Report. Accessed at: http://www.cob.org/documents/pw/lw/psp-final-report.pdf
k	Cascadia Consulting Group, Inc. and Applied Research Northwest. 2008. Yard Care and Water Quality Study: A Telephone Survey of Lake Whatcom and Samish Watershed Residents. Prepared for Whatcom County Public Works. June 2008.
l	Applied Research Northwest and Cascadia Consulting Group, Inc. 2008. Final Report: City of Bellingham Water Conservation Survey. Prepared for the City of Bellingham, Washington. January 2008.