# Tenmile Lakes Watershed
# Total Maximum Daily Load (TMDL)

**Prepared by: Oregon Department of Environmental Quality**

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DEQ

State of Oregon
**Department of Environmental Quality**

Oregon Department of Environmental Quality
Water Quality Division
811 S.W. 6th Avenue
Portland, OR 97204

This document can be accessed on the Internet at:
http://www.deq.state.or.us/wq/TMDLs/southcoast.htm

*For more information contact:*

*Pamela Blake, South Coast Basin Coordinator*
*Department of Environmental Quality*
*381 N Second*
*Coos Bay, Oregon 97420*
*blake.pam@deq.state.or.us*

*Eugene Foster, Manager of Watershed Management Section*
*Department of Environmental Quality*
*811 Southwest 6th Avenue*
*Portland, Oregon 97204*
*foster.eugene@deq.state.or.us*

*John Blanchard, Western Region Watersheds Manager*
*Department of Environmental Quality*
*221 Stewart Ave., Suite 201*
*Medford, Oregon 97501*
*blanchard.john@deq.state.or.us*

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# ACKNOWLEDGMENTS

This Total Maximum Daily Load (TMDL) document has been developed with strong links to the Tenmile Lakes Nutrient Study (TLBP, 2002a). The Tenmile Lakes Basin Partnership (TLBP) has incorporated findings from the nutrient study into a Tenmile Lakes Assessment and Action Plan (TLBP 2003). The Tenmile Lakes Nutrient Study is provided in whole as part of this document in Appendix A. With the permission of the TLBP, in many instances information was incorporated directly from both of these documents. In addition, many of the pictures contained in this document were provided by the TLBP.

The Nutrient Study was prepared by E&S Environmental Chemistry, Inc. and submitted by Joseph Eilers, the primary investigator. The study was jointly funded through Oregon Department of Environmental Quality (ODEQ) 319 grant program as well as through the Oregon Watershed Enhancement Board (OWEB) and implemented through an agreement with the City of Lakeside, fiscal agent for the TLBP. The reader is encouraged to reference the Nutrient Study frequently as it contains additional detailed information that will be helpful in understanding the context of this TMDL.

The TLBP is currently in the process of developing a voluntary Water Quality Implementation Plan (WQIP) for inclusion into their action plan. This WQIP effort will further clarify water quality issues and enhancement goals. TLBP is recognized for their proactive efforts to work with landowners in a voluntary manner to identify mutually acceptable approaches to enhance and protect water quality and beneficial uses important to the community.

The Section 314 of the Federal Water Pollution Control Act was revised by Congress in 2000 to include North and South Tenmile Lakes, among other lakes throughout the nation, as high priority for inclusion in the Demonstration Program. The Clean Lakes Demonstration Program promotes the development of cost effective technologies for the control of pollutants to preserve or enhance lake water quality while optimizing multiple lakes uses; the control of nonpoint sources of pollution which are contributing to the degradation of water quality in lakes; the evaluation of the feasibility of implementing regional consolidated pollution control strategies; the demonstration of environmentally preferred techniques for the removal and disposal of contaminated lake sediments; the development of improved methods for the removal of silt, stumps, aquatic growth, and other obstructions which impair the quality of lakes; the construction and evaluation of silt traps and other devices or equipment to prevent or abate the deposit of sediment in lakes; and the demonstration of the costs and benefits of utilizing dredged material from lakes in the reclamation of despoiled land.

This TMDL document does not seek to reinvent or replace these ongoing collaborative efforts to improve water quality in the Tenmile Lakes Watershed. Rather this TMDL seeks to strengthen the understanding of water quality linkages, and to build upon and support ongoing assessment and enhancement activities.

# STATEMENT OF PURPOSE

This TMDL document has been prepared to meet the requirements of Section 303(d) of the 1972 Federal Clean Water Act.

TMDLs are numerical loadings that are set to limit pollutant levels such that numeric and/or narrative in-stream water quality standards are met. ODEQ recognizes that TMDLs are values calculated from mathematical models and other analytical techniques designed to simulate and/or predict very complex physical, chemical and biological processes. Models and techniques are simplifications of these complex processes and, as such, are unlikely to produce an exact prediction of how streams and other water bodies will respond to the application of various management measures. It is for this reason that the TMDL has been established with a margin of safety.

Although many may question the process utilized herein to select reference water quality and landscape conditions from which to derive loading allocations, clearly improvements can be made to reduce sediment and nutrient loading in the Tenmile Lakes Watershed. The use of selected streams within Tenmile Lakes Watershed as reference for the first iteration of this TMDL sets clear and attainable load reduction targets. Because TMDLs are an iterative process, additional data should be gathered over time to refine model calibration and to adjust reference loading targets as necessary to ensure the protection of beneficial uses.

It is possible, after application of all reasonable best management practices, that this TMDL or the associated surrogates may not be able to be achieved as originally established. Technology for controlling nonpoint source pollution continues to develop. The Tenmile Lakes Watershed Water Quality Management Plan (WQMP) is designed to help guide efforts to reduce pollutant loads to meet this TMDL. ODEQ recognizes that it may take some period of time - from several years to several decades - after full implementation, before management practices identified in a WQMP become fully effective in reducing and controlling pollution. Despite the best and most sincere efforts, natural events beyond the control of humans may interfere with or delay attainment of the TMDL and/or its associated surrogates. Such events could be, but are not limited to: floods, fire, insect infestations, and drought.

Full attainment of pollutant surrogates may not be feasible at all locations due to physical, legal or other regulatory constraints. For instance, at this time, the existing location of managed wetlands may preclude attainment of system potential nutrient reductions. In the future, however, should the opportunity to implement mutually acceptable wetland enhancement activities arise, consideration should be given to designs that support TMDL load allocations and pollutant surrogates, such as re-establishing the buffering functions of historic wetlands. To the extent possible, the Implementation Plans should identify potential constraints, but should also provide the ability to mitigate those constraints should the opportunity arise.

ODEQ intends to regularly review progress of the WQMP and the associated Implementation Plans developed to achieve this TMDL. If and when ODEQ, in consultation with the management agencies, determines that either water quality standards have been met, or that the WQMP has been fully implemented and all feasible management practices have reached maximum expected effectiveness and the TMDL, its associated surrogates, or its interim targets have not been achieved, ODEQ shall reopen the TMDL and adjust it or its interim targets and its associated water quality standard(s) as necessary.

The determination that all feasible steps have been taken will be based on, but not limited to, a site-specific balance of the following criteria: naturally occurring pollutant concentrations prevent the attainment of the use; or human caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place; or hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use; or physical conditions related to the natural features of the water body preclude attainment of uses; or the cost of compliance would result in substantial and widespread economic and social impact. This process for making this determination is defined in 40 CFR 131 and further clarified in ODEQ's Draft Internal Management Directive (IMD) for Use Attainability Analysis (ODEQ, 2005).

# ACRONYMS

## Alphabetic List of Acronyms

| | |
|---|---|
| 33 USC Section 1342 | Federal Water Pollution Control Act Section 402 |
| 303(d) | Section 303(d) of the Clean Water Act |
| 401 | Clean Water Act, Section 401, Water Quality Certification |
| 404 | Clean Water Act, Section 404, Fill & Removal |
| 1200C | Storm Water Construction Site Permit |
| AWQM | Agricultural Water Quality Management |
| AWQMP | Agricultural Water Quality Management Plan |
| BMP | Best Management Practices |
| BOF | Board of Forestry |
| CAFO | Confined Animal Feeding Operations |
| CMS | Conservation Management System |
| CWA | Clean Water Act |
| DMA | Designated Management Agency |
| EFS | Elliot State Forest |
| EQC | Environmental Quality Commission |
| ESU | Evolutionary Significant Unit |
| FIP | Forestry Incentives Program |
| FPA | Forest Practices Act |
| FPAC | Forest Practices Advisory Committee |
| FPMP | Forest Practices Management Program |
| IPM | Integrated Pest Management |
| IVM | Integrated Vegetation Management |
| LA | Load Allocation |
| LAC | Local Advisory Committee |
| MOA | Memorandum of Agreement |
| MOS | Margin of Safety |
| MOU | Memorandum of Understanding |
| MS4 | Storm Water Permit |
| NEPA | National Environmental Policy Act |
| NMFS | National Marine Fisheries Services |
| NPDES | National Pollution Discharge Elimination System |
| NPS | Nonpoint Source |
| National Strategy | National Strategy for Development of Regional Nutrient Criteria |
| Nutrient Ecoregion II | Western Forested Mountains |
| OAR | Oregon Administrative Rules |
| ODA | Oregon Department of Agriculture |
| ODEQ | Oregon Department of Environmental Quality |
| ODF | Oregon Department of Forestry |
| ODFW | Oregon Department of Fish & Wildlife |
| ODOT | Oregon Department of Transportation |
| OFIC | Oregon Forest Industries Council |
| OPSW | Oregon Plan for Salmon and Watersheds |
| ORS | Oregon Revised Statutes |
| OSDS | On-Site Disposal System |
| OSU | Oregon State University |
| OWEB | Oregon Watershed Enhancement Board |
| PSU | Portland State University |
| R & E | Restoration and Enhancement Board |
| RMA | Riparian Management Area |
| RTAG | Regional Technical Assistance Group |
| SAR | Sediment Accumulation Rate |
| SB | Senate Bill |

| | |
|---|---|
| SCS | Soil Conservation Service |
| SMA | Streamside Management Area |
| SWAT | Soil and Watershed Assessment Tool |
| T & E | Threatened and Endangered |
| TEA | Transportation Equity Act |
| TMBP | Tenmile Lakes Basin Partnership |
| TMDL | Total Maximum Daily Load |
| TN | Total Nitrogen |
| TP | Total Phosphorous |
| TSS | Total Suspended Solids |
| Type D | Domestic Drinking Water Stream as per Forest Practices Act |
| Type F | Fish Bearing Stream as per Forest Practices Act |
| Type N | Non-Fish Bearing Stream as per Forest Practices Act |
| USDA | United States Department of Agriculture |
| USEPA | United States Environmental Protection Agency |
| USFWS | United States Fish & Wildlife Services |
| WHIP | Wildlife Habitat Incentive Program |
| WHO | World Health Organization |
| WLA | Wasteload Allocation |
| WPCF | Water Pollution Control Facility |
| WQL | Water Quality Limited |
| QS | Water Quality Standards |
| WQMP | Water Quality Management Plan |
| WSC | Watershed Council |
| WWF | Wet Weather Flow |
| WWTP | Waste Water Treatment Plant |

# CHAPTER 1 - EXECUTIVE SUMMARY

The following document contains the required components for a Total Maximum Daily Load (TMDL) as described by the US Environmental Protection Agency (USEPA) for compliance with the Federal Clean Water Act. The document and its appendices provide a thorough analysis of pollutant sources and processes in the Tenmile Lakes Watershed.

## *1.1 SCOPE*

The Tenmile Lakes Watershed is situated in southwestern coastal Oregon. The watershed encompasses an area of approximately 98 square miles and is located in both Coos and Douglas Counties. The watershed is comprised of a diverse landscape including several lakes, river valleys, and ocean dunes. Tenmile Creek is the singular outlet for the watershed, draining directly to the Pacific Ocean. The City of Lakeside is located on South Tenmile Lake near Tenmile Creek. The City of Lakeside is the only incorporated area in the watershed and utilizes Eel Lake as its drinking water source.

## *1.2 LISTED PARAMETERS*

Oregon Department of Environmental Quality (ODEQ) is proposing to address weed and algae limitations through TMDL development. Based upon further data review, ODEQ is proposing to remove Eel Lake from the 303(d) list for pH. There are currently three discrete 303(d) listed “segments” including Tenmile Lake (referred to as South Tenmile Lake within this document), North Tenmile Lake, and Eel Lake. While multi parameter water quality data is somewhat limited for these water bodies, approaches identified in this TMDL assessment and Water Quality Management Plan will support integrated and adaptive water quality improvement efforts. These approaches are designed to address water quality as a whole and should yield multi-parameter water quality improvements beyond the 303(d) listed parameters of weeds and algae. Although the focus of this TMDL is upon lake water quality, stream and upland water quality and landscape assessments are the starting points for improving lake water quality.

**Table 1 – 303(d) Listings for the Tenmile Lakes Watershed Water Quality Limited Segments** (ODEQ, 2002a)

| Waterbody Name | River Mile | Parameter | Season | List Date | Listing Status |
|---|---|---|---|---|---|
| North Tenmile Lake | | Aquatic Weeds Algae | Undefined | 1998 | 303(d) List |
| Tenmile Lake | | Aquatic Weeds Algae | Undefined | 1998 | 303(d) List |
| Eel Lake | | pH | Summer | 1998 | 303(d) List |
| Benson Creek | 0 to 8.2 | Habitat Modification | Undefined | 2002 | |
| Big Creek | 0 to 8.4 | Habitat Modification | Undefined | 2002 | Water Quality Limited Not Needing a TMDL |
| Johnson Creek | 0 to 9.3 | Habitat Modification | Undefined | 2002 | |

Habitat conditions do affect beneficial uses. Although habitat modifications were identified on the 303(d) list, they are not the direct result of a pollutant. Because a pollutant is not the cause, the concept of establishing loading capacity and allocations do not apply to habitat modification. This is not meant to minimize the close relationship aquatic habitat condition and good water quality share.

## ***1.3 TMDL SUMMARY***

Excess nutrients entering a water body can have a variety of detrimental effects on designated beneficial uses. These impacts can affect drinking water supplies, recreational uses, and aquatic life and fishery uses. Important measures for preventing excessive weed and algal growth will involve reducing nutrient inputs to the lakes.

In recent years, testing conducted in Both North and South Tenmile Lakes has revealed concentrations of microcystin, a toxin produced by algae, in the lake. Algae and toxin levels have triggered five health advisories since 1997 related to lake water consumption (drinking water) and/or recreational contact with lake waters. These advisories often remain in effect for several months in the summer and early fall. Although caution should always be exercised by lakeshore owners who are using lake water for drinking water, the presence of toxins in the Tenmile Lakes adds further complexity to drinking water treatment. Recreational contact advisories triggered by elevated toxin levels in lake water have had adverse impacts on local economics related both to property values and tourism.

In addition, the water quality of the lakes has been adversely affected by the presence of excessive aquatic plant growth, especially non-native plants. Although, the Tenmile Lakes contain a diverse plant community, Brazilian elodea (*Egeria densa*), an invasive species, has become the dominant macrophyte or rooted plant. The problem is severe in many areas during the summer and occasionally prohibits boat traffic and mail delivery in the arms of the lake due to the density of plant material. Excessive plant growth in a eutrophic water body can affect recreational water uses by interfering with swimming, boating, and fishing activities, and impair aesthetic uses of the water body. It can also adversely impact fish habitat and plant material can become a nutrient sink, serving to both store and utilize nutrients from the lake bottom. In the case of the Tenmile Lakes, this invasive weed species is primarily responding to increases in lake sedimentation. This sedimentation is increasing the area within the lakes where water depth supports the rooting plant community. Brazilian elodea is most abundant at depths less than 16 ft where conditions favoring the photosynthetic and rooting processes support weed growth.

**Macrophytes- Brazilian Elodea (*Egeria densa)***

Although these examples illustrate direct impacts associated with excessive nutrient loadings, waters more often are listed as impaired by nutrients because of their role in accelerating eutrophication. Eutrophication, or the nutrient enrichment of aquatic systems, is a natural aging process of a water body that transforms a lake into a swamp and ultimately into a field or forest. This aging process can accelerate with excessive nutrient inputs. Increases in the rate of sediment deposition have been observed by homeowners located near the mouths of tributaries where accelerated delta building is occurring and has been documented through the evaluation of sediment cores taken from the lake bottom which reflected elevated sediment accrual rates (SAR).

A eutrophic system typically contains an undesirable abundance of plant growth, particularly weeds and algae. Phytoplanktons (algae) are photosynthetic microscopic organisms which exist as individual cells or grouped together as clumps or filamentous mats in the water. Periphyton are a group of organisms that grow on underwater surfaces and include algae, bacteria, yeasts, molds, and other colony forming organisms. The term macrophyte refers to any larger than microscopic plant life in aquatic systems. Macrophytes may be vascular plants rooted in the sediment, such as pond weeds, cattails, and Elodea or free-floating plant life, such as duckweed or coontail.

The nutrient loading indicators discussed in this document have been selected because of their direct relationship to impaired beneficial uses in this watershed. These indicators have important connections to water quality and can be quantified and measured.

**Table 2 - Selected Indicators of Nutrient Loading and Lake Eutrophication**

| Parameter | Waterbody | TMDL Context |
|---|---|---|
| Total Suspended Solids | Lake tributaries (event driven) | Sediment load allocation |
| Sediment accrual rates | Lake sedimentation (lake bottom cores, deltas at the mouths of tributaries) | Target - use as a long term measurement of decreased sedimentation rates. |
| Total phosphorus | Lake water column | Target – used as an interim goal to track water quality improvements |
| Weed management | Weed mapping and the implementation of control measures | Target – used to track status of invasive weeds and physical control efforts |

Because water quality factors that affect weed and algal growth are interrelated, the measures referenced above rely on reducing sediment (phosphorus) delivery to the Tenmile Lakes. Achieving these reductions will require a landscape based approach beginning with reductions in upland sediment delivery, stream bank erosion, and lakefront erosion. Restoring the hydrological connection of wetlands to filter and store sediment prior to entering the lake has also proven to be an effective sediment buffering mechanism. Healthy riparian vegetation is an important component to provide nutrient filtering and uptake, channel stability and shade, and to reduce heat loads.

Under normal conditions, phosphorus is scarce in the aquatic environment. Unlike nitrogen, phosphorus does not exist as a gas and therefore does not have gas-phase atmospheric inputs to aquatic systems. Rocks and natural phosphate deposits are the main reservoirs of natural phosphorus. Release of these deposits occurs through weathering, leaching, and erosion. Some phosphorus is inevitably transported to aquatic systems by water or wind. Human activities have resulted in the increased loading of phosphorus into the Tenmile Lakes. Excess available phosphorus in freshwater systems can result in an imbalance of the natural cycling processes leading to accelerated plant and algae growth if other potentially limiting factors are available.

Phosphorus, because of its tendency to attach to soil particles and organic matter, is primarily transported in surface runoff with eroded sediments. Phosphorus attached to sediments in the water column and on the lake bottom is less readily available than the dissolved form of phosphorus. In lakes and reservoirs, continuous accumulation of sediment can leave some phosphorus too deep within the substrate to be reintroduced to the water column. However, a portion of the phosphorus stored in lake bottom sediments is available to be reintroduced to the water column. Because of this phenomenon, a reduction in phosphorus loading might not effectively reduce algal blooms for many years.

## *1.4 CLEAN WATER ACT SECTION 303(D)*

The quality of Oregon's streams, lakes, estuaries and groundwater is monitored by the ODEQ and other entities. This information is used to determine whether water quality standards are being violated and, consequently, whether the *beneficial uses* of the waters are *impaired*.

Under Section 303(d) of the Clean Water Act, USEPA or its state delegates are required to develop a list of the surface waters in each state that do not meet water quality standards. These standards are developed by each of the states to protect designates "beneficial uses" and must be approved by USEPA. The resulting "303(d) list" is based on the best available data and, in most cases, must be revised every two years (ODEQ, 2002a).

Water bodies that are listed as impaired must have TMDLs developed for each pollutant (with a few exceptions, such as in cases where violations are due to natural causes the listing is not due to a pollutant, or other controls will be effective at assuring support of beneficial uses). TMDLs are written plans with analyses that determine the total amount of a pollutant (from all sources) that can be present in a specific water body and still meet water quality standards.

<table>
<tr><th colspan="2">Table 3 - Tenmile Lakes Watershed TMDL – Summary of Required Elements</th></tr>
<tr><td colspan="2">State: Oregon<br>Waterbody Name(s): All intermittent and perennial streams within the 5th field HUC (hydrologic unit code) 1710030111– Tenmile Lakes Watershed, mouth to headwaters.<br><br>Nonpoint Source Only TMDL Date: February 2006</td></tr>
<tr><th>Component</th><th>Comments</th></tr>
<tr><td>Pollutant Identification</td><td>Pollutant: Sedimentation expressed as metric tones per hectare (t/ha). Sediment is a primary mechanism of phosphorus transport to the lake.<br><br>Anthropogenic Contribution: Sedimentation analysis identifies management related increases in sediment and sediment related phosphorus inputs as compared to reference conditions.</td></tr>
<tr><td>Target Identification<br><br>CWA 303(d)(1)<br>40 CFR 130.2(f)</td><td>Applicable Water Quality Standards<br>Weeds and Algae Narrative Criterion:<br>OAR 340-41-0007 (11) The development of fungi or other growths having a deleterious effect on stream bottoms, fish or other aquatic life, or which are injurious to health, recreation, or industry shall not be allowed.<br><br>Sediment (OAR 340-041-0285 (2)(J)) The formation of appreciable bottom or sludge deposits or the formation of any organic or inorganic deposits deleterious to fish or other aquatic life or injurious to public health, recreation, or industry shall not be allowed.</td></tr>
<tr><td>Existing Sources<br>(Timber, agricultural, urban, residential)<br><br>CWA 303(d)(1)</td><td>Anthropogenic sources of sediment:<br>• Surface erosion resulting from ground disturbing activities from all land uses throughout the watershed<br>• Increased mass wasting<br>• Hydromodified streams accelerating peak flows and sediment delivery<br>• Low gradient stream bank instability and erosion<br>• Urban storm water runoff<br>• Lakefront residential activities (construction, lawns, lakefront vegetation removal, lakefront erosion, on-site waste treatment, etc)</td></tr>
<tr><td>Seasonal Variation<br><br>CWA 303(d)(1)</td><td>The sediment load allocation is stated as an annual input and is applied year around.<br><br>Sediment inputs are highly dependent on the quantity and intensity of precipitation. Winter is the time of maximum watershed sediment input and movement.<br><br>Other sources of nutrients, like those from lakefront activities may be at their maximum in the summer months.</td></tr>
</table>

| Table 3 continued - Tenmile Lakes Watershed TMDL – Summary of Elements | |
|---|---|
| **TMDL Allocations**<br><br>40 CFR 130.2(g)<br><br>40 CFR 130.2(h) | *<u>Loading Capacity:</u>* *****See Appendix C for daily loading discussion System potential conditions are expressed as a reference condition sediment loading target *(*metric tones = t) for fourteen watershed catchments (Refer to Table 44).<br>• 0.07 t/ha (18 t/mile$^2$) of sediment per year for eleven mixed use watershed catchments<br>• 1.35-3.38 t/ha (46-59 t/mile$^2$) of sediment per year for 3 urban/residential catchments<br>*<u>Wasteload Allocations:</u>* None (Refer to Table 48).<br>*<u>Load Allocations:</u>* 100% of the available reference load is allocated to natural processes (Refer to Table 46). |
| **Margin of Safety**<br><br>CWA 303(d)(1) | <u>*Explicit Margin of* Safety:</u> 10% of load allocation (Refer to table 46). Although conservative modeling assumptions were incorporated into the sediment loading assessment, pollutant loads from some watershed processes were not implicitly defined. Examples of these processes include sediment storage in the lake bottom, fishery management, and some direct lakefront activities. |
| **Numeric Targets**<br><br>Not a required element | A target of attaining a 50% reduction in annual sediment loads within the next 25 years has been incorporated (See Tables 32 and 34).<br><br>The reduction of the lake sediment accrual rate by 50% within the next 25 years is identified as a target. (See Tables 36).<br><br>A numeric target of 7.1ug/L total phosphorus year around average in lake water has been identified as a guideline to incorporate watershed phosphorus loading and phosphorus loading from in lake processes (See Table 38). |
| **WQS Attainment Analysis**<br><br>CWA 303(d)(1) | • Reduction in management-related sediment loading will result in reduced sedimentation rates and lake water phosphorus levels which will, over time, reduce nuisance algae and weeds.<br>• The watershed assessment identifies management related increases in sediment inputs as compared to reference conditions and identifies management related sediment and direct lake sediment and phosphorus inputs which can be reduced below current levels. |
| **Public Participation**<br><br>40 CFR 25<br><br>(OAR 340-42-0050) | ODEQ will establish a local advisory group or identify an existing group or forum to assist in developing a TMDL and will provide an opportunity for persons to review and comment on a draft TMDL and on proposals to revise loading capacity or allocations in a TMDL as follows: (a) ODEQ will maintain a mailing list for each TMDL. (b) ODEQ will provide notice and an opportunity for public comment on a proposed TMDL or revision to loading capacity or allocations in a TMDL. The public comment period will generally be 60 days.<br>(c) ODEQ will respond to public comments received during the public comment period and will prepare a written summary of responses. |

### 1.4.1 TMDL Load Capacity and Allocations

USEPA's current regulation defines loading capacity as "*the greatest amount of loading that a waterbody can receive without violating water quality standards*." (40 CFR § 130.2(f)) A loading capacity provides the reference for calculating the amount of pollutant reduction needed to bring waters into compliance with standards. The total permissible pollutant load (loading capacity) is allocated to point, nonpoint, background and future sources of pollution [40 CFR 130.2(i)]. Simply stated, *allocations* are quantified measures designed to achieve water quality standard compliance.

*Wasteload Allocations* are portions of the total load that are allotted to point sources of pollution, such as municipal wastewater treatment plants or industries. These *Wasteload Allocations* are used to establish effluent limits in discharge permits. There are currently no individual point sources discharging into Tenmile or Eel Lakes. The City of Lakeside Waste Water Treatment Plant does discharge seasonally to Tenmile Creek, below the lake outlet. No portion of the pollutant load has been allocated to point source discharge.

*Load Allocations* are portions of the *Total Maximum Daily Load* that are attributed to nonpoint sources. To address the 303(d) listed water quality parameters of pH, weeds and algae, this TMDL identifies a target of no measurable increase in annual sediment and phosphorus loading rates beyond that of reference streams.

The streams in the table below have been selected as reference streams for this TMDL effort. Phosphorus exports are low and compare well with other studies regarding phosphorous inputs from forested landscapes as well as pastured and open parks. This approach sets load reduction targets utilizing 0.07 t/ha/yr as the reference sediment loads for tributary streams and drainages to the Tenmile Lakes.

**Table 4 – "Reference Streams"**
**Streams Where Sediment Loading is at or Near Reference Condition**

| Name | Area (ha) | Reference Feature | Current Annual Sediment Loads (tones/ha) |
|---|---|---|---|
| W. Shutters | 109 | intact wetland | 0.08 |
| Adams* | 693 | *intact wetland | 0.09 |
| Central North | 678 | 23% lake surface area | 0.07 |
| Lindros | 426 | low stream development | 0.05 |
| Murphy | 713 | intact wetland | 0.07 |
| Templeton | 231 | 22% lake surface area | 0.08 |
| | **2850 Total** | | **0.07 Weighted Average** |

* It should be noted that the Adams Creek stream channel has recently been channelized (managed) in a very traditional manner and wetland function has been diminished.

ODEQ intends to regularly review progress of the WQMP and the associated Implementation Plans developed to achieve this TMDL. If and when ODEQ, in consultation with the management agencies, determines that either water quality standards have been met, or that the WQMP has been fully implemented and all feasible management practices have reached maximum expected effectiveness and the TMDL, its associated surrogates, or its interim targets have not been achieved, ODEQ shall reopen the TMDL and adjust it or its interim targets and its associated water quality standard(s) as necessary. Although many may question the process utilized herein to select reference water quality and landscape conditions from which to derive loading allocations, clearly improvements can be made to reduce sediment and nutrient loading in the Tenmile Lakes Watershed. The use of selected stream within Tenmile Lakes Watershed as reference for the first iteration of this TMDL sets clear and attainable load +reduction targets. Because TMDLs are an iterative process, additional data should be gathered over time to refine model calibration and to adjust reference loading targets as necessary to ensure the protection of beneficial uses.

A target of attaining a 50% reduction in annual sediment loads within the next 25 years has been incorporated. The target of 25 years was selected by the local advisory group as a timeframe wherein significant sediment abatement activities could occur and allow for a positive response of in lake processes (e.g. stored sediment), and improvements in lake water quality might be realized. The advisory group felt that the 50% reduction target represent significantly less lake sedimentation and sets a clear attainable goal for land managers. It is not intended to limit sediment reductions should the opportunity to reduce loading beyond 50% occur.

**Table 5 – Load Allocations and Reduction Targets**

| Name | Area (ha) | Current Annual Sediment Loads (t/ha) | ***Tenmile Lakes Watershed Reference Streams vs. Current*** Potential Annual Sediment Load Reduction (t/ha) | ***Target 50% Reduction Within 25 Years***Target Annual Sediment Load Reduction (t/ha) |
|---|---|---|---|---|
| Devore | 116 | 0.15 | 0.08 | **0.08** |
| S. Shutters | 644 | 1.06 | 0.99 | **0.53** |
| Johnson | 4473 | 0.28 | 0.21 | **0.14** |
| Benson | 2411 | 0.26 | 0.19 | **0.13** |
| Wilkins | 478 | 0.18 | 0.11 | **0.09** |
| Big | 3412 | 0.36 | 0.29 | **0.18** |
| Rex | 218 | 0.85 | 0.78 | **0.43** |
| E. Shutters | 105 | 0.44 | 0.37 | **0.22** |
| Upper North | 751 | 0.12 | 0.05 | **0.06** |
| Black | 819 | 0.26 | 0.19 | **0.13** |
| Coleman | 343 | 0.13 | 0.06 | **0.07** |
| Total | 13,770 | 4.09 | 3.32 | 2.06 |

These watersheds support mixed use land management activities including agriculture, timber, residential, transportation, and lakefront development. Because these land uses are truly mixed, in close proximity, and/or overlapping between multiple uses no specific load allocations have been identified by land use.

The watershed catchments in the table below are positioned immediately adjacent to SouthTenmile Lake in and near the City of Lakeside. These drainages contribute a disproportionately greater amount of TSS to the lake even under the pre development predictive modeling scenario. These areas did not historically have wetlands to the extent of other catchments in the watershed and have been assigned load allocations and targets based upon loading estimates under historical conditions.

**Table 6 – Load Allocations and Reduction Targets**

| Name | Area (ha) | Current Annual Loads Sediment (t/ha) | ***Pre Development vs. Current***<br>Potential Annual Sediment Load Reduction (t/ha) | ***Target 50% Reduction Within 25 Years***<br>Target Annual Sediment Load Reduction (t/ha) |
|---|---|---|---|---|
| Lakeside | 792 | 2.35 | 2.12 | **1.18** |
| W. North | 357 | 3.38 | 3.16 | **1.69** |
| Central South | 553 | 1.35 | 1.17 | **0.68** |
| Total | 1,702 | 7.08 | 6.45 | 3.55 |

*Pollutant Allocations* can also be set aside in reserve for future uses. This TMDL does not allocate a specific reserve capacity at this time but does acknowledge that water quality standards applicable to continuing land development activities do not require zero water quality pollutant contributions. Land development activities must be conducted in a manner consistent with management practices identified in water quality implementation plans as they become available or in required National Pollution Discharge Elimination System (NPDES) permits. NPDES permits and emerging implementation plans are required to be sufficiently rigorous so as to achieve water quality standards and criteria defined in OAR 340-40.

Nutrient limits will be incorporated into any future individual NPDES permits. These limits will also be sufficiently rigorous so as to achieve water quality standards for chlorophyll a and algae and should be derived in the context of the water column phosphorus target defined within this TMDL.

# CHAPTER 2 - BACKGROUND AND INTRODUCTION

This document seeks to clearly address the elements required by USEPA for a Total Maximum Daily Load (TMDL). The TMDL and its associated Water Quality Management Plan (WQMP) were prepared by the ODEQ with assistance from a diverse group of local partners.

## 2.1 OREGON'S TMDL PROGRAM (GENERALLY DEFINED)

The quality of Oregon's streams, lakes, estuaries, and groundwater is monitored by ODEQ and a variety of partners. This information is used to determine whether water quality standards are being violated and whether the beneficial uses of the waters are being threatened. Specific State and Federal plans and regulations are used to determine if violations have occurred: these regulations include the Federal Clean Water Act of 1972 and its amendments (40 Codified Federal Regulations 131), Oregon's Administrative Rules (OAR Chapter 340**)** and Oregon's Revised Statutes (ORS Chapter 468).

The term *water quality limited* is applied to streams and lakes where best management practices as well as required treatment processes are being used, but violations of state water quality standards still occur. With a few exceptions, such as in cases where violations are due to natural causes, the State must establish a TMDL for any water body designated as water quality limited. A TMDL is the maximum amount of a pollutant (from all sources) that can enter a specific water body without causing a violation of water quality standards.

The term TMDL as defined in OAR 340-41-0002 (59) "Total Maximum Daily Load (TMDL)" means the sum of the individual waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint and background sources. The total permissible pollutant load is allocated to point, nonpoint, background, future sources of pollution and a margin of safety. Wasteload allocations are portions of the total pollutant load that are allotted to point sources of pollution, such as sewage treatment plants or industries and are used to establish effluent limits in discharge permits. Load allocations are portions of the TMDL that are attributed to either natural background sources, such as natural runoff, or from nonpoint sources, such as roads, agriculture, rural residential, urban, or forestry activities. Allocations can also be set aside in reserve for future uses.

TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure. If Best Management Practices (BMPs) or other nonpoint source pollution controls make more stringent load allocations practicable, then wasteload allocations can be made less stringent. Thus, the TMDL process provides for nonpoint source control tradeoffs.

The Clean Water Act requires that each TMDL be established with a margin of safety (MOS). This requirement is intended to account for uncertainties in the available data or in the effectiveness of control actions. The margin of safety may be implicit, as in conservative assumptions used in calculating the loading capacity, wasteload allocations, and loading allocations. The margin of safety may also be explicitly stated as an added separate allocation in the TMDL calculation. The margin of safety is not meant to compensate for a failure to consider known sources. Implicit margins of safety were developed for sediment loading and phosphorus water column target levels in this TMDL.

## ***2.2 REQUIRED ELEMENTS***

**A TMDL is required to include the following elements per OAR 340-42-0040 (4):**

(a) Name and location. This element describes the geographic area for which the TMDL is developed and includes maps as appropriate.

(b) Pollutant identification. This element identifies the pollutants causing impairment of water quality that are addressed in the TMDL.

(c) Water quality standards and beneficial uses. This element identifies the beneficial uses in the basin and the relevant water quality standards, including specific basin standards established in OAR 340-041-0202 through 340-041-0975. The beneficial use that is most sensitive to impairment by the pollutant or pollutants addressed in the TMDL will be specified.

(d) Loading capacity. This element specifies the amount of a pollutant or pollutants that a water body can receive and still meet water quality standards. The TMDL will be set at a level to ensure that loading capacity is not exceeded. Flow assumptions used in the TMDL will be specified.

(e) Excess load. This element evaluates, to the extent existing data allow, the difference between the actual pollutant load in a water body and the loading capacity of that water body.

(f) Sources or source categories. This element identifies the pollutant sources and estimates, to the extent existing data allow, the amount of actual pollutant loading from these sources. The TMDL will establish wasteload allocations and load allocations for these sources. ODEQ will use available information and analyses to identify and document sources.

(g) Wasteload allocations. This element determines the portions of the receiving water's loading capacity that are allocated to existing point sources of pollution, including all point source discharges regulated under the **Federal Water Pollution Control Act Section 402 (33 USC Section 1342)**.

(h) Load allocations. This element determines the portions of the receiving water's loading capacity that are allocated to existing nonpoint sources of pollution or to background sources. Load allocations are best estimates of loading, and may range from reasonably accurate estimates to gross allotments depending on the availability of data and appropriate techniques for predicting loading. Whenever reasonably feasible, natural background and anthropogenic nonpoint source loads will be distinguished from each other.

(i) Margin of safety. This element accounts for uncertainty related to the TMDL and, where feasible, quantifies uncertainties associated with estimating pollutant loads, modeling water quality and monitoring water quality. The TMDL will explain how the margin of safety was derived and incorporated into the TMDL.

(j) Seasonal variation. This element accounts for seasonal variation and critical conditions in stream flow, sensitive beneficial uses, pollutant loading and water quality parameters so that water quality standards will be attained and maintained during all seasons of the year.

(k) Reserve capacity. This element is an allocation for increases in pollutant loads from future growth and new or expanded sources. The TMDL may allocate no reserve capacity and explain that decision.

(l) Water quality management plan (WQMP). This element provides the framework of management strategies to attain and maintain water quality standards. The framework is designed to work in conjunction with detailed plans and analyses provided in sector-specific or source-specific implementation plans.

**OAR 340-42-0040 (5) describes the process for assigning pollution allocations to sources throughout the landscape.**

To determine allocations for sources identified in the TMDL, ODEQ:

(a) Will use water quality data analyses, which may include statistical analyses or mathematical models.

(b) May use surrogate measures to estimate allocations for pollutants addressed in the TMDL. ODEQ may use one or more surrogate measures for a pollutant that is difficult to measure or highly variable. A surrogate measure will be closely related to the pollutant, and may be easier to monitor and track. The TMDL will establish the correlation between the surrogate measure and pollutant.

**OAR 340-42-0040(6) describes considerations for assigning pollutant allocations to sources throughout the landscape.**

ODEQ will distribute wasteload and load allocations among identified sources and in doing so, may consider the following factors:

(a) Contributions from sources;
(b) Costs of implementing measures;
(c) Ease of implementation;
(d) Timelines for attainment of water quality standards;
(e) Environmental impacts of allocations;
(f) Unintended consequences;
(g) Reasonable assurances of implementation; and
(h) Any other relevant factor.

**OAR 340-42-0040 (7) describes a review and revision process that will accommodate and promote application of an adaptive management approach.**

Adaptive management is an important component of TMDLs. TMDLs are designed to be evaluated and adjusted as necessary through time as additional information becomes available. ODEQ intends to regularly review progress of the WQMP and the associated Implementation Plans developed to achieve this TMDL. If and when ODEQ, in consultation with the management agencies, determines that either water quality standards have been met, or that the WQMP has been fully implemented and all feasible management practices have reached maximum expected effectiveness and the TMDL, its associated surrogates, or its interim targets have not been achieved, ODEQ shall reopen the TMDL and adjust it or its interim targets and its associated water quality standard(s) as necessary. In making these revisions, ODEQ will comply with the public notice provisions in OAR 340-042-0050(2) and procedures for issuing TMDL orders in OAR 340-042-0060.

# CHAPTER 3 - WATERSHED CHARACTERIZATION

An in depth discussion of the watershed can be found in the attached Nutrient Study, Appendix A. The reader is encouraged to reference the Nutrient Study (TLBP 2002a) frequently as it contains additional detailed information that will be helpful in understanding the context of this TMDL.

The Tenmile Lakes Watershed is located on the Southern Oregon Coast and includes both North Tenmile and South Tenmile Lakes. These highly productive lakes are considered important fishery as well as recreational resources. Because of declining salmonid populations, the lakes have been the subject of fisheries related studies focusing on the possible interaction between introduced exotic fish species and native salmonid populations. Because of the complex nature of the food webs now in existence in the lakes, management options and control are limited. Attempts to manipulate the system by manipulating a single species can have negative or reverse effects to those intended. (Griffiths and Yeoman, 1941; Schwartz, 1977; Abrams et al., 1991; Dambacher et al.; 1999).

North and South Tenmile Lakes are important recreational resources and serve as a primary drinking water supply for many lakeshore residents. Drinking water quality is limited by high populations of the cyanobacteria, Microcystis aeroginosa, and, for the first time in 1997, a health advisory was issued warning residents of the presence of algal toxins in improperly treated drinking water (Kann and Gilroy, 1998). A review of a statewide assessment of lakes (Johnson et al., 1985) resulted in the identification of both North and South Tenmile Lakes and Eel Lake on the Oregon 303(d) list of impaired surface waters.

**<u>Water quality problems in the Tenmile Lakes include:</u>**

1.) the presence of weeds (macrophytes) at densities that impair multiple recreational beneficial uses
2.) toxic and nuisance algal blooms impairing recreational, aesthetics, and drinking water beneficial uses

**<u>Fishery issues in the Tenmile Lakes include:</u>**

1.) a major reduction in the historical anadromous fisheries populations (Abrams et al., 1991)
2.) the presence of exotic fish species (Abrams et al., 1991)

**<u>Related issues in the Tenmile Lakes include:</u>**

1.) sediment accumulation at the mouths of streams (based on historical aerial photographs) resulting in significant changes in lake bathymetry
2.) increased sediment accrual rates for the lake as a whole (TLBP, 2002)

Landowners, as well as management entities, have initiated multiple actions to address these water quality concerns. The identification of this water body on the State of Oregon’s 303(d) list of impaired waters, the adverse ramifications of toxic algae blooms, declining salmonid populations, and the formation of the local watershed council in response to the Oregon Plan for Watersheds have all played important roles.

Because of the diverse nature of the problems associated with the Tenmile Lakes’ water quality, fishery, public health, and economic connections, the need to address the problems from multiple avenues is clear. It is hoped that the Nutrient Budget assessment initiated by the Tenmile Lakes Basin Partnership and this TMDL and WQMP process can provide the basis for a more comprehensive understanding of lake water quality and its connection to the watershed and serve to further guide enhancement and restoration activities.

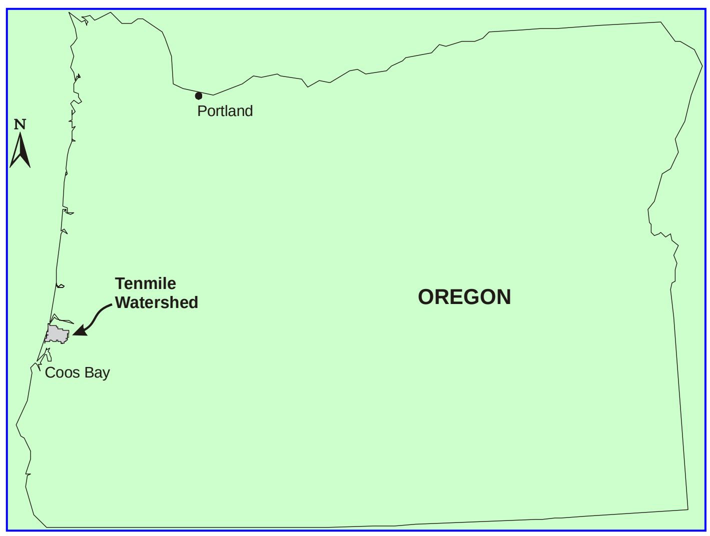
**<u>The nutrient budget assessment, the foundation of this TMDL, provided:</u>**

- An improved understanding of the inputs of nutrients to the lake from selected representative tributaries during both base flow and storm runoff conditions.
- An improved understanding of nutrient concentrations and related water quality parameters in lake waters.
- An improved understanding of lake algal community composition.
- The establishment of representative sites and the collection of sediment core samples to begin to quantify a history of sediment accumulation rates for the lakes.
- Calibration of a watershed model based upon nutrient and sediment inputs to the lake under current land use.
- Predictive modeling of nutrient loading under several landscape condition scenarios.

## *3.1 GEOGRAPHIC DESCRIPTION*

The Tenmile Lakes Watershed is situated in southwestern coastal Oregon. The watershed encompasses an area of approximately 98 square miles and is located in Coos County with a small portion of the upper watershed extending into Douglas County. The watershed is comprised of a diverse landscape including several lakes, river valleys, and ocean dunes. Tenmile Creek is the only outlet for the watershed, and this creek drains directly to the Pacific Ocean. Clear Lake and Eel Lake are both located to the northwest of the Tenmile Lakes. These lakes discharge to Tenmile Creek just west of the City of Lakeside which is located on South Tenmile Lake.

The City of Lakeside is the only incorporated area in the watershed and utilizes Eel Lake as the drinking water source. ODEQ completed a Drinking Water Source Water Assessment for Eel Lake in 2002. (ODEQ, 2002b)




Elevations in the watershed range from near sea level to about 1,800 feet at the Coast Range watershed divide. Coastal sand dunes often encroach on the mouth of Tenmile Creek, the only lake outlet in the summer months creating a condition known as “bar bound”. Surface flows are prevented by this encroachment but some sub-surface flow continues while the watershed is bar bound.

The area climate provides cool, wet winters and mild, dry summers. The annual average precipitation ranges from 79 inches in Lakeside to 97 inches in the eastern uplands of the Coastal Range. November, December, and January are historically wet months with an average of over 30” of rainfall during this period. There is occasional short term, light snow accumulation at the higher elevations. The summer months average only 4.4 inches of rain for June, July, August, and September. July is the driest month, averaging only 0.31 inches of precipitation.

The Tenmile Lakes are highly dendritic or irregular in shape. North and South Tenmile Lakes are similar in depth with average depths of 15-16 feet and maximum depths of about 27 feet. South Lake is the larger of the two lakes with a surface area of about 1,130 acres as compared to North Tenmile Lake’s surface area of 829 acres. The table that follows summarizes morphometry statistics for both North and South Tenmile Lakes with information provided both two units of measurement.

**Table 7 - Lake Morphometry Statistics for North and South Tenmile Lakes**
Based on the May 1995 GPS/SONAR survey (Source: Eilers et al. 1996a).

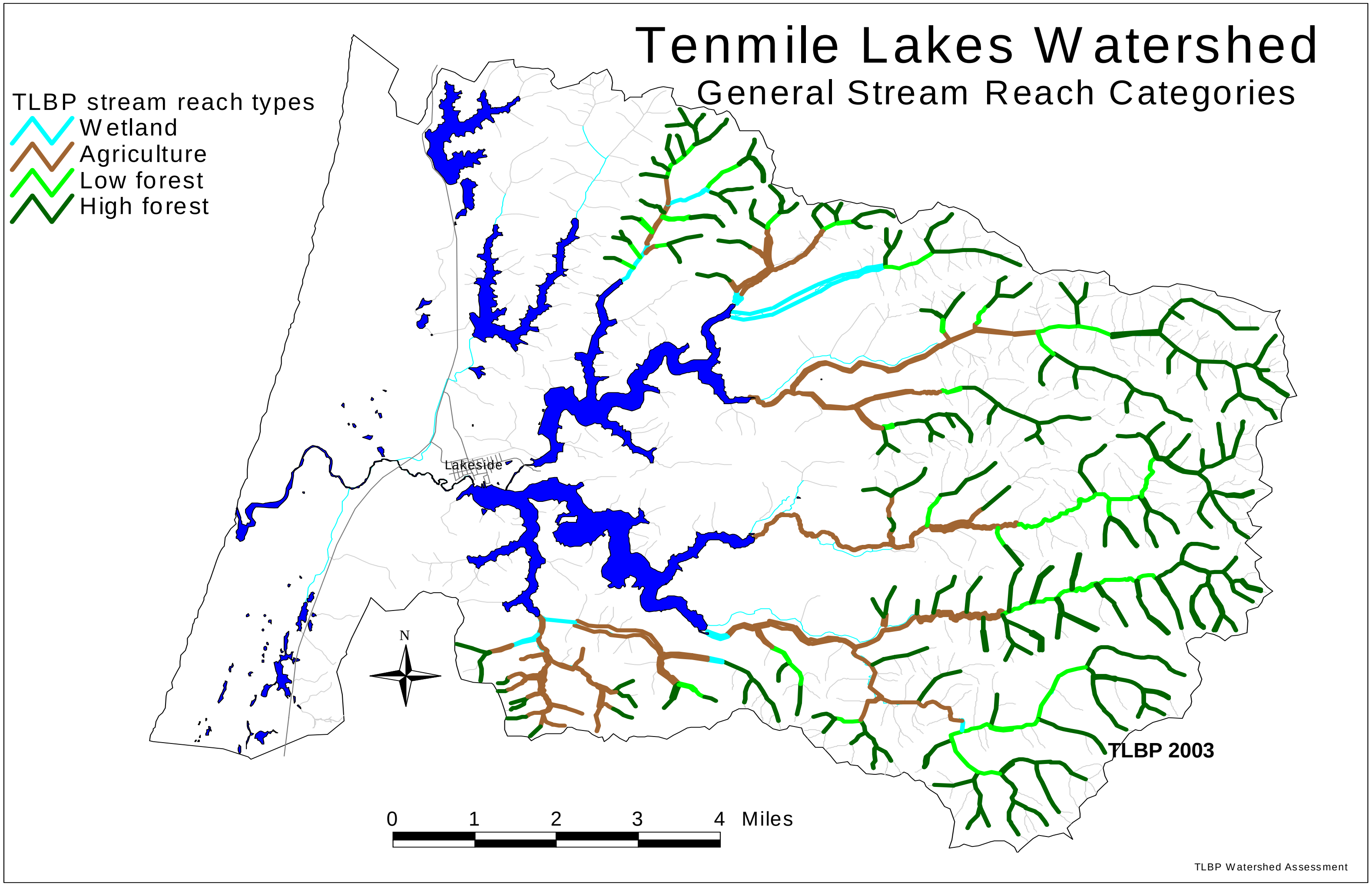
| | North Tenmile | South Tenmile | Combined |
|---|---|---|---|
| Area[a] (ha) / (acres) | 335.6 / (829.3) | 457.3 / (1,129.9) | 792.9 / (1,958.2) |
| Perimeter[b] (km) / (mi) | 31.83 / (19.78) | 37.28 / (23.17) | 69.11 / (42.95) |
| Depth,[c] maximum (m) / (ft) | 8.17 / (26.8) | 8.23 / (27.0) | - |
| Depth,[c] mean (m) / (ft) | 4.50 / (14.75) | 4.98 / (16.33) | - |

[a] Excluding an area for Willow Island. Two previous digitized versions of the lake area are within 1% of these values (J. Kelsey, pers. comm.).
[b] Includes Willow Island and the channel connecting the two lakes. Digitized from 1:24,000-scale USGS topographic map. Even considering variation associated with scales used on the source maps, actual miles of shoreline are probably within 2% of these measurements.
[c] Normalized to a lake elevation of 9.0 ft MSL

Clear Lake and Eel Lakes discharge to Tenmile Creek west of the city of Lakeside and downstream of the Tenmile Lakes' outlet. Wetland characteristics exist in the watershed just upstream from the lake interface in tributary valleys. Some of these areas are functioning as true wetlands and others are managed as agricultural wetlands. These flat, narrow, valley floors, bordered by steep forested slopes, extend up to ten miles into the watershed before the terrain abruptly changes slope as streams extend into the forested uplands. Soils present on upland steep slopes are highly erodible when disturbed or exposed.

The dominant pre-settlement vegetative types are coniferous stands predominated by Douglas fir in the uplands, mixed hardwood and coniferous stands in mid gradient areas and wetland plant communities, inclusive of woody vegetation, in the flat lowlands.

**Figure 1 – Tenmile Lakes Watershed Detail**



### 3.1.1 Land Use

The present land use in the upper watershed supports timber management in the uplands. There is a large block ownership of the Elliott State Forest (ESF) in the eastern portion of the watershed and these holdings are actively managed for timber harvest. Private land holdings to the west of the state forest and ownerships on steep slopes running laterally to valley floors are also subject to timber harvest.

Many of the valley floors, which historically supported meandering stream channels with hydrologically connected flood plains, are now managed as agricultural wetlands with channelized or simplified channels. Agricultural land is principally used for livestock grazing and hay production.

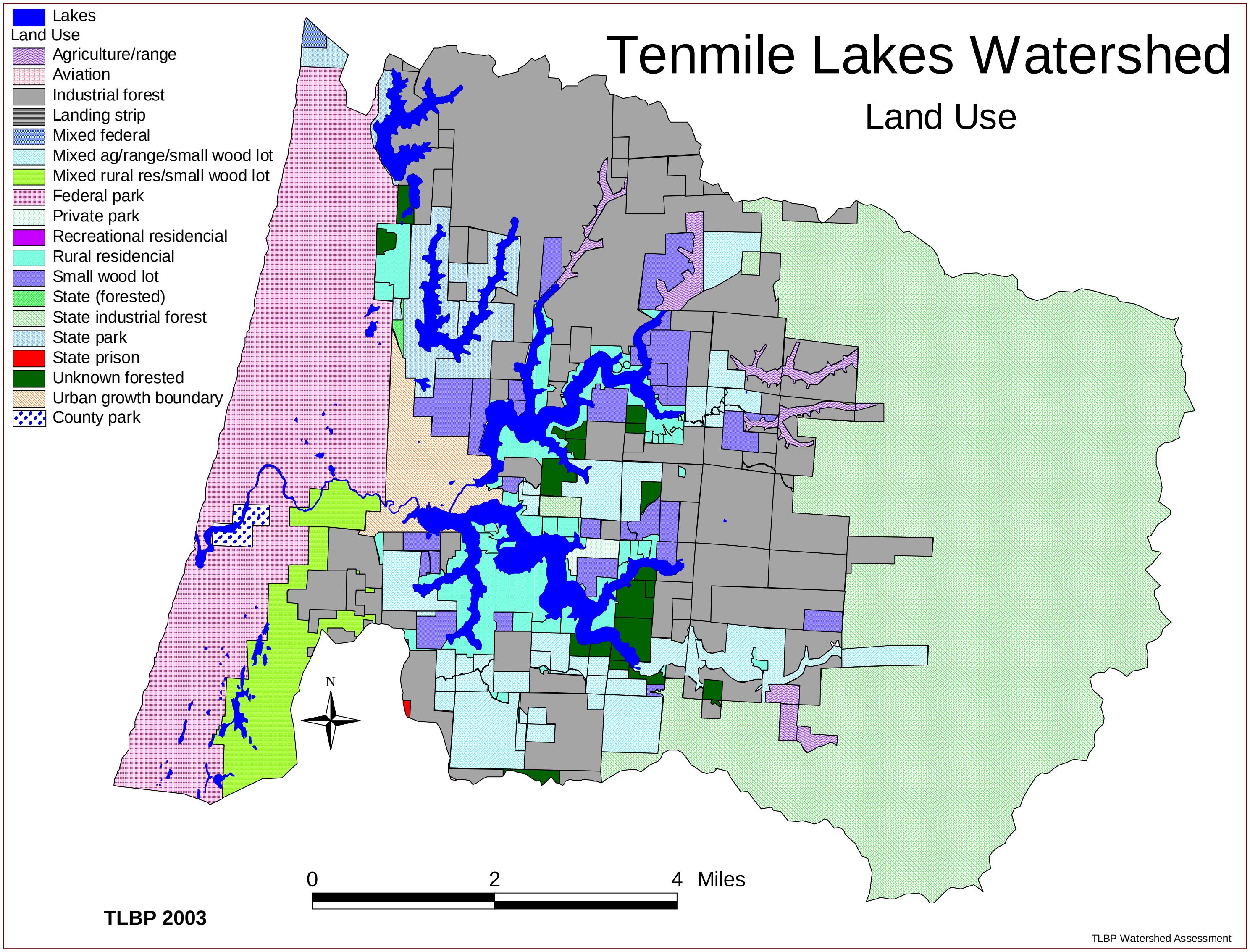
***Over 58 percent of the lands within the Tenmile Lakes Watershed support forestry related uses.***

Higher-density urban development is restricted largely to the City of Lakeside on the western shore. Lakeshore development is widespread on much of the accessible, upland portions of the shoreline. Many of these properties are developed to the lakes edge. Approximately 500 dwellings are present on the lakes, divided nearly equally between the north and south basins. Based upon the current number of lakefront lots, the lakefront is about ½ developed. The lake is used extensively for water based recreational opportunities including boating, skiing, and fishing. The lake is an important and popular aesthetic resource. The table and figure to follow summarize land use throughout the watershed.

**Table 8 - Land Use Throughout the Watershed**

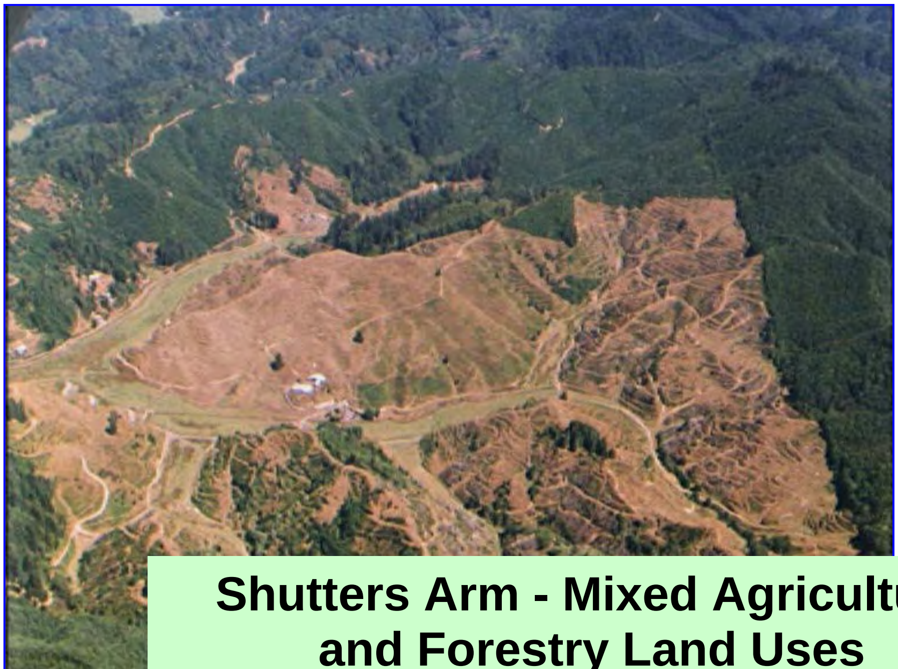
| Land Use | Acreage | % of total |
|---|---|---|
| Elliott State Forest | 21,504 | 34 |
| Oregon Dunes NRA | 8,650 | 14 |
| State Parks | 790 | 1 |
| State Lands | 672 | 1 |
| Industrial Forest | 14,837 | 24 |
| County Park | 177 | <1% |
| Rural residential, Small woodlot | 4,180 | 7 |
| Agriculture | 2,650 | 4 |
| Wetlands | 1,720 | 3 |
| Lake surface area | 2,830 | 5 |
| Urban | 1,442 | 2 |
| Total watershed acreage | 62,777 | |

**Figure 2 - Land Use Throughout the Watershed**



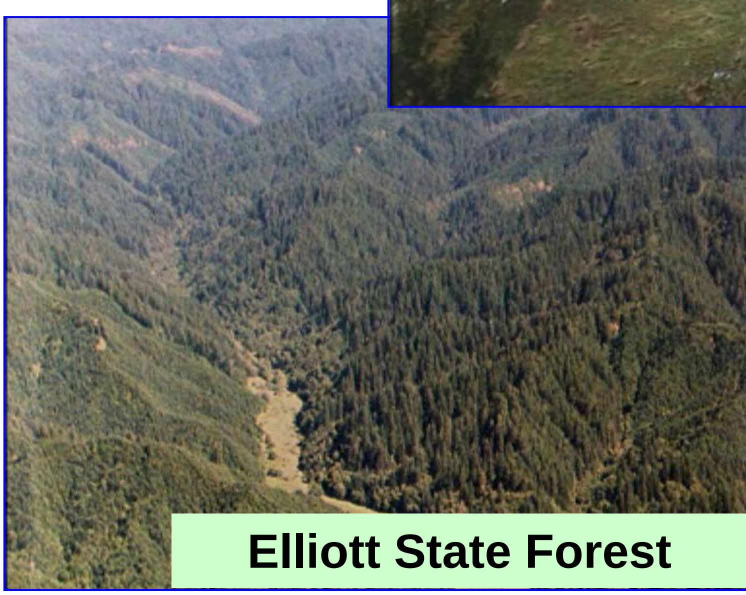

Lakefront Rural Residential
7. 10. 2000


Lakefront Rural Residential
10. 1. 2000

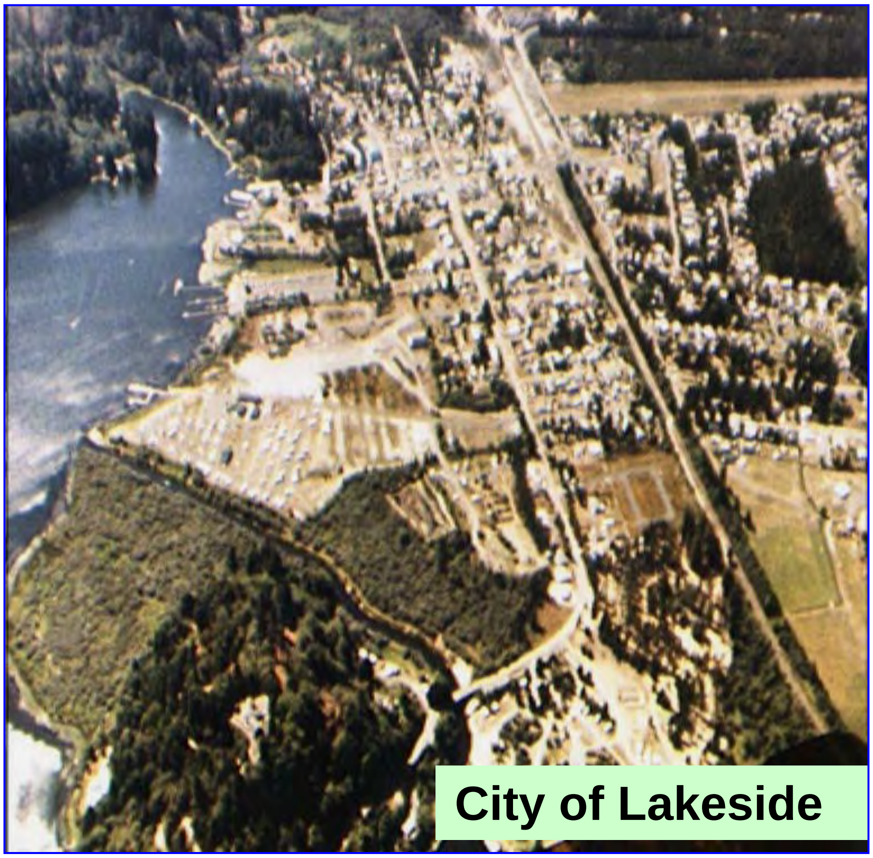


Shutters Arm - Mixed Agriculture and Forestry Land Uses

Agricultural Grazing (finger valley)



Elliott State Forest



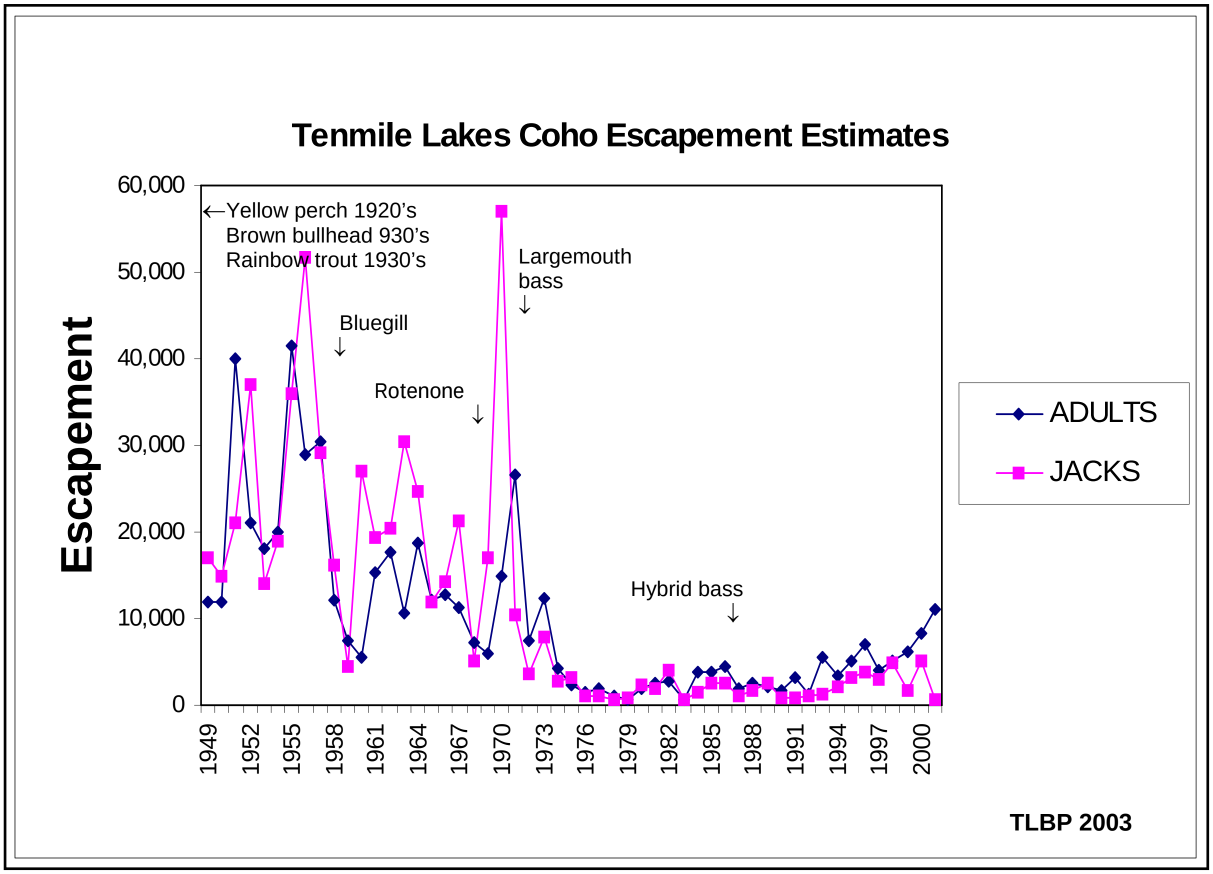

### 3.1.2 Fisheries

The watershed historically was a major producer of coho salmon, with runs of over 75,000 fish. The figure below details coho returns to the Tenmile Lakes over the last 50 years. The lake provided ideal low gradient rearing habitat for coho salmon who over summered freely with little predatory competition. The lake also had substantial runs of steelhead and sea-run cutthroat. Following the introduction of largemouth bass, the Tenmile Lakes' coho escapement had remained below 10,000 adults and jacks (Abrams et al., 1991). Coho escapement numbers increased in 2001 to 11,039 and in 2002 to 13,861 (pers. comm. Mike Gray, District Biologist). The impacts of bass predation on coho salmon populations and the benefits of various management scenarios are actively discussed. North and South Tenmile Lakes are currently are important sites for bass fishing tournaments in Oregon and balancing warm and cold water fishery interests is challenging. The table below details the fisheries history of the Tenmile Lakes.

**Table 9 - Fisheries History of the Tenmile Lakes**
(Derived from Griffiths and Yeoman [1941], Abrams et al. [1991]) and TLBP (2003).

| Species | Native or Introduced | Year Introduced | Management |
|---|---|---|---|
| Coho salmon | Native[B,C] | ----- | Population declined from >75,000 adults/year to about 4000. |
| Coho Salmon | Introduced | 1968<br>1980's | 930,000 smolts from native eggs and salvaged fry were introduced after the Lakes were treated with Rotenone. Smaller efforts in prior years. |
| Winter steelhead | Native & Hatchery | ----- | Current population estimated at 20% of 19th century levels; currently stocked. Alsea & Coos River broodstock used in the past. |
| Cutthroat trout | Native[C] | ----- | Historically abundant population; currently managed for wild stock |
| Rainbow trout | Introduced | 1930's | Currently managed as a "put and take" fishery |
| Brown bullhead | Introduced[A] | 1920's | High population was not impacted by a commercial fishery in 1952-53; not eradicated by rotenone; continued abundant population |
| Yellow perch | Introduced[A] | 1930's | Affected but not eradicated by rotenone treatment. Still present and fished for. (M. Mader) |
| Bluegill | Introduced[A] | 1960's | Currently most abundant fish in the lakes; attempt to eradicate the species in 1968 with rotenone was unsuccessful |
| ------ | ----- | 1968 | Rotenone treatment to eradicate introduced species (Montgomery 1969) |
| Kokanee | Introduced into Eel Lake | 1968 | One time release. Status unknown. Source; Tenmile STEP group |
| Largemouth bass | Introduced | 1971 | Highly successful fishery. May have been earlier illegal introductions. |
| Hybrid bass<br>Striped bass X White bass | Introduced | 1982 | Successful fishery discontinued after 1988 because of concerns for hybrids straying into other river systems. Still present in small #'s |
| Black crappie | Introduced[A] | 1987 | ODFW study showed presence in '87 |
| Miscellaneous native species<br>Eulachon<br>Staghorn sculpin<br>Threespine stickleback<br>Green sturgeon<br>Pacific lamprey<br>Western brook lamprey<br>Prickly sculpin<br>Shiner perch | | | Populations unknown |
| Chinook | Introduced | 1905 &<br>1980's | 250,000 Fall Chinook released in South Tenmile Lake in 1905. Another 260,000 released in 1940. (Tenmile STEP). |
| A=Illegal introduction B=Federally listed C=State listed | | | |

**Figure 3 – Coho Escapement Estimates**




Coho escapement estimates for 1995-2004 averaged 7,400. Winter steelhead hatchery stock was re-founded around 1999-2002, using strictly Tenmile unmarked adults to develop "localized" broodstock. Rainbow trout are managed as a "put and take fishery." Some of these fish are caught at 17" length and greater within the next few years after stocking, and some holdovers do survive. Yellow perch were absent from the lake for several decades following rotenone treatment but they re-appeared in 2000 in annual gillnet lake sampling, and are now re-established. Hybrid bass observations have nearly disappeared with the last observation of a hybrid bass by ODFW staff was in 2004.

Smallmouth bass have appeared in Eel Lake, apparently from illegal introduction and their presence was confirmed in 2005 by ODFW District electrofishing. ODFW fish Division records indicated that kokanee were stocked in Eel Lake in 1968, in Clear Lake in 1967, and in Saunders Lake in 1967. In the absence of suitable spawning habitat, and through evidence collected in annual sampling with gillnets and/or electrofishing, we have no indication that they were self-sustaining to present.

Bluegills are abundant, but no current population estimate is available. Annual gillnet sampling for relative abundance at index sites is conducted but it is not possible to derive lake population estimates from this information. The various warmwater fish populations have fluctuated significantly in recent years, which is typical based upon both population dynamics and the current sampling methodology.

In a study of the effects of introduced fishes on wild juvenile coho salmon using three shallow western Washington lakes fish predation was a significant source of mortality of coho salmon juveniles (Bonar et. al., 2004). Over the two-year study, 30,622 fish were sampled and the contents of 10,262 stomachs were pumped and analyzed. Percent of salmon in the diet was highest for largemouth bass. Other species primarily targeted insects and zooplankton. Some salmon were found in the diet of black crappie, brown bullhead, cutthroat trout, prickly sculpin, and yellow perch. Although in three instances salmon constituted 5-10% of the total weight of the stomach contents for these fishes, this usually represented one salmon in the diet the entire year for the species. No evidence of rainbow trout, bluegill, or pumpkinseed sunfish feeding on any salmon were found. While some salmon were eaten by other species, the vast majority of total salmon was eaten by largemouth bass in all three lakes.

### *3.1.2.1 Biomanipulation Theory*

It is now understood that lake productivity is affected not only by inputs from the watershed, but also by the biological activity within the lake. Altering the fisheries can promote major changes in the zooplankton community which in turn can alter the grazing rate of phytoplankton (Sarnelle 1992, 1993). Planktivorous fish such bluegills feed, by sight. Size-selective predation occurs, in which planktivorous fish preferentially remove the largest zooplankton species

With the dominance of exotic species, the current fishery is vastly different than the historical condition. Largemouth bass is the primary game fish and there are also abundant populations of bluegill, yellow perch, and crappie (Abrams et al. 1991). The fishery is currently dominated by highly planktivorous fish. These taxa (e.g. bluegill, yellow perch) are very efficient at consuming the larger zooplankton species. The reduction of large zooplankton, in turn, reduces their grazing pressure on phytoplankton. This allows phytoplankton (algae and cyanobacteria) biomass to increase. Phytoplankton biomass is able to further take advantage of the reduced grazing pressure because more nutrients are available from watershed inputs. This suggests that water quality problems in the lakes, including nuisance algae blooms, are the product of changes in *both* the watershed and fishery populations (Shapiro, 1979, 1982).

In addition to preferential grazing impacts, populations of introduced fish can further stimulate phytoplankton growth by increasing nutrient availability via increases in biomass. Excessive zooplankton grazing following introduction of the exotic tui chub into Diamond Lake has been identified as the primary mechanism for the deterioration of water quality in Diamond Lake. This recent assessment conducted on Diamond Lake implicates the biomass of exotic fish species as the primary driver of nuisance algae blooms even in the absence of significantly increased upland nutrient loading. (Eilers et al, 2001 and 2004).

It appears that juvenile salmon are significantly outnumbered by non-native fish populations in the Tenmile Lakes. Reimers (1989) hypothesized that “nomad” coho fry that migrated down to the lakes from streams above were no longer able to survive to any great degree, mostly due to predation resulting from the change in fish species composition in the lakes. The implications of this native salmon verses warm water predatory fish imbalance, and the potential implications on nuisance algae blooms, suggests that further assessment is warranted in this watershed.

Juvenile salmonids that travel through the lakes to the ocean in their final winter of rearing are still apparently successful. They are passing through the lakes at a period of time when water temperatures are cool and predator feeding rates are low. Also, larger salmonid smolts tend to be more pelagic in the open water of the lake, whereas the “nomad fry” in their first summer tend to be more shoreline/shallows-oriented, where predators are more common. Salmon smolts that utilize the lakes prior to moving out to the ocean attain a relatively large size as compared to stream-reared coho smolts. This size advantage in the ocean appears to provide a survival advantage, keeping the lake system one of the most stable and healthy coho populations along the Oregon Coast, albeit at a reduced number compared to historic run sizes.

# CHAPTER 4 - WATER QUALITY STANDARDS AND BENEFICIAL USES

The objective of the Clean Water Act (CWA) is to restore and maintain the physical, chemical and biological integrity of the Nation's waters (CWA 101(a)). To help implement these objectives, states develop and adopt water quality standards. Water quality standards include three components:

- beneficial uses
- narrative and numeric water quality criteria
- anti-degradation policies

In practice, water quality standards have been set at a level to protect the most sensitive beneficial uses. Seasonal standards may be applied for uses that do not occur year-round. Cold-water aquatic life such as salmon and trout are often the most sensitive *beneficial uses* occurring in a watershed. In the case of the Tenmile Lakes Watershed, weed and algae problems impact multiple beneficial uses including domestic water supply, water contact recreation, and aesthetic quality, boating, transportation, fishing, and salmonid rearing (ODEQ, 1995).

Oregon's water quality standards and beneficial uses are contained in Oregon's Administrative Rules (OAR) 340 Division 41. Beneficial uses are listed by Oregon Water Resource Department basin delineations. The specific designated beneficial uses for the Tenmile Lakes Watershed are presented in the table below. Beneficial uses which are currently occurring have been bolded. There may be impacts on other beneficial uses not specifically identified that are less understood.

**Table 10 – Beneficial Uses in the Tenmile Lakes Watershed**

| **Public Domestic Water Supply** | **Anadromous Fish Passage** |
|---|---|
| **Private Domestic Water Supply** | **Salmonid Fish Spawning** |
| Industrial Water Supply | **Salmonid Fish Rearing** |
| **Irrigation** | **Resident Fish and Aquatic Life** |
| **Livestock Watering** | **Wildlife and Hunting** |
| **Boating** | **Fishing** |
| **Aesthetic Quality** | **Water Contact Recreation** |
| **Commercial Navigation & Transportation** | Hydro Power |

## *4.1 303(D) INTEGRATED REPORT SUMMARY*

The 2002 303(d) Integrated Report Summary (ODEQ 2002a) summarizes the results of the review of the available data at that time for the Tenmile Lakes Watershed. Data were reviewed against State of Oregon Water Quality Standards and 303(d) listing criteria. The listing status indicates the result of this review. Where the listing status indicates "303(d) List", water quality standard were not achieved and these water quality standards exceedances were found to have significant potential to impact beneficial uses. When beneficial uses are impaired, the water body is water quality limited (WQL). This status requires a TMDL assessment of the specific water body be conducted for the listed parameter.

### 4.1.1 Other Listing Status

In addition to water quality limited other listing status can include:

- Potential concern - insufficient data was available to fully assess the water quality parameter but available data does indicate the potential for beneficial use impairment.
- Attaining Criteria/Uses - available water quality data indicates that beneficial uses are fully supported.
- Water Quality Limited Not Needing a TMDL - the parameter may influence water quality and beneficial uses but is not officially recognized as a pollutant and hence will not require the development of pollutant loads in TMDL.
- Insufficient/No Data - a data set is either unavailable or is not of sufficient rigor to meet 303(d) data requirements.

Once a water body is identified as being water quality limited, Section 303(d) requires that Total Maximum Daily Loads (TMDLs) be developed. TMDLs are based upon more watershed specific information and allow assessment of water quality criterion in the context of the specific water body. TMDLs describe the amount of each pollutant a water body can receive and assimilate and not violate water quality standards. Adaptive management is an important component of TMDLs. TMDLs are designed to be evaluated and adjusted as necessary through time as additional information becomes available. The process is designed to keep the water quality of Oregon's water bodies at a level where multiple beneficial uses can be supported.

This TMDL will address all parameters currently present on the state's 2002 303(d) list (ODEQ 2002a). In addition, approaches defined in the TMDL and WQMP should result in collateral multi parameter water quality improvements. As a result of exceedances of water quality criteria for weeds, algae and pH, South and North Tenmile Lakes as well as Eel Lake have been identified on both the 1998 and 2002 303(d) lists.

## *4.2 POLLUTANT IDENTIFICATION*

### 4.2.1 Deviation from Water Quality Standards and 303(d) Water Quality Limitations (WQL)

Monitoring has shown that water quality in the Tenmile Lakes Watershed does not meet state water quality standards at all times of the year. Section 305(b) of the Clean Water Act (CWA) requires states to report on the extent to which all surface waters, including rivers, streams, lakes, ponds, reservoirs, wetlands, estuaries and coastal waters meet water quality standards.

Section 303(d) of the CWA requires each state to identify those waters for which existing required pollution controls are not stringent enough to achieve that State's water quality standards. These water bodies are considered "water quality limited" or "impaired." These impaired waters are placed on a list called the 303(d) list.

**Listings can be based upon:**

- Evidence of a numeric water quality criteria exceedance
- Evidence of a narrative water quality criteria exceedance
- Evidence of a beneficial use impairment
- Evidence of anti-degradation (i.e. a declining trend in water quality such that it would exceed a standard prior to the next listing period)

The tables below show water quality parameters which were considered as "water quality limited" or "impaired" and those parameters identified as attaining criteria for the Tenmile Lakes Watershed on the state of Oregon's 303(d) list. These listings were derived from the review of the available data sets at the time the 2002 303(d) list was developed.

**Table 11 – 303(d) Listings of Water Quality Limited Segments for the Tenmile Lakes Watershed**

| Water body Name | River Mile | Parameter | Season | List Date | Listing Status |
|---|---|---|---|---|---|
| North Tenmile Lake | | Aquatic Weeds or Algae | Undefined | 1998 | 303(d) List |
| (South) Tenmile Lake | | Aquatic Weeds or Algae | Undefined | 1998 | 303(d) List |
| Eel Lake | | pH | Summer | 1998 | 303(d) List |
| Benson Creek | 0 to 8.2 | Habitat Modification | Undefined | 2002 | Water Quality Limited Not Needing a TMDL |
| Big Creek | 0 to 8.4 | Habitat Modification | Undefined | 2002 | |
| Johnson Creek | 0 to 9.3 | Habitat Modification | Undefined | 2002 | |

**Table 12 - Segments of the Tenmile Lakes Watershed Identified as Supporting Beneficial Uses**

| Water body Name | River Mile | Parameter | Season | List Date | Listing Status |
|---|---|---|---|---|---|
| Eel Lake* | | Turbidity | Year Around | 1998 | Attaining Criteria/Uses |
| Murphy Creek | 0 to 3.9 | Temperature | Summer | 1998 | Attaining Criteria/Uses |

*1994 Eel Lake Limnological Survey (Systma, PSU, 1995): Turbidity was typically less than 2 NTU with higher turbidity (ranging from 3 to 9.5 NTU) occurring in winter months (as measured by City of Lakeside at water intake structure).

# ***4.3 APPLICABLE WATER QUALITY STANDARDS***

## 4.3.1 Aquatic Weeds (Macrophytes) – North and South Tenmile Lakes

**Beneficial Uses Affected**: Water Contact Recreation, Aesthetics, Fishing

**Narrative Criterion**: OAR 340-41-0007 (11) The development of fungi or other growths having a deleterious effect on stream bottoms, fish or other aquatic life, or which are injurious to health, recreation, or industry shall not be allowed;

**303(d) listing Criteria for Aquatic Weeds (Macrophytes):** Documented reports of an abundance of invasive, non-native macrophytes (those listed on the "A" or "B" Noxious Weed List maintained by the Oregon Department of Agriculture, ODA) that dominate the lake assemblage of plants and significantly reduces the surface area available for lake usage; frequent herbicide treatments to control aquatic weeds; or other activities initiated to manage weed growth such as through a Coordinated Resources Management Plan in response to frequent complaints about weeds interfering with various uses.

**Supporting Data***:* The Tenmile Lakes Limnology Survey (Systma (PSU), 1995): Extensive growth of Elodea densa, a non-native aquatic plant and a "B" designated weed by ODA, dominates the macrophyte assemblage and interferes with beneficial uses.

"The Tenmile Lakes contain a diverse macrophyte community…Brazilian elodea (*Egeria densa*) was the dominant macrophyte. Brazilian elodea was most abundant at depths less than 16 ft. Coontail (*Ceratophyllum demersum*) was commonly abundant near the bottom at depths between 16 and 20 ft. Big-leaf pondweed (*Potomogeton amplifolius*) exhibited dramatic seasonality in abundance; it was common and formed dense stands, particularly in Templeton and Carlson Arms in July, but was rare in August. Other macrophytes present included: *Potomogeton natans, Elodea canadensis, Callitriche palustris, Lemna* spp., *Brasenia schreberi, Nuphar* spp., *Nympheae odorata, Myriophyllum hippuroides, Potomogeton praelongus, Potomogeton richardsonii,* and *Myriophyllum aquaticum.* Because of the seasonality of native species and the patchy distribution of macrophytes, complete description of the macrophyte community in the Tenmile Lakes would require a year round sampling program at more stations in the lakes."

**Time period of water quality impairment**: Annual

## 4.3.2 Chlorophyll a (Phytoplankton) – North and South Tenmile Lakes

**Beneficial Uses Affected**: Water Contact Recreation, Aesthetics, Fishing, Water Supply, Livestock Watering

**Numeric Criteria**: OAR 340-41-0019 (1) Standards applicable to all basins:
(a)The following average Chlorophyll a values shall be used to identify water bodies where phytoplankton may impair the recognized beneficial uses:

- (A) Natural lakes which thermally stratify: 0.01 mg/l
- (B) Natural lakes which do not thermally stratify, reservoirs, rivers and estuaries: 0.015 mg/l (15ug/l)
- (C) Average Chlorophyll a values may be based on the following methodology (or other methods approved by ODEQ): A minimum of three samples collected over any three consecutive months at a minimum of one representative location (e.g., above the deepest point of a lake or reservoir or at a point mid-flow of a river) from samples integrated from the surface to a depth equal to twice the secchi depth or the bottom (the lesser of the two depths); analytical and quality assurance methods must be in accordance with the most recent edition of Standard Methods for the Examination of Water and Wastewater.

*The Tenmile Lakes are relatively shallow lakes and in general do not distinctly stratify for significant periods of time.

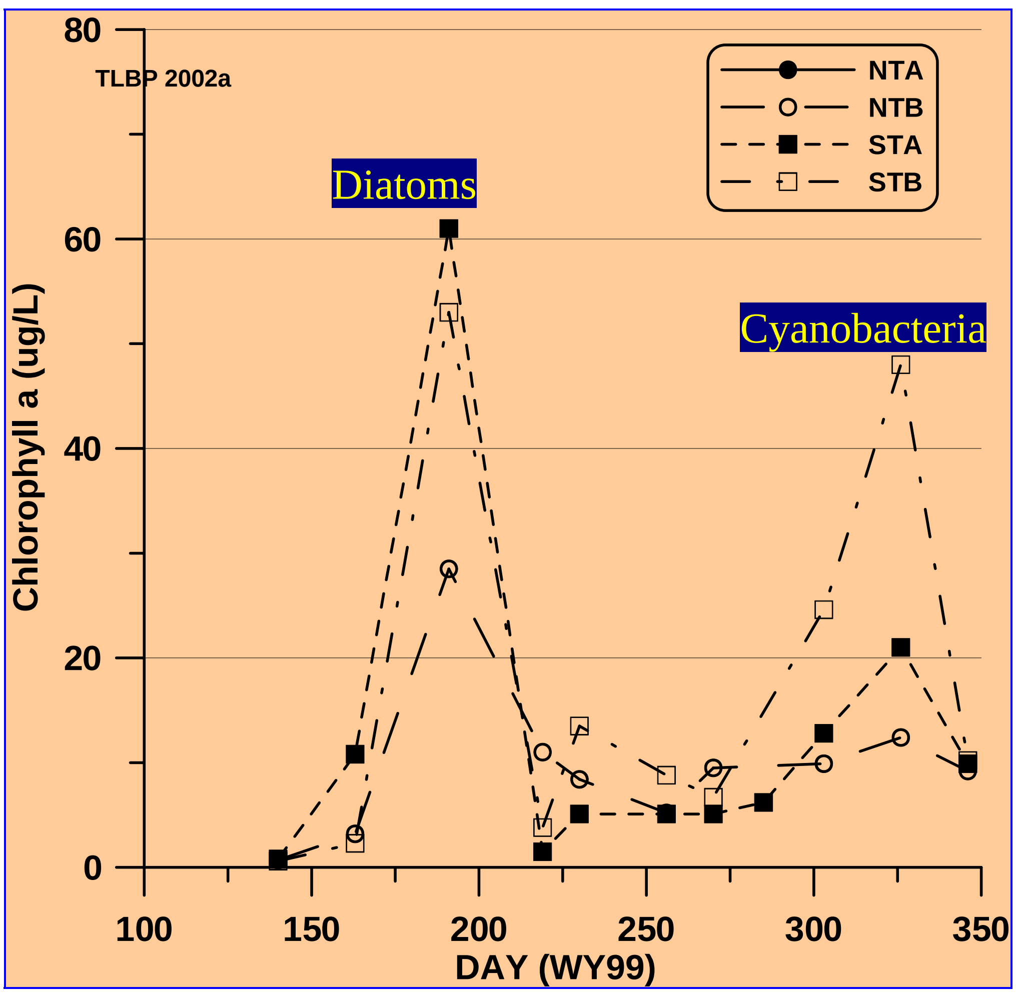
**Supporting Data**: Tenmile Lakes Nutrient Budget: Chlorophyll a exceeds numeric criteria 3 month average value of 15ug/l.

Data collected as part of the Nutrient Study (TLBP 2002a) supporting this TMDL document revealed that episodically high chlorophyll a values occur in conjunction with algal blooms. Chlorophyll a has not been routinely collected as a companion parameter to algae sampling. This has resulted in a rather small data base for review. Currently, ongoing algae monitoring efforts are coupled with chlorophyll a monitoring. Review of the dataset for the period 1995-2001 reveals chlorophyll a samples collected at ten Tenmile Lake sites in August 1995 exceeded 15ug/L ranging from 17-33ug/L. One value of 152ug/L was recorded in September 2000 and a value of 61ug/L was recorded in October 2000.

**Time Period of Water Quality Impairment**: Summer: June 1 through September 30 (period of highest use for water contact recreation).

The chlorophyll a data depicted in the figure below was collected during the 1999 water year. A water year begins on October 1 and ends on September 30 of a given year. Note that because of companion algae characterization efforts predominant organisms have been identified during bloom events.

**Figure 4 – 1998 Chlorophyll a Data for the Tenmile Lakes**
*(Water year 1999 - October 1, 1998 to September 30, 1999)*



**The following parameters were not specifically identified on the 2002 303(d) list but are limiting to beneficial uses and are addressed within this TMDL.**

- **Algae**
- **Sedimentation**
- **Phosphorus**
- **pH**
- **Habitat Modification**
- **Biological Criteria**

## 4.3.3 Algae (Phytoplankton) – North and South Tenmile Lakes

**Beneficial Uses Affected**: Water Contact Recreation, Aesthetics, Fishing, Water Supply, Livestock Watering

**Narrative Criterion**: OAR 340-41-0007(11) The development of fungi or other growths having a deleterious effect on stream bottoms, fish or other aquatic life, or which are injurious to health, recreation, or industry shall not be allowed;

*Phytoplankton (floating algae):* Documented evidence that algae is causing other standard exceedances (e.g. pH or dissolved oxygen) or impairing a beneficial use.

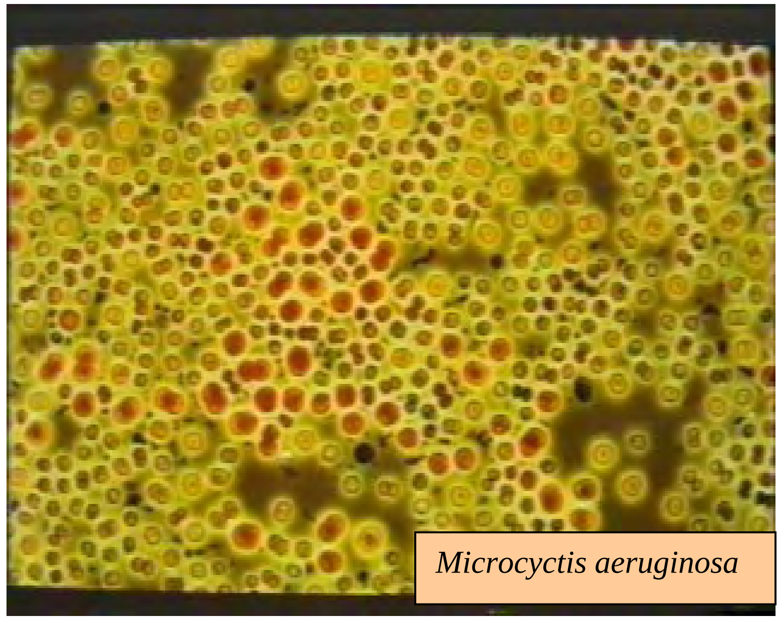
A toxic bloom of *M. aeruginosa* was first documented in the Tenmile Lakes in September of 1997, prompting the Oregon Department of Human Services to issue a health advisory recommending that the lake not be used for drinking water and that contact recreation be avoided (Kann and Gilroy 1998). Routine sampling of the Tenmile Lakes for Microcystis aeruginosa has been conducted since that time and concentrations of the toxin microcystin have episodically continued to exceed World Health Organization levels of concern for drinking water and recreational contact in the spring, summer, and fall.

| Table 13 –Nuisance Algal Bloom Health Advisory History for the Tenmile Lakes Department of Human Resources (DHS) | |
|---|---|
| March 11, 2004 | Algae Toxin Advisory Lifted for the Tenmile Lakes |
| September 22, 2003 | Potential recreational and drinking water hazard in the Tenmile Lakes |
| July 6, 2002 | Potential recreational and drinking water hazard in the Tenmile Lakes |
| August 31, 2001 | Potential hazard due to Microcystis aeruginosa in the Tenmile Lakes |
| December 1, 1997 | Tenmile Lakes Health Advisory Lifted |
| October 3, 1997 | Ten Mile Lake Health Advisory |

**Time Period of Water Quality Impairment**: Annual

A Department of Health Services (DHS) fact sheet containing additional information about public health risks associated with algal blooms in the Tenmile Lakes can be seen in Appendix B. Issued health advisories warned the public of the presence of *Microcystis aeruginosa* a blue-green algae capable of producing a dangerous liver toxin called microcystin. Advisories warned that the toxin poses danger to humans or animals using the water and that ingestion of the water is the most significant hazard, but direct contact with algae may also pose some toxin hazard as well as possible skin reactions.

The microorganisms *Microcystis aeruginosa* and *Anabaena spp.*, are both types of cyanobacteria, the oldest known organisms on Earth. These blue-green algae or cyanobacteria are very much like bacteria and are considered one of the largest groups of bacteria on the planet. Microcystis and Anabaena are abundant at times in both of the Tenmile Lakes. Chemicals produced by certain species and strains of cyanobacteria presents a problem to humans and other animals due to toxicity. Microcystis aeruginosa can produce both microcystin and anatoxin toxins. Neurotoxins affect the nervous system by interfering with neurotransmitters and hepatoxins disrupt blood flow in the liver and may interfere with other cellular processes.



*Microcyctis aeruginosa*

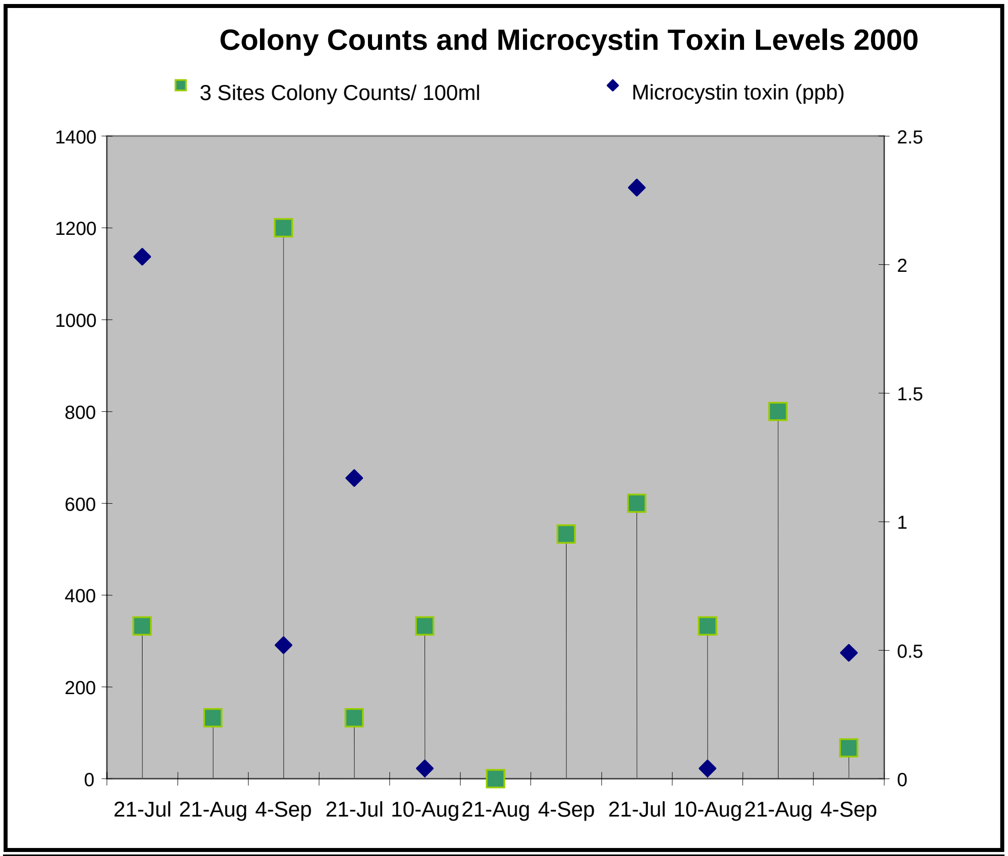
The World Health Organization) sounds a cautionary note on cyanobacterial toxins, but notes that related acute illnesses are rare.

> "Outbreaks of human poisoning attributed to toxic cyanobacteria have been reported in Australia, following exposure of individuals to contaminated drinking water, and in the UK, where army recruits were exposed while swimming and canoeing. However, the only known human fatalities associated with cyanobacteria and their toxins occurred in Caruaru, Brazil, where exposure through renal dialysis led to the death of over 50 patients. Fortunately, such severe acute effects on human health appear to be rare, but little is known of the scale and nature of either long term effects (such as tumor promotion and liver damage) or milder short term effects, such as contact irritation."
>
> http://www.who.int/water_sanitation_health/resourcesquality/toxicyanbact/en/

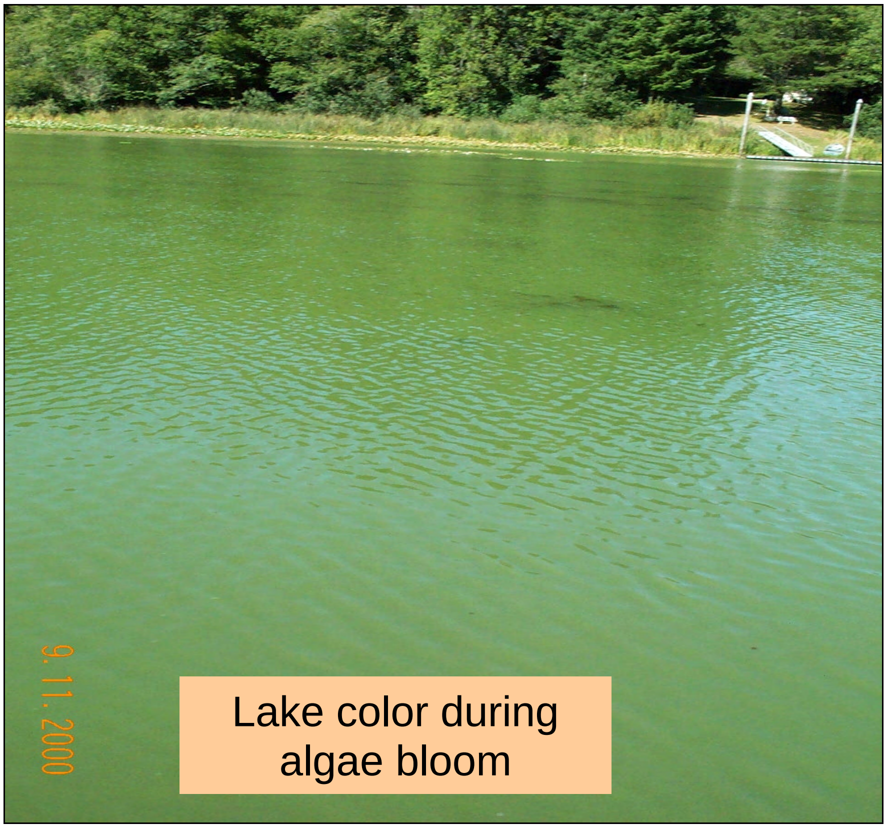
In recent years, algae and toxin testing in Oregon's lakes and reservoirs has increased both spatially and temporally and the need for increased health advisories has resulted. The organism, Microcystis, and the toxin it produces, microcystin, are not always found together, and the amount of toxin isn't necessarily related to an obvious bloom of cyanobacteria. The figure below shows Microcystis colony counts at three sample sites in the summer and fall of 2000. Microcystin toxin levels are depicted as dark blue diamonds. *M. aeruginosa* was present at low levels at the time of the first sample trip on July 21, 2000 with microcystin values that were ~2X the World Health Organization (WHO) guidance level for drinking water (1 ppb or 1 µg L-1; Falconer et al. 1999).

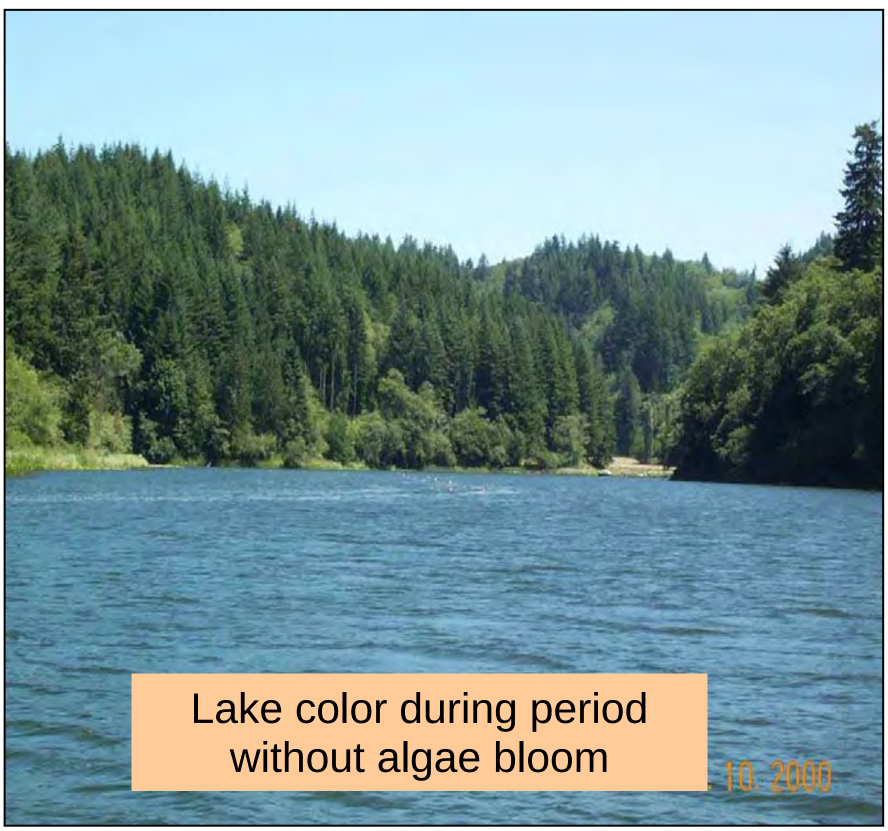
Cyanobacteria was investigated as a possible cause when a Wisconsin teen mysteriously died in 2002 after swimming in a scummy pond. These events support human and animal health concerns related to toxic blue green algae blooms.

**Figure 5 – Microcystis Colony Counts and Microcystin Toxin Levels (ppb)**




Testing in the Tenmile Lakes has concentrated on Microcystis and microcystin due to its early identification and heightened awareness by public and governmental entities. Monitoring programs have most recently been expanded to include testing for the presence of anatoxins as well as microcystins. The level of current testing is funding dependant. Tenmile Lakes Basin Partnership sampling programs are currently designed to collect supplemental water quality information in an effort to better understand water quality conditions present during algae growth, bloom formation, and toxin production.


9.11.2000
Lake color during
algae bloom


Lake color during period
without algae bloom
10. 2000

## 4.3.4 Sedimentation – North and South Tenmile Lakes

This TMDL identifies sedimentation as a water quality parameter which contributes to conditions which impair beneficial uses in the Tenmile Lakes.

**Sedimentation Narrative Criterion:** OAR 340-041-0007(13) "The formation of appreciable bottom or sludge deposits or the formation of any organic or inorganic deposits deleterious to fish or other aquatic life or injurious to public health, recreation, or industry shall not be allowed."

Sediment core sample results indicate dramatically increased sediment accrual rates above those that were occurring under "natural" conditions. These results are discussed in depth in the Paleolimnological Reconstruction of Past Conditions section of this document. In addition, the review of historical aerial photography provides documentation of physical conditions indicative of delta building at the mouths of lake tributaries and further supports the finding that increased sedimentation is impairing beneficial uses in the Tenmile Lakes.

Watershed specific documentation also supports the determination that upland sediment loading has resulted in increased rates of lake filling resulting in conditions that favor the establishment of nuisance weeds (TLBP, 2002). An in depth discussion of total suspended solids (TSS) delivery via tributaries to the lakes can be found in the Hydrology and Pollutant Loading Assessments section of this document. Assessment of this information has resulted in the development of load reduction targets for these creeks based upon measured data. Predictive modeling was utilized to simulate loading for other tributaries not specifically monitored. It is recommended that ongoing monitoring programs seek to collect field data on systems where TSS loading targets were derived via modeling.

This TMDL identifies load allocations for sediment loads for tributaries and targets interim tributary load reductions, for sediment accrual rates (SAR), and for total phosphorus in lake waters. These parameters tie directly to lake filling, a primary driver for the expansion of nuisance weeds. They also tie to the delivery of phosphorus via sediments.

**Time Period of Water Quality Impairment**: Annual

## 4.3.5 Phosphorus (mg/L) – North and South Tenmile Lakes

This TMDL identifies the nutrient phosphorus (P) as a water quality parameter which contributes to conditions which impair beneficial uses in the Tenmile Lakes. Nutrient loading studies have identified elevated phosphorus levels in lake waters. Several forms of phosphorus can be measured. Total phosphorus (TP) is a measure of all forms of phosphorus, dissolved or particulate, that is found in a sample. TP has been used throughout North America as a basis for setting trophic state criteria and in developing related models (NALMS, 1992). TP is relatively easy to measure and during the analysis, all forms of phosphorus are converted into orthophosphorus. TP generally reflects the amount of orthophosphorus plus some polyphosphates in the sample. The distinction between "particulate" and "dissolved" is primarily a function of the filter used.

Because the primary nuisance algae are nitrogen fixing and cannot be limited by nitrogen, lake water column total phosphorus (TP) is proposed as a target which has direct linkages to nuisance algal blooms. Phosphorus is present in the lake during the summer months from multiple sources including; summertime lakefront activities as well as internal lake cycling (sediments, fishery, weeds, etc). Because discrete loads from these sources are elusive to define, TP is proposed as a target, to work towards, rather than an LA for the following reasons:

- No point sources are present in the basin and no WLAs are proposed.
- Although the derivation of a load allocation (LA) for TP is possible, no precision is added to the project.
- A LA for TP would be solely allocated to internal lake processes (current levels are significantly elevated).

- Setting a LA, or developing further modeling at this time, would not change nonpoint source (NPS) implementation priorities.
- Setting of the target allows more monitoring to occur through time and supports an adaptive management approach.
- Nutrient data is needed for Oregon lakes to support nutrient standards discussions.

The parameter TP has been selected by USEPA for use in their Nutrient Criteria Technical Guidance Manual for Lakes and Reservoirs. It is proposed as a good general indicator of phosphorous loading expressed as an all season average. The use of an all season average over time incorporates winter loading events as well as summer conditions (the period of algal blooms). TP data from the Tenmile Lakes indicates that current TP values significantly exceed USEPA recommended criteria.

The phosphorus target for lake waters is 7.1ug/L (ppb) total phosphorus all season average or median. Derivation of the phosphorus reference value is discussed in depth in the Pollutant Loading Assessments section. All season average values for phosphorus in Tenmile Lake waters at four long term monitoring sites range from 23 to 38 ppb depending upon the sampling site.

**Time Period of Water Quality Impairment**: Annual

## 4.3.6 pH – Eel Lake

**Recommendation for identification of water body of potential concern:** Eel Lake is proposed for removal from the 303(d) list.

**Beneficial Uses Affected**: Resident Fish & Aquatic Life, Water Contact Recreation

**Numeric Criteria**: OAR 340-41-021
Summary: pH shall not fall outside the following ranges: 6.5 – 8.5
*when 25% of the measurements taken between June and September are greater than pH 8.7, ODEQ shall determine whether the value higher than 8.7 are anthropogenic or natural in origin

**The 1998 303(d) Listing for Eel Lake Was Based Upon the Following Supporting Data:**
1994 Eel Lake Limnological Survey (Systma, PSU, 1995): pH values were recorded above standard (8.5) in 1990, 91, and 94 with durations of one week to three months and a maximum of 9.4 by City of Lakeside (at water intake structure). Eel Lake water quality data collected by the Lakeside Water District revealed pH values were recorded above the standard of 8.5 in 1990, 91, and 94 with durations of one week to three months with a maximum value of 9.4.

**Supporting Data Update:** The Lakeside Water district measure pH on a daily basis**.** A detailed review of data collected during the 1995-2004 period reveals that although elevated pH values were episodically recorded, they did not occur at durations long enough to meet the water quality limited listing criteria. The data does support the determination that Eel Lake does meet the 303(d) list attaining criteria for this parameter. The quality assurance and control (QA/QC) program has improved during this period of time and the plant is operating under an Oregon Human Services approved QA/Qc plan.

- 2002 - One value of 9.7 was recorded on January 14, 2002. (Jan 13 = 6.93, Jan 15 = 6.77)
- 2001 - One value of was recorded 8.73 on July 24, 2001
- 2000 - No values over 8.5 were recorded
- 1999 - No values over 8.5 were recorded.
- 1998 – Four values over 8.5 were recorded (September 2 = 8.73, August 3 = 8.57, August 29 = 8.74, August 31 = 8.62)
- 1997 - No values over 8.5 were recorded
- 1996 - No values over 8.5 were recorded
- 1995 - One value of 8.56 was recorded on June 14

As a result of this more recent data review Eel Lake is proposed for removal from the 303(d) list of impaired waters. It should be noted that in years where historic pH standard exceedances did occur during the summer months, elevated turbidity levels were documented during the previous winter period. This link between upland sediment (nutrient) delivery and subsequent pH response indicates that algae cycles may be occurring in response to sediment delivery. This algae response is likely an influencing factor on lake pH. It is recommended that, because of the episodic occurrence of elevated pH, that Eel Lake be identified as a water body of Potential Concern.

**Water Quality Limited Determination:** A minimum of 5 samples per time period are required. More than 10 percent of the samples exceed criterion and a minimum of at least two exceedances of the criterion for the season of interest.

**Attaining Criterion:** A minimum of 5 samples per time period (summer or fall/winter/spring) and 90% of the samples attain the criterion.

**Time Period of Concern**: Summer: June 1 through September 30

## 4.3.7 Habitat Modification – Tenmile Lakes Watershed

**Recommendation for identification of water body of insufficient/no data**: Habitat modification is not the direct result of a pollutant although it does affect beneficial uses. Because a pollutant is not the cause, the concept of establishing a loading capacity and allocations through the development of a TMDL does not apply. This is not meant to minimize the close relationship aquatic habitat condition and good water quality share. As a result of this clarification, segments identified in the habitat modification category changed status to Water Quality Limited Not Needing a TMDL. Upon further examination it has been determined that insufficient data is available for review to warrant the continued listing of Big, Johnson, and Benson Creeks as WQL.

Changes in instream habitat can affect sediment supply and delivery. Stream channels with complex structure present tend to store sediments, releasing then into downstream areas more slowly. Reductions in hydrologic velocity around instream structure allow sediments to fall out and settle. Sediment digestion is an important function of instream structure. The improvement of fish habitat through increasing channel complexity will have positive affects on lake water quality by ameliorating upland sediment delivery.

**Habitat Modification Standard: OAR 340-041-0007(12), OAR 340-41-011:** The beneficial uses affected by habitat modification include Resident Fish & Aquatic Life, Salmonid Fish Spawning & Rearing. The standard that applies is: The creation of tastes or odors or toxic or other conditions that are deleterious to fish or other aquatic life, or affect the potability of drinking water, or the palatability of fish or shellfish shall not be allowed; or: Waters of the State shall be of sufficient quality to support aquatic species without detrimental changes in the resident biological communities.

**Table 14 - Summary of Habitat Modification Listing Status**

| Water body Name | River Mile | Parameter | List Date | Listing Status |
|---|---|---|---|---|
| Benson Creek | 0 to 8.2 | Habitat Modification | 2002 | Water Quality Limited Not Needing a TMDL |
| Big Creek | 0 to 8.4 | Habitat Modification | 2002 | Water Quality Limited Not Needing a TMDL |
| Johnson Creek | 0 to 9.3 | Habitat Modification | 2002 | Water Quality Limited Not Needing a TMDL |

### 4.3.8 Biological Criteria – Benson and Eel Creeks

ODEQ's biological assessment process includes the review of fish and invertebrate data. Invertebrate data is assigned a "multivariate score" which is generally thought to be a valuable indicator of localized or stream reach specific water quality conditions. Fish data is assigned a "multimetric score" (Index of Biological Integrity or IBI) which is a valuable indicator of overall watershed health.

**The narrative biological criterion:** OAR 340-41-027, Standards applicable to all basins: Waters of the state shall be of sufficient quality to support aquatic species without detrimental changes in the resident biological communities.

In the 1998 303(d) list, ODEQ evaluated biological data using multimetric scores and multivariate models. A water body was determined to be water quality limited by the following evaluation (ODEQ 1998 303(d) Listing Criteria):

Aquatic communities (primarily macroinvertebrates) which are 60% or less of the expected reference community for both multimetric scores and multivariate model scores are considered impaired.

ODEQ is in the process of developing numeric biological criteria and is currently re-analyzing its data against the draft numeric criteria (Rick Hafele, ODEQ, personal communication, February, 2002). The numeric criteria will be different than the values used in previous 303(d) lists. Water bodies placed on the 1998 303(d) list based on interpretation of the narrative biological criterion will be maintained on the 2002 303(d) list unless a TMDL addressing the listing has been approved by USEPA. Biological data collected during the 2002 303(d) list cycle will be evaluated during the next list cycle.

ODEQ will report the results of the biological monitoring in the narrative discussion of the state's water quality program.

<u>For Benson Creek</u> the Discriminant Score was 93, however, a multimetric measure was very low so the stream was listed as a Potential Concern.

<u>For Eel Creek</u> the stream was sampled in 1994 and 1995 and the Discriminant Score was 60. Streams are considered impaired with Discriminant Scores <61 and healthy with Discriminant Scores>75 points. The variability of the scores is a potential concern.

The table below summarizes the Bio-Criterion listing status for this watershed.

**Table 15 – Listing Status for Biological Criteria**

| Water body Name | River Mile | Parameter | List Date | Listing Status |
|---|---|---|---|---|
| Eel Creek | 0 to 2.5 | Biological Criteria | 1998 | Potential Concern |
| Benson Creek | 0 to 8.2 | Biological Criteria | 1998 | Potential Concern |

# CHAPTER 5 - TENMILE LAKES WATERSHED NUTRIENT TMDL

## *5.1 WATER QUALITY IMPAIRMENTS PROBLEM ASSESSMENT*

### 5.1.1 Study Design

This TMDL assessment is based upon an approach which focused on the ability of the Tenmile Lakes to process sediment, phosphorus, and nitrogen. The connections between these water quality parameters and documented weed and algae problems were closely examined. Intensive data collection was initiated in 1998 and extended to 2001. Ongoing monitoring programs continue to further enrich water quality data sets..

All field activities were described in a written sampling plan provided to all field personnel. Quality assurance protocols and analytical methods were detailed in a QA/QC plan submitted to the TLBP. Duplicate and blank samples were included among the routine samples as checks on the quality of the analytical results. Water quality data utilized for modeling met minimum QA/QC requirements as identified in the plan. Phytoplankton was collected as split samples with the lake water samples

The sediment ages and accumulation rates were calculated using the constant-rate-of-supply (CRS) model of Appleby and Oldfield with old age dates, using the method described by Binford (1990). Diatoms were analyzed according to protocols developed for the Paleoecological Investigation of Recent Lake Acidification (PIRLA) Program (Charles et al. 1990).

Additional general information regarding data quality assurance requirements and procedures can be found at the following website http://www.deq.state.or.us/lab/techrpts/technicaldocs.htm.

The nutrient budget assessment, the foundation of this TMDL, provided the following information:

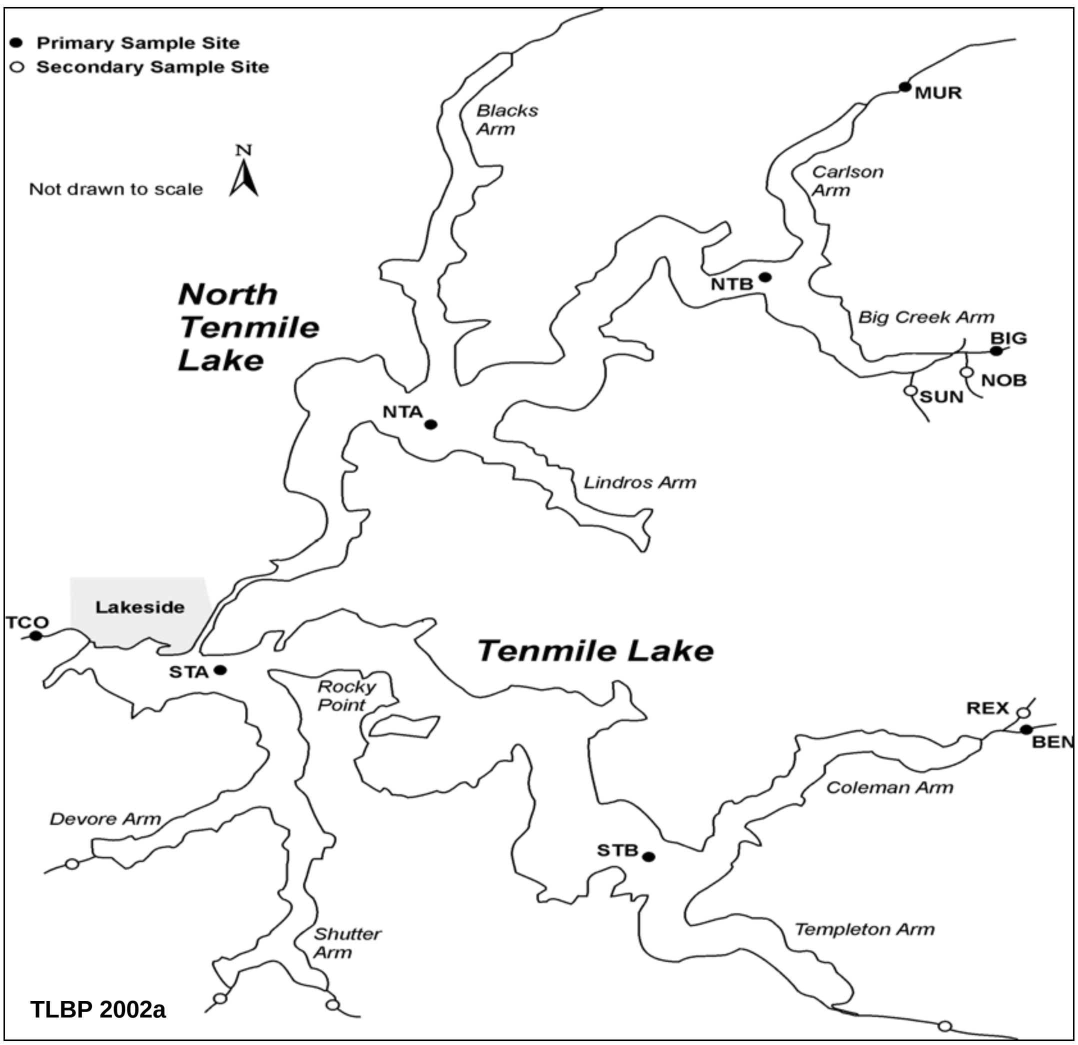
- An improved understanding of the inputs of nutrients to the lake from selected representative tributaries during both base flow and storm runoff conditions.
- An improved understanding of nutrient concentrations and related water quality parameters in lake waters.
- An improved understanding of lake algal community composition.
- The establishment of representative sites and the collection of sediment core samples to begin to quantify a history of sediment accumulation rates for the lakes.
- Calibration of a watershed model based upon nutrient and sediment inputs to the lake.
- Predictive modeling of nutrient loading under several landscape condition scenarios.

Stream nutrient data, sediment core analyses, phytoplankton sampling, and the Soil and Watershed Assessment Tool (SWAT) watershed model form the basis for this TMDL. SWAT is a public domain model actively supported by the USDA Agricultural Research Service (Arnold et al, 1995).

Three primary tributary sites, Big, Benson, and Murphy Creeks, were selected and sampled during both base flow and storm events to begin to represent watershed conditions. Johnson Creek was added as a core site later in the study.

| Table 16 – Monitoring Network | | |
|---|---|---|
| **Lake Tributary Water Quality Sample Sites** | **% of watershed size** | **Predominant Land Use** |
| Johnson Creek | 24 | agriculture, forest, sparse rural residential |
| Benson Creek | 13 | agriculture, forest |
| Unnamed Tributary to Benson Creek (called Rex) | 1 | small tributary, forest land use (recent management) |
| Murphy Creek | 4 | forest, wetland |
| Big Creek | 19 | agriculture, forest, sparse rural residential |

**Figure 6 - Graphic Depiction of the Primary Nutrient Budget Project Sample Sites**



These sites were selected based upon their representativness of catchment size and land use patterns. Additional sites were sampled in several locations in the watershed, on a less frequent basis, to complement core information. Stream discharge and chemistry data were used to calibrate SWAT, a watershed model, in order to estimate annual loads of sediment, nitrogen, and phosphorus to the lake from other unmeasured tributaries.

Four lake sites were selected for routine sampling and were comprised of two each in North and South Tenmile Lakes and at the outlet on Tenmile Creek. The lake sites were selected to represent both North and South Lake deep water, mid lake sites (A), as well as sites selected because of their close proximity to major tributary arms (B). Lake sites were sampled for sediment accrual rates, nutrients, phytoplankton, and profile conditions (e.g. dissolved oxygen, temperature, specific conductance, etc.).

The Tenmile Lakes core water quality sampling sites

- 2 sites in North Tenmile Lake NTA & NTB (A=mid basin, B=major arms)
- 2 sites in South Tenmile Lake STA & STB (A=mid basin, B=major arms)
- Tenmile Creek @ South Tenmile Lake outlet (TLO)

Sediment cores were collected from both lake basins and analyzed for rates of sediment accumulation. Selected sediment cores were analyzed for nitrogen, nitrogen isotope ($^{15}N$), cyanobacterial akinetes, and fossil diatoms.

The Tenmile Lakes sediment core sampling sites

- South Lake, STA
- North Lake, NTA
- North Lake Tributary/Major Arm, NTB
- Lindros Arm

## ***5.2 SUMMARY OF STUDY RESULTS***

### 5.2.1 Stream Nutrients

The results of stream monitoring showed that Big, Benson, and Johnson Creeks had discharge water with concentrations of sediment and nutrients about tenfold and threefold, respectively, greater than were measured at Murphy Creek.

Murphy Creek is distinguished from the other two sites by the presence of a major restored wetland at the stream mouth extending up the channel for about 2.5 km. Maximum concentrations of total suspended solids (TSS) at Murphy Creek never exceeded 12 mg/L, whereas values of 580 mg/L and 423 mg/L were measured at Benson and Big Creeks, respectively. Concentrations of both TSS and total phosphorus in the streams were strongly related to stream discharge, whereas stream nitrate concentrations were related to season. Nitrate concentrations measured in lake tributaries were greatest during the fall early rains and declined through the winter and into spring.

### 5.2.2 Lake Nutrients

Water quality in the Tenmile Lakes varied considerably in time and space. Water quality was generally the most favorable in winter, although the lake was episodically visibly impacted by high inputs of suspended solids. In spring 2000, the lake experienced a major diatom bloom and produced chlorophyll a concentrations exceeding 60ug/L. A second major algal bloom occurred in late summer; in this case the phytoplankton was dominated by cyanobacteria (blue-green algae). Despite its relatively shallow depth, periods of quiescence were sufficient to allow significant oxygen depletion below depths of 4 meters. In some cases, the bottom waters were anoxic. Secchi disk transparency varied from a high of 4.9 m in November to a low of 0.6 m following a storm event.

Total phosphorus measurements collected between water years 1998 – 2001 averaged 25ug/L in the Tenmile Lakes. Nearly all measures of water quality were indicative of eutrophic conditions. Water quality in the center of the lakes was generally better than that observed near the mouths of major tributaries. The lake sites situated near major tributary confluences were characterized by high concentrations of total phosphorus, higher chlorophyll, and lower transparency than lake sites in deeper, mid lake sites. This was particularly the case at site NTB located at the intersection of the Big Creek and Carlson Arm.

## 5.2.3 Lake Algae

Sampling the lake for Microcystis aeruginosa in 2000 showed that the populations were relatively low and never exceeded 13% of the phytoplankton biomass. Despite these findings, concentrations of the toxin, microcystin, exceeded World Health Organization levels for drinking water safely. The nutrient concentrations in the Tenmile Lakes are sufficient to support robust populations of Microcystis, and variations in climatic conditions are primary factors determining its relative abundance at any given time. The single most significant factor (other than nutrient availability) affecting the Microcystis population appears to be lake temperature. The Tenmile Lakes algal population response to increasing water temperatures aligns well with other studies which indicate that growth is limited below 15$^{o}$C and optimal at 25$^{o}$C or greater (Robarts, 1987). Because of the moderately high concentrations of microcystin measured in the lake, considerable caution should be exercised through time by lakeshore owners using the lake as a drinking water supply.

## 5.2.4 Lake Sediment Cores

The analysis of the lake sediments showed that the sediment accumulation or accrual rate (SAR) has increased substantially over historical conditions. The greatest increase in SAR occurred at site NTB, Carlson Arm near Big Creek. The lowest rate of increase in SAR occurred in Lindros Arm, a site which lacks input from management activities related to agriculture or timber.

The sediment core results show that the upper sediment cores had nearly twice as much nitrogen present when compared to the older bottom portion of sediment cores. The nitrogen isotope $^{15}N/^{14}N$ ratio is also increasing suggesting that there has been a qualitative change in the source of nitrogen to the lake. The increase of $^{15}N$ would be expected if the population of N-fixing algae have increased. The increase in $^{15}N$ from nitrogen fixing algae would have had to be large to overcome the expected loss of marine derived $^{15}N$ associated with the decline in the salmonid population.

A small number of sediment intervals were analyzed for akinetes (cell structures found on some cyanobacteria) and showed a major increase in their deposition rate compared to historical rates. This finding is consistent with an increase in the biomass of cyanobacteria in the lake during the latter half of the 20th century. The diatom remains in the lake sediments show an increase in taxa such as Asterionella formosa, which are often associated with nutrient-rich waters. The relative abundance of benthic (bottom-dwelling) diatoms has greatly decreased in the lake, which is consistent with a reduction in lake transparency and increased sedimentation.

## 5.2.5 Lake Modeling

The watershed modeling using the Soil and Watershed Assessment Tool (SWAT) indicated current loads of sediment and nutrients to the lake have increased throughout the watershed when compared to historic (historical) loading. Factors most strongly associated with increased loads include land use disturbances that are persistent and close to the lake or streams. The physical aspects of modified and simplified channels near the base of the tributaries appear to provide a hydrologic condition which increases the delivery of sediment and nutrient loads to the lake. High concentrations of sediment and nutrients were measured in major tributaries which were directly sampled. The predictive model indicates that other tributaries, whose inputs were not directly measured, may contribute higher sediment and nutrients loads on a weighted-area basis.

Using published estimates of nutrient generation per capita, and estimating Tenmile Lakes' lakefront home occupancy per month, a range of monthly phosphorus and nitrogen load estimates associated with septic inputs from shoreline were generated. On an annual basis, the inputs of nutrients from the septic inputs are relatively modest, representing only about 20% of the watershed loadings. However, during the summer when tributary loads are small, the relative contribution of septic inputs increases to about 50%. Considering that the blooms of cyanobacteria occur in late summer and early fall, it is likely that septic inputs constitute an important component of the nutrient load.

Other lakefront sources of nutrient loading include lawn and garden management, riparian vegetation removal, lakeshore erosion from boat wake and wind, and erosion related to lakefront construction activities and rural residential activities.

Load reductions focus on phosphorus rather than nitrogen at this time. Because documented toxic algae blooms consist of nitrogen fixing organisms, nitrogen was not determined to be a viable limiting factor to control this problem. Similarly, many of the controls that might be implemented to reduce phosphorus loading may also reduce nitrogen loading.

### 5.2.6 Conclusions

The Tenmile Lakes Nutrient Study (TLBP 2002a) consistently showed that sediment and nutrient loads to the Tenmile Lakes are substantially elevated above historical conditions and that the water quality in the lake has declined accordingly. Measures of water quality in the lake point to eutrophic or near-eutrophic conditions, and the trends indicated in the sediments show that the level of deterioration is continuing.

## *5.3 NUTRIENTS AND WATER QUALITY*

This section provides background information on nutrient impacts on designated uses, nutrient sources and transport, and potential control strategies. This section briefly addresses the role nutrients play in the environment and provides background information on nutrient cycling, nutrient sources and transport, and potential control strategies (USEPA, 1998).

### 5.3.1 Impact of Nutrients on Designated Uses

Excess nutrients in a water body can impair multiple beneficial uses including drinking water supply, recreational use, aquatic life use, and fishery use. An example of nutrients having a direct impact would be the presence of elevated algal growth which affects color, taste and odor and nuisance algal blooms with accompanying toxin releases to the water column. Although these direct impacts are often associated with excessive nutrient loading, waters more often are listed as impaired by nutrients because of the role of nutrients in accelerating eutrophication.

### 5.3.2 Eutrophication

The nutrient enrichment of aquatic systems, is a natural aging process of a water body that transforms a lake into a swamp and ultimately into a field or forest. This aging process can accelerate with excessive nutrient inputs because of the impact they can have when other factors, such as light, are not limiting. A eutrophic system typically contains an undesirable abundance of plant growth, particularly phytoplankton, periphyton, and macrophytes.

- Phytoplankton are photosynthetic microscopic organisms (algae) and exist as individual cells or grouped together as clumps or filamentous mats.

- Periphyton is the assemblage of organisms that grow on underwater surfaces. It is commonly dominated by algae but also can include bacteria, yeasts, molds, protozoa, and other colony forming organisms.

- Macrophyte refers to any larger than microscopic plant life in aquatic systems. Macrophytes may be vascular plants rooted in the sediment, such as pond weeds or cattails, or free-floating plant life, such as duckweed or coontail. Elodea is an invasive weed that is specifically problematic in the Tenmile Lakes.

The eutrophication process quantified by Vollenweider (1968, 1975, 1976), developed a mass balance model demonstrating a strong relationship between nutrient inputs to lakes and concentration of nutrients within the lake. This relationship was sufficiently powerful to stand out against other sources of among-lake variation and signaled that nutrient loading, as modified by hydrology, morphology, and in-lake sedimentation, was the dominant factor explaining lake eutrophication.

The Tenmile Lakes' water quality conditions are clearly indicative of a eutrophic system when compared to the characteristics of eutrophic systems adapted from Rast and Lee, 1987, described in the table below.

**Table 17 - Illustration of a Typical Trophic Classification System Based on Lake Characteristics**

| Variable | General Characteristics | |
|---|---|---|
| | Oligotrophic | Eutrophic |
| Total aquatic plant production | Low | High |
| Number of algal species | Many | Few |
| Characteristic algal groups | Greens, diatoms | Blue-greens |
| Rooted aquatic plants | Sparse | Abundant |
| Oxygen in hypolimnion | Present | Absent |
| Characteristic fish | Deep-dwelling, cold water fish such as trout and salmon. | Surface-dwelling, warm water fish such as pike, perch, and bass; also bottom-dwellers such as catfish and carp |
| Water quality for domestic and industrial use | | Poor |

**The eutrophication process can impair the beneficial uses of a water body in the following ways:**

- *Aquatic life and fisheries.* These impairments can result when dead plant matter settles to the bottom where microbial breakdown processes that require oxygen occur. Eventually, oxygen in the hypolimnion of a lake can be depleted. Lowered oxygen levels can change the benthic community structure from organisms who like well aerated conditions to those who prefer conditions with less oxygen. Oxygen and pH levels can change throughout the day as a result of plant respiration.

- *Drinking water supply.* The periodic presence of toxins produced by the algae community is especially problematic in the Tenmile Lakes. When algal blooms produce toxins at levels of concern, drinking water treatment must be increased or alternative drinking water sources utilized. Algae can clog water treatment filters and disinfection of water supplies can be impaired by algal growth. These conditions can also adversely affect the taste and odor of the drinking water.

- *Recreational use.* The periodic presence of toxins produced by the algae community is especially problematic in the Tenmile Lakes. When algal blooms have produce toxins at levels of concern sufficient to result in health hazard advisories warning against recreational contact.

  Excessive plant growth in a eutrophic water body can affect recreational water use by interfering with swimming, boating, and fishing activities, and impair aesthetic uses of the water body.

### *5.3.2.1 Nitrogen*

Nitrogen is plentiful in the environment. Although available in the atmosphere, nitrogen must be converted to other forms, such as nitrate ($NO_3$-), before most plants and animals can use it. Nitrogen fixation allows conversion of nitrogen into usable forms. Another process called denitrification, converts fixed nitrogen back to the gaseous $N_2$ state.

Nitrogen related parameters were measured in the lake and tributaries of the Tenmile Lakes during the development of the Nutrient Budget. Nitrogen was shown to be transported from managed landscapes to the lake during storm runoff events. In addition, on-site systems serving lakefront homes likely contribute nitrogen during periods of lower base flows which occur during high use summer periods.

Once introduced into the aquatic environment, nitrogen can exist in several forms:

- dissolved nitrogen gas ($N_2$)
- ammonia ($NH_4$+ and $NH_3$)
- nitrite ($NO_2$-)
- nitrate ($NO_3$-)
- particulate and organic nitrogen

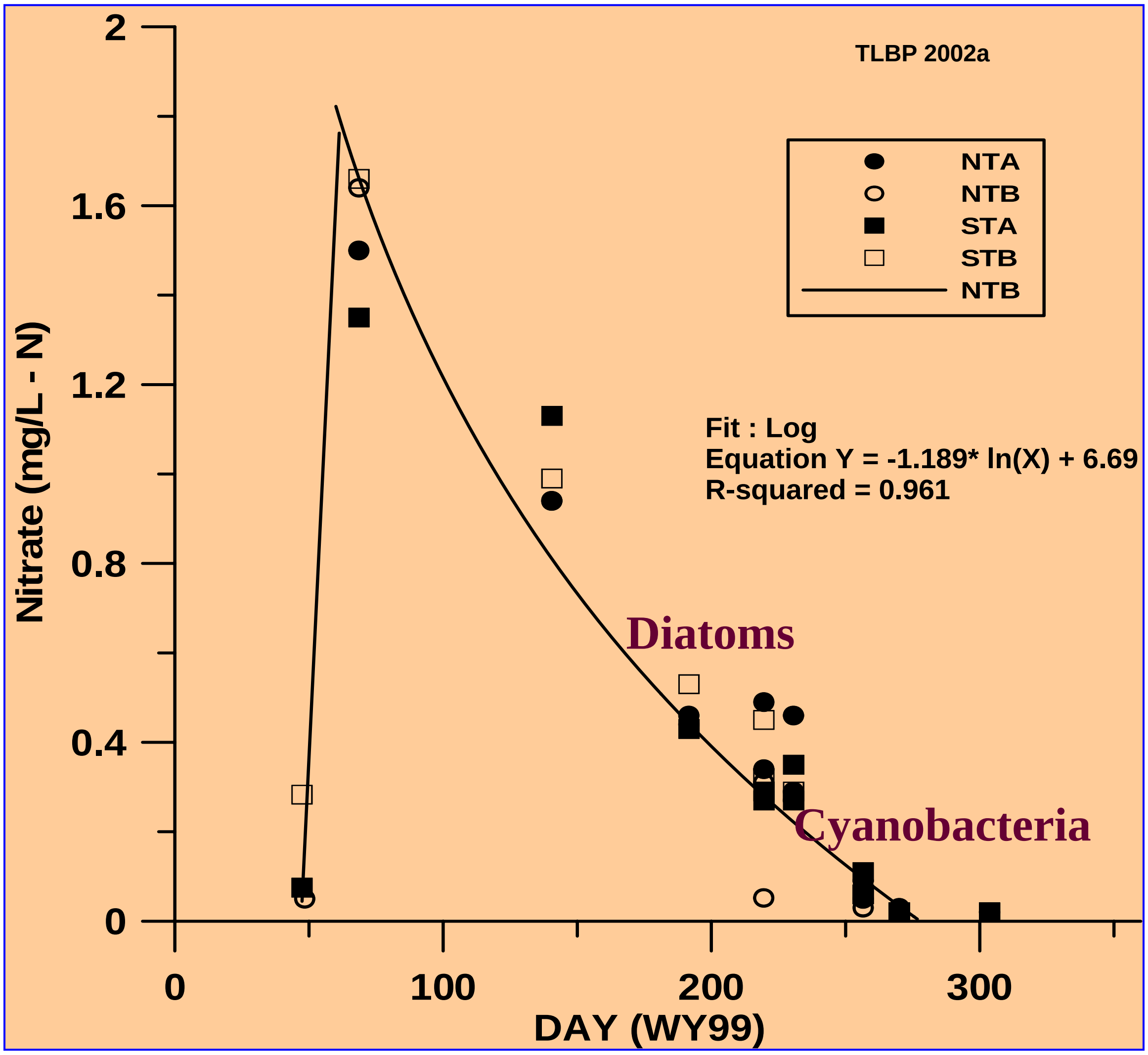
The most important forms of nitrogen in terms of their immediate impact on water quality are the readily available ammonia ions, nitrites, and nitrates (dissolved nitrogen). Organic nitrogen is largely comprised particulate matter. Particulate and organic nitrogen, because they must be converted to a usable form, are less important in the short term but the storage of this type of nitrogen can be an important influence in the long term. Total nitrogen (TN) is a measurement of all forms of nitrogen.

Nitrogen continuously cycles in the aquatic environments, although the rate is temperature-controlled and thus varies seasonally. Aquatic organisms incorporate available dissolved inorganic nitrogen into proteinaceous matter. Dead organisms decompose, and nitrogen is released as ammonia ions and then in the presence of oxygen converted to nitrite and nitrate, where the process begins again.

Nitrate is normally the most common inorganic nitrogen compound in lakes and streams and is essential to algal and plant growth. However, excessive nitrate levels may stimulate algal growth to the point of choking streams and lakes, lowering oxygen concentrations for aquatic life, and interfering with water supply systems and recreational uses. Nitrate, oxidized to nitrite, can also cause oxygen starvation in babies (blue baby syndrome) at levels exceeding 10 milligrams per liter (mg/l) as nitrogen.

The figure below depicts nitrate levels in the Tenmile Lakes. Note that because of companion algae characterization efforts, predominant organisms have been identified in conjunction with water quality nitrogen data during periods of bloom events. As summer water temperatures rise, algal blooms begin. If surface water lacks adequate nitrogen, nitrogen-fixing organisms can convert nitrogen from its gaseous phase into ammonia ions. As nitrogen levels in the lake water column begin to decrease, nitrogen fixing, blue-green algae begin to predominate (WY day 200 = April 18).

**Figure 7 - Nitrate Levels in the Tenmile Lakes**
*(Water year 1999 - October 1, 1998 to September 30, 1999)*



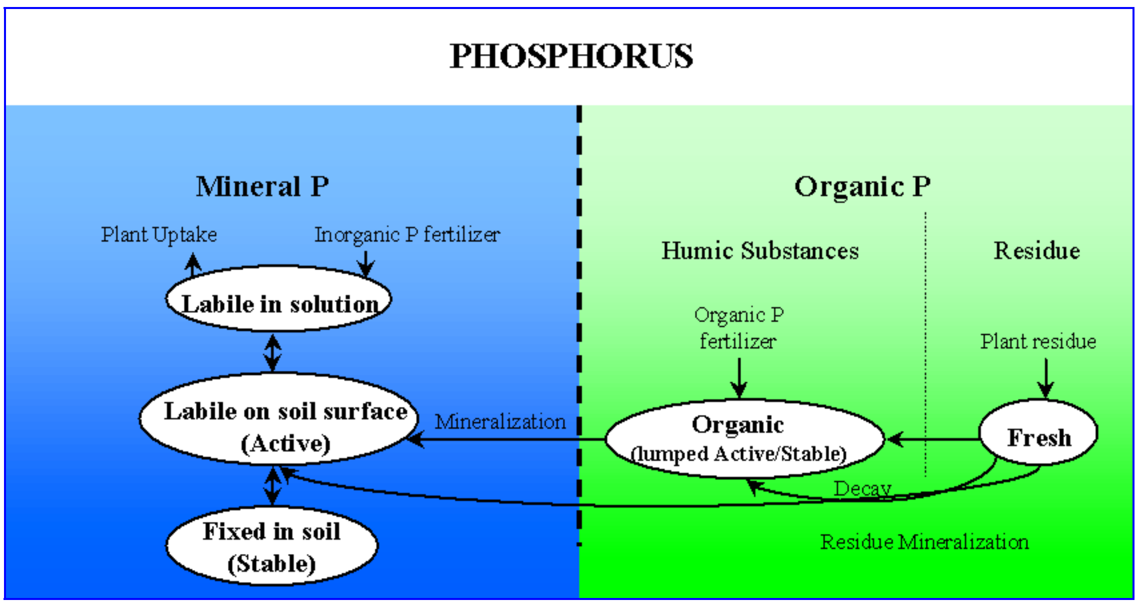

### *5.3.2.2 Phosphorus*

Under normal conditions, phosphorus is scarce in the aquatic environment. Unlike nitrogen, phosphorus does not exist as a gas and therefore does not have gas-phase atmospheric inputs to aquatic systems. Rocks and natural phosphate deposits are the main reservoirs of natural phosphorus. Release of these deposits occurs through weathering, leaching, erosion, and mining. Terrestrial phosphorus cycling includes immobilizing inorganic phosphorus into calcium or iron phosphates, incorporating inorganic phosphorus into plants and microorganisms, and the breaking down of organic phosphorus to inorganic forms by bacteria. Some phosphorus is inevitably transported to aquatic systems by water or wind.

Phosphorus in soils is almost entirely associated with soil particles. Phosphorus, because of its tendency to sorb to soil particles and organic matter, is primarily transported in surface runoff with eroded sediments. Phosphorus can sorb to sediments in the water column and on the substrate and become unavailable. Lake sediments may act as a sink for phosphorus or as a source of phosphorus in solution. Phosphates in soils are associated more with fine particles than coarse particles. When soil erosion occurs, more fine particles are delivered to a water body than coarse particles. Because of this relationship, sediment leaving a soil through erosion is enriched in phosphorus. In lakes and reservoirs, continuous accumulation of sediment can leave some phosphorus too deep within the substrate to be reintroduced at a later time to the water column. If left undisturbed however, a portion of the phosphorus in the substrate might be reintroduced to the water column. The activities of benthic invertebrates, bottom feeding fishes, and changes in water chemistry (such as the reducing conditions of lake bottom waters and sediments often experienced during the summer months in a lake) also can cause phosphorus to desorb from sediment. Because of this phenomenon, a reduction in phosphorus loading might not effectively reduce algal blooms for many years.

When fertilizers containing phosphates are added to soils, phosphate levels in water passing over or through these soils can be increased. The figure below illustrates different forms of phosphorus and their interactions.

**Figure 8 – Phosphorus Availability**

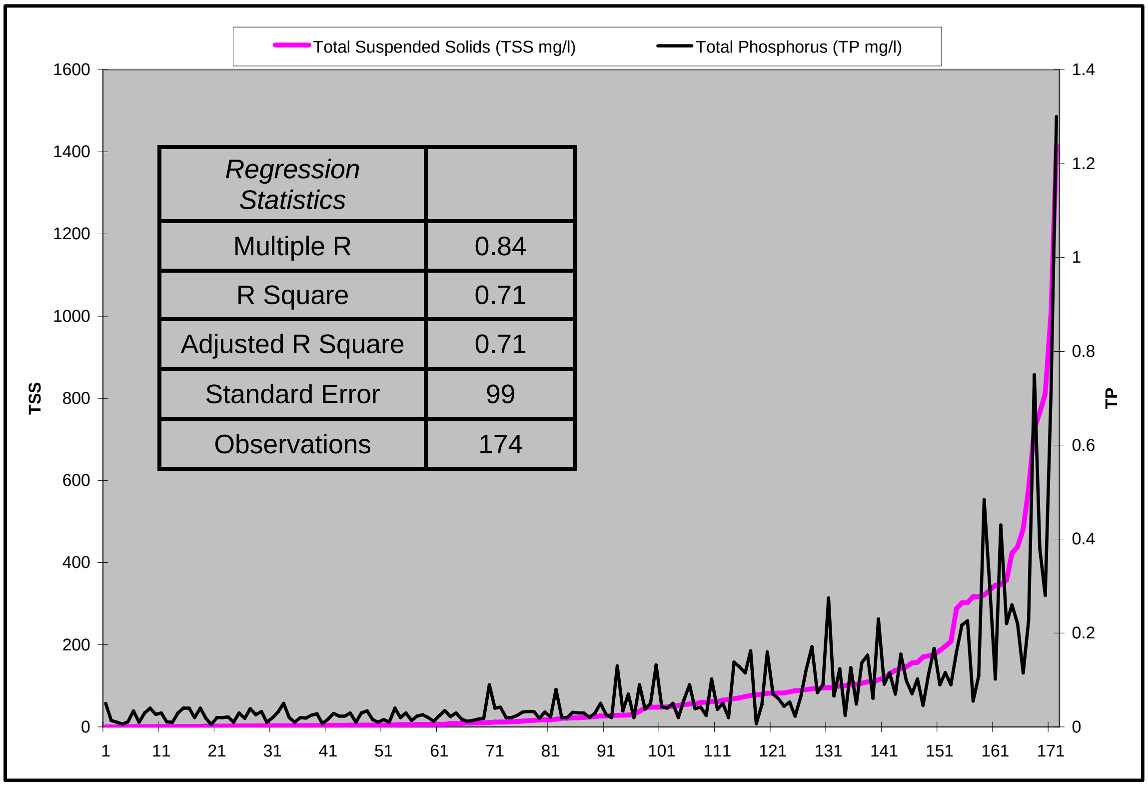



Human activities have resulted in excessive loading of phosphorus into many freshwater systems. Overloads result in an imbalance of the natural cycling processes. Excess available phosphorus in freshwater systems can result in accelerated plant growth if other nutrients and other potentially limiting factors are available.

Implementing upland sediment controls and abatement activities will help to reduce amount of sediment delivered to the lakes and consequently will, over time, reduce the amount of phosphorus that is available in the water column.

The figure below depicts the total phosphorus and total suspended solids data collected from tributaries during the Nutrient Study. Phosphorus levels increased as total suspended solids increased during storm events.

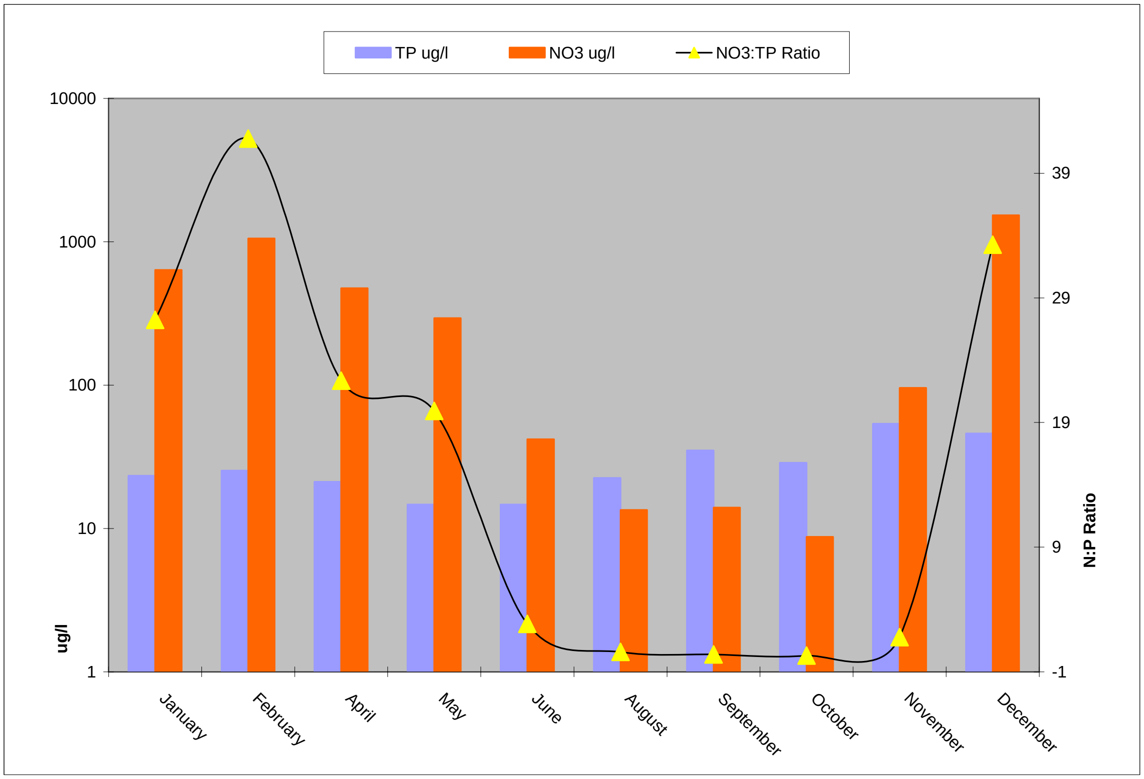
**Figure 9 – Total Suspended Solids (TSS mg/l) and Total Phosphorus (TP mg/L) Relationship for Tributaries**




### *5.3.2.3 Nitrogen to Phosphorus Ratio*

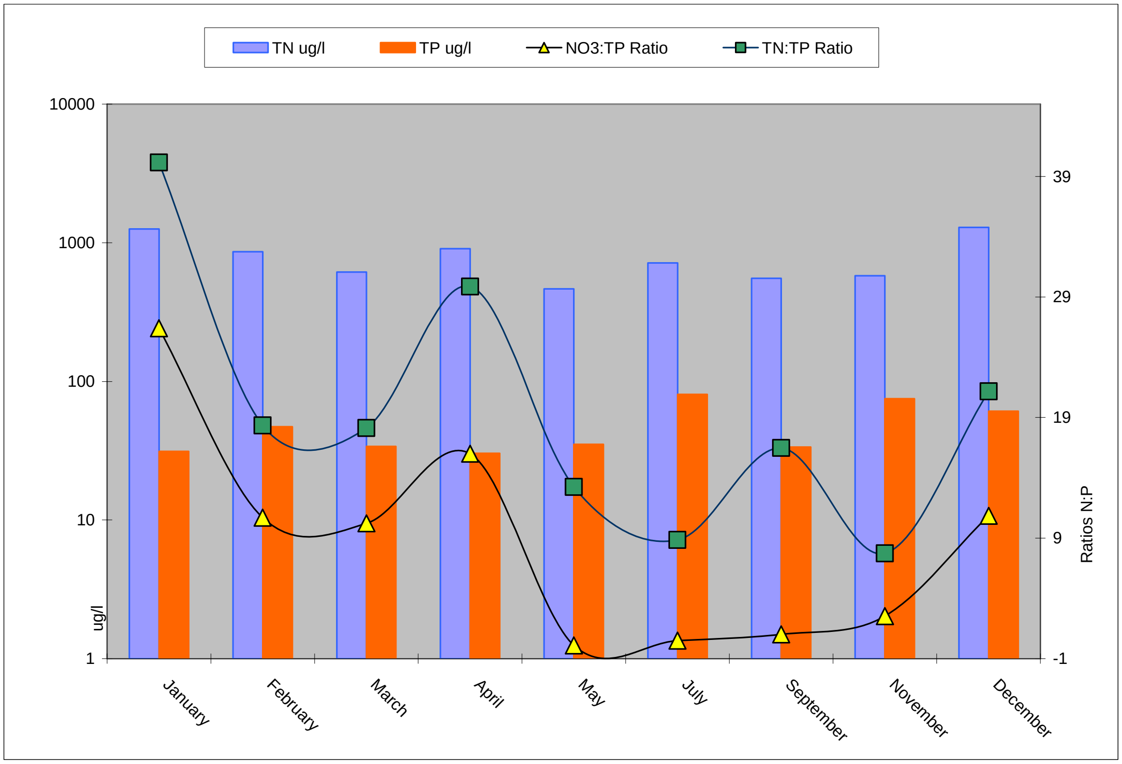
All phytoplankton require nitrogen for their growth, but mounting scientific evidence suggests that under conditions of nitrogen limitation, cyanobacteria may be better competitors than are other phytoplankton. Like terrestrial legumes, several species of cyanobacteria have a specialized structure called a "heterocyst" that can be used to fix molecular nitrogen gas ($N_2$) dissolved in the water. In contrast, other phytoplankton species are only able to use dissolved inorganic nitrogen in the form of nitrate or ammonia, just as nonlegume terrestrial plants do. Nitrogen: phosphorus (N: P) ratios less than about 10:1 by weight in a waterbody's nutrient supply create conditions of nitrogen limitation, and these low N: P loading ratios have been found to strongly favor dominance by heterocystous cyanobacteria. Extensive evidence worldwide supports this N: P ratio hypothesis, even when it is extended to *all* species of cyanobacteria. (Smith, 2001)

**Figure 10 - Lake Seasonal Nitrogen Phosphorus Relationships 1999-2001**




| Table 18: Monthly Average Nitrate: Total Phosphorus Ratio<br>All Lake Sites 1999-2001 | |
|---|---|
| **Month** | **$NO_3$ -:TP** |
| January | 27 |
| February | 42 |
| April | 22 |
| May | 20 |
| June | 3 |
| August | 0.6 |
| September | 0.4 |
| October | 0.3 |
| November | 2 |
| December | 33 |

**Figure 11 - Lake Seasonal Nitrogen Phosphorus Relationships 2004-2005**




| Table 19: Monthly Average Total Nitrogen: Total Phosphorus and Nitrate: Total Phosphorus Ratios All Lake Sites 2004-2005 | | |
|---|---|---|
| **Month** | **TN:TP** | **$NO_3$-:TP** |
| January | 40 | 26 |
| February | 18 | 11 |
| March | 18 | 10 |
| April | 30 | 16 |
| May | 13 | 0 |
| July | 9 | 0 |
| September | 16 | 1 |
| November | 8 | 3 |
| December | 21 | 11 |

### *5.3.2.4 Other Factors Influencing Weed and Algal Growth*

Many other factors can combine to determine rates of plant growth in a water body. First of these factors is whether sufficient phosphorus and nitrogen exist to support plant growth. The absence of one of these nutrients generally will restrict plant growth. In inland waters, typically phosphorus is the limiting nutrient of the two, because blue-green algae can "fix" elemental nitrogen from the air as a nutrient source. Many other, natural factors, including light availability, temperature, flow levels, substrate, fishery (grazing), and elevation, control the levels of macrophytes, periphyton, and phytoplankton in waters.

Effective management of weeds and algae in a water body may require multiple approaches.

- Light availability. As the lakes gets shallower light is able to penetrate deeper into the water column and can allow light to reach the bottom, increasing the amount of light available for photosynthesis.

- Temperature. Temperature affects the rates of photosynthesis and algal growth, as well as the composition of algal species. Algal community species composition in a water body often changes with temperature. Diatoms often dominate in cooler waters with green and blue-green algae populations dominating at warmer temperatures.

- Substrate. Aquatic weeds prefer areas of fine sediment in which to root.

- Grazing. Populations of algae-consuming grazers can directly effect algal populations. The historic shift in fishery populations in the lakes (cold water to warm water fishery) likely provides a friendlier environment for the blue-green algae community.

## 5.4 HYDROLOGY

### 5.4.1 Modified Stream Channels

Many agricultural lowlands have modified channels present for the purpose of flood control and drainage improvement. Other modified channels in the watershed include managed drainage ways within the city of Lakeside. Stabilization projects as well as the clearing, cleaning, straightening, widening, deepening, or relocating of existing stream channels fall into this category. These forms of hydromodification typically result in more uniform channel cross sections, steeper stream gradients, and reduced average pool depths.

Agriculture activities in the Tenmile Lakes Watershed consist primarily of pasture land and hay fields in the valley lowland areas. Stream reaches in these areas were historically wetlands or low forest. These typically low gradient reaches and can act both as sediment sources and depositional areas. The historical management of agricultural wetlands in the watershed has resulted in channel straightening and in many cases placement of stream channels to the fringes of finger valleys. Levees are sometimes placed along stream banks to prevent flooding in adjacent areas during extreme high-water events.

High flows and velocities in these channelized streams tend to scour the banks and stream bed, with net erosion being the result. Once a steam has breached its banks and covered the flood plain, water velocity is slower and suspended solids settle out of the water column. Farmers along these streams recognize this process as a source of their productive soils.

**Benson Creek Finger Valley and Channelized Stream**


Maps of channel modifications, shown by watershed quarter sections, are presented in the figures that follow (TLBP, 2003).

**Figure 12 – Channel Modifications Northeast**

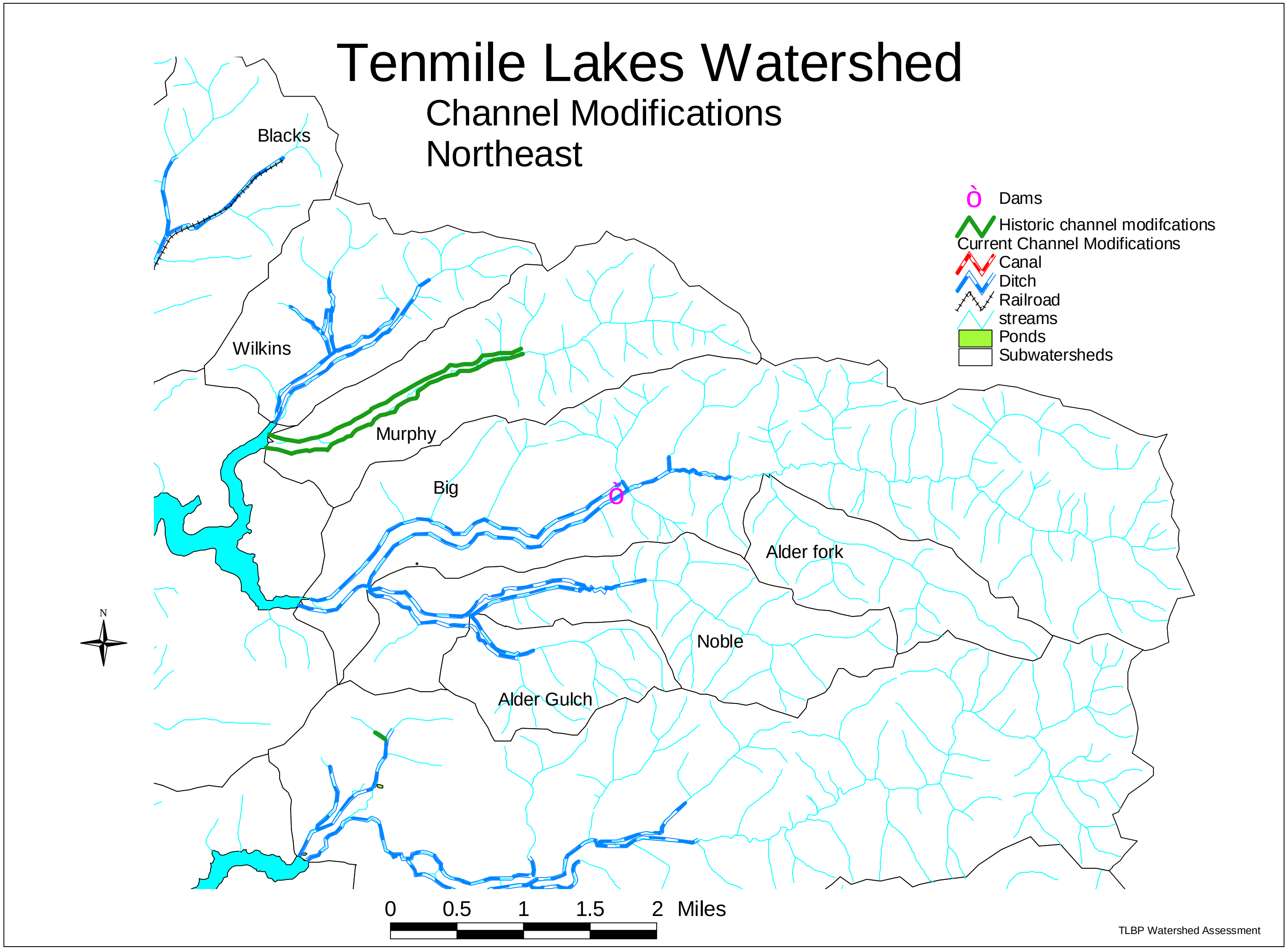


**Figure 13 - Channel Modification Northwest**

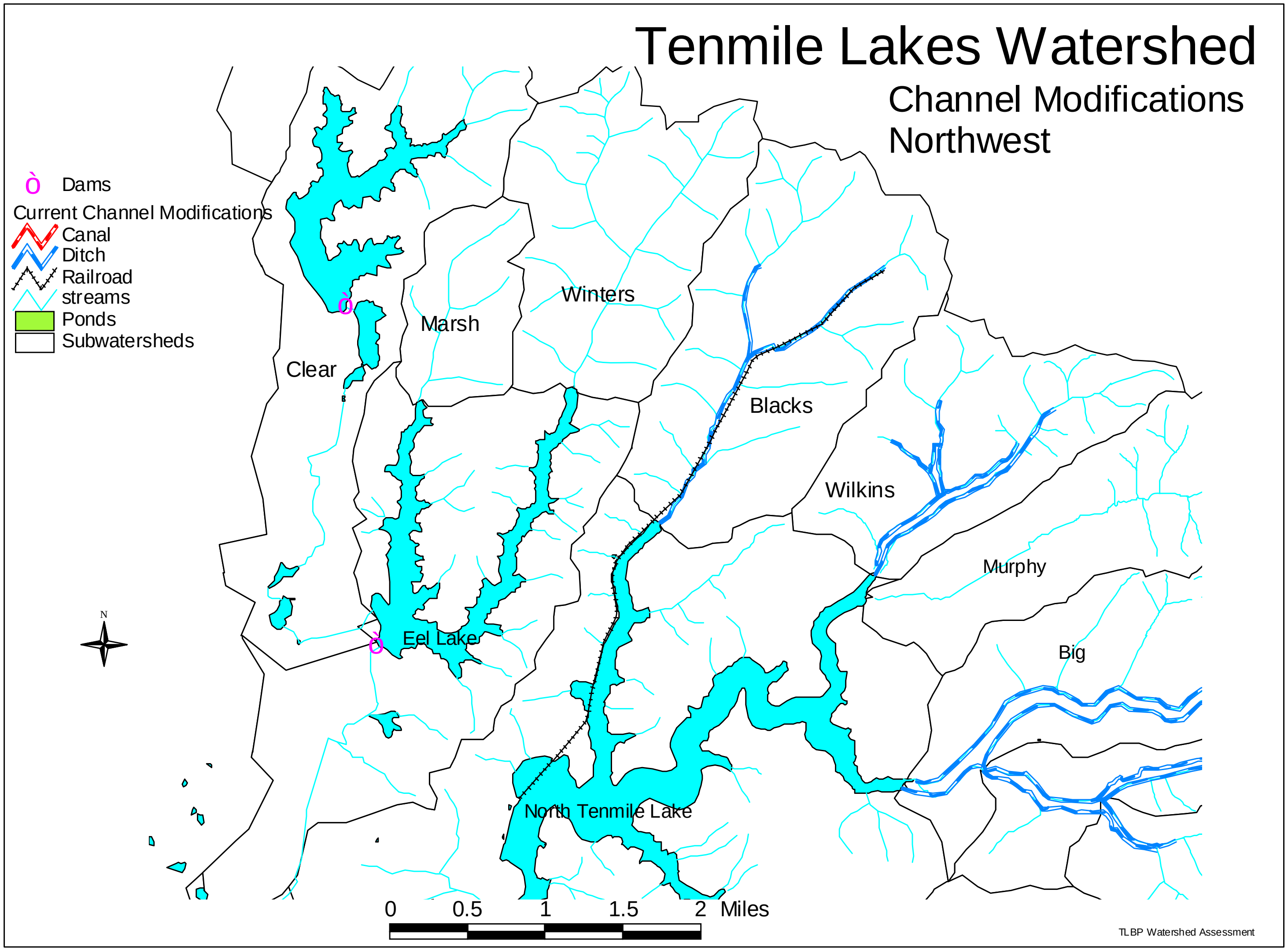


**Figure 14 – Channel Modifications Southeast**

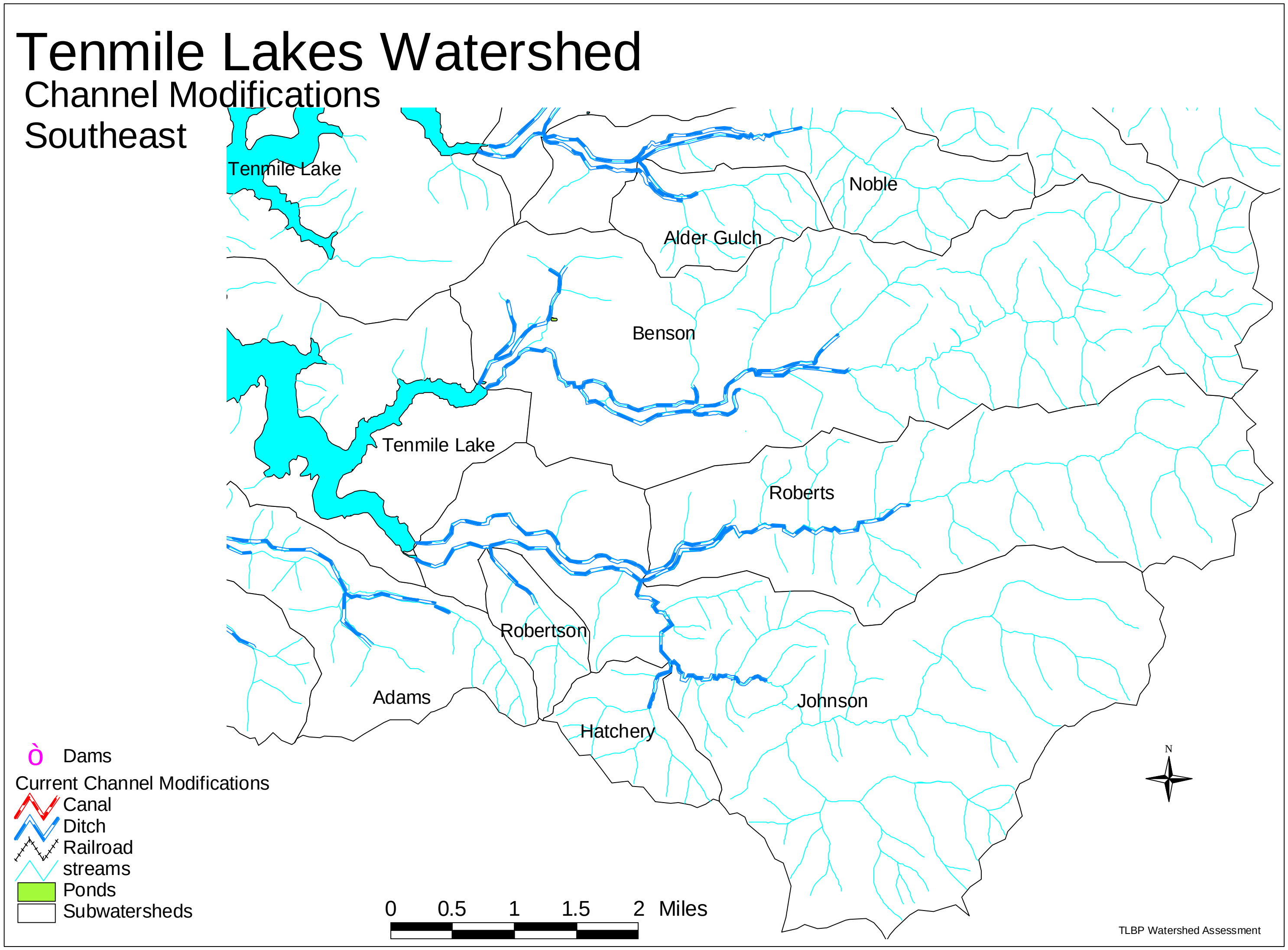
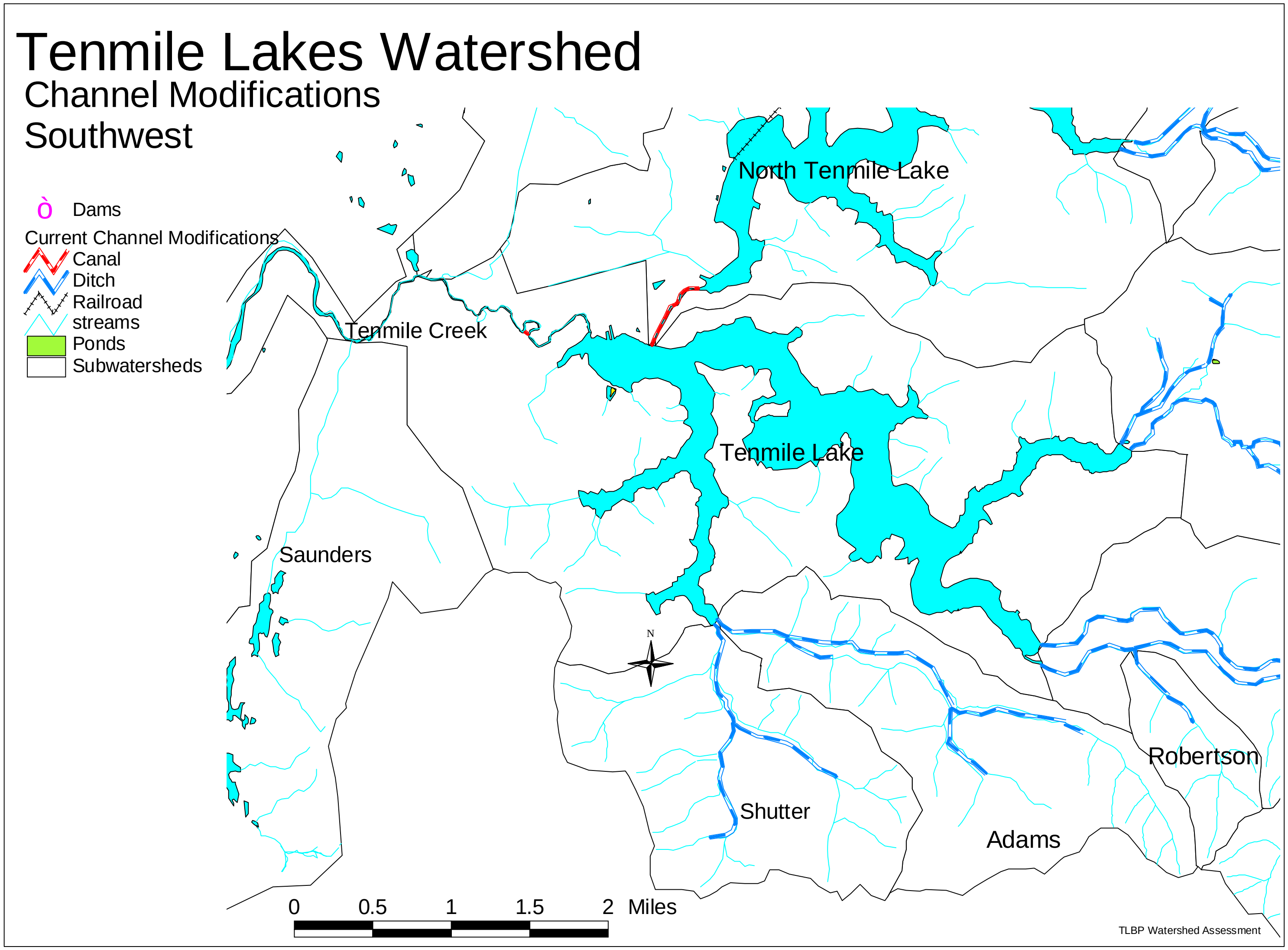


**Figure 15 – Channel Modifications Southwest**

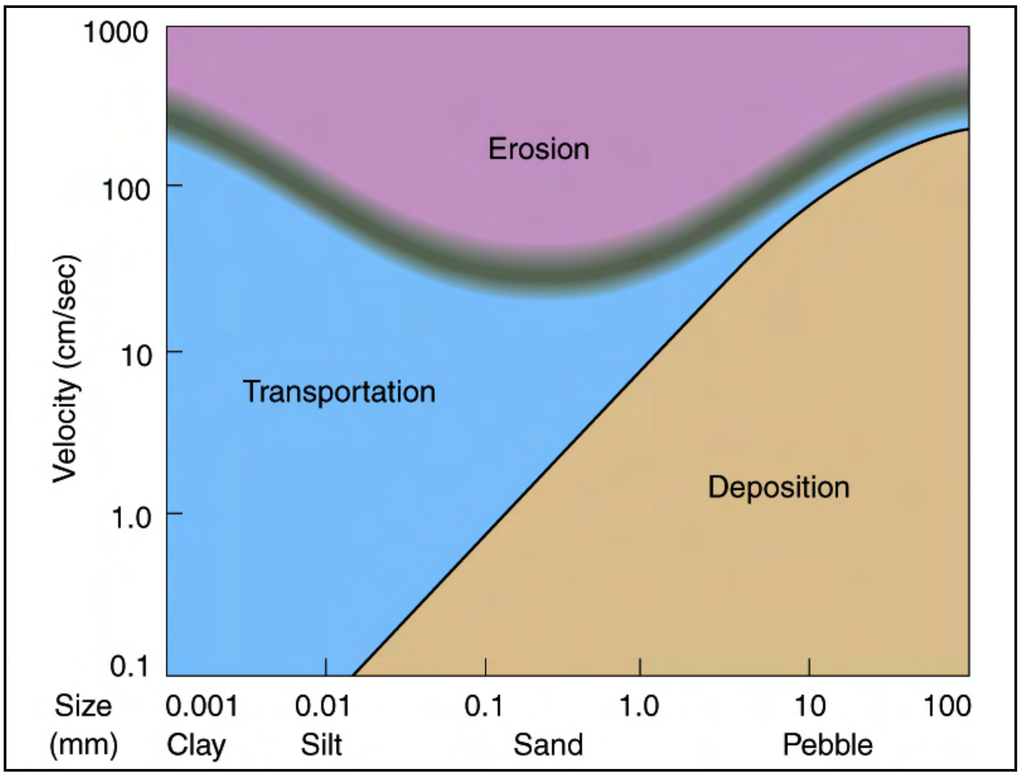


### *5.4.1.2 Accelerated Delivery of Pollutants*

Channel modification projects can lead to an increased quantity and accelerated rate of delivery of pollutants to downstream sites. Channel changes that increase the velocity of surface water or that increase flushing of the streambed during high flow events can lead to more pollutants being transported to downstream areas at faster rates. In many instances Tenmile Lakes Watershed tributaries that once meandered and contained wetland vegetation to filter out nutrient and sediment are now channelized. Channel modifications have increased the movement of NPS pollutants from the upper reaches of watersheds into the lakes (Sherwood, 1990; USEPA, 1993).

The figure below depicts Hjulstrom Curves (Graf 1971) where two important points are illustrated: Because sediments are denser than water, they do not float; they sink. With enough applied energy, the sediments move up into the water column. Hjulstrom's curve depicts a description of the amount of energy needed to get sediments of different sizes up into the water column (erosion) and to mobilize or displace them (transportation). Lower the energy and the particle drops out of the water column and is deposited.

**Figure 16 - Hjulstrom Curves**




Suspended sediment levels entering the lake are much larger than those at the lake outlet. Because streams velocities dramatically decrease after entering the lake, sediment is readily deposited. The large seasonal fluctuation in lake stage corresponds with considerable variation in the hydraulic residence time in the lake. High discharge from the tributaries in the winter reduce the hydraulic residence time in the Tenmile Lakes to approximately 15 days, compared to a residence time of 30 days in the spring and 300 days in the summer.

### *5.4.1.3 Loss of Contact with Valley Wetland Areas*

Instream hydraulic changes can decrease or delay surface water contact to valley wetlands and riparian areas during floods or other high-water events. Channel modification activities that lead to a loss of surface water contact in wetland valleys may result in reduced filtering of NPS pollutants by streamside and wetland area vegetation and soils.


**Channelized Stream - Streambank Erosion**

Areas of the valleys that are dependent on surface water contact (i.e., riparian areas and wetlands) may change in character and function as the frequency and duration of flooding change. Increased stream velocities confined within the modified channel can result in increased stream bank erosion. Modified channels which confine flows can result in increased transport of sediment, nutrients, and other NPS pollutants to the lakes during high flow events. (Sherwood, 1990; USEPA, 1993)

Benson Creek is an example of a managed stream which has been channelized and although it does continue to make contact with its floodplain, larger storm events are needed for this to occur. Because Benson Creek is confined to its channel for a longer period of time, it transports more sediment to the lake for a longer period of time than do streams with improved connectivity to adjoining wetlands. In addition, Benson Creek stream bank instability is resulting in channel widening, and the loss of adjoining pasture lands to erosion.

In the case of Benson Creek the much larger channel confines high water velocities much longer prior to flows making contact with adjacent wetlands and riparian areas. Sediments are transported more efficiently at these higher velocities.


**Benson Creek**

### *5.4.1.4 Channel Maintenance Activities*

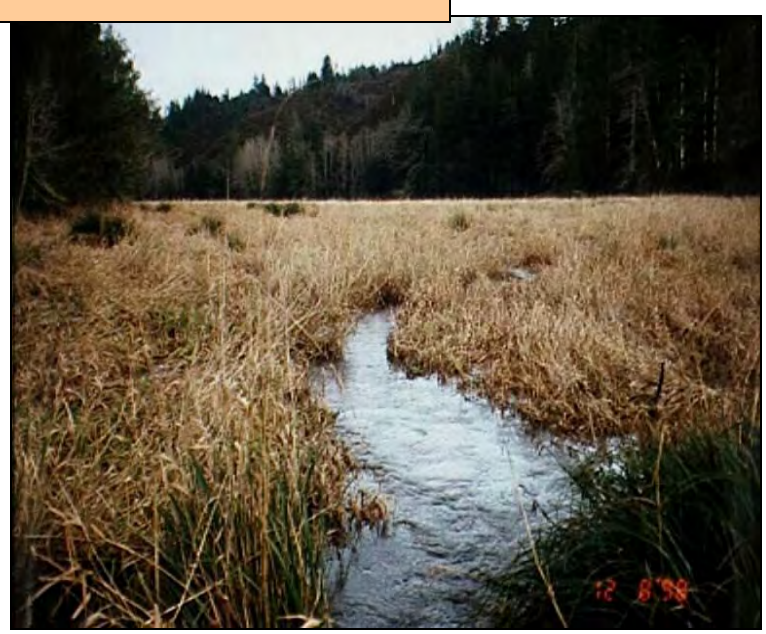
Maintenance activities conducted on channelized streams also result in episodic disturbances of instream and riparian habitat.

Channel designs which can allow streams to make contact with valley wetland pastures, while also providing a desired level of flood protection to adjoining lands, are desirous.

## 5.4.2 Stream Channel Recovery

Conditions in a watershed like Murphy Creek allow the stream to make contact with its floodplain quickly during storm events. Wetlands in Murphy Creek extend through the entire valley floor. Murphy Creek was formerly channelized, but for the last 20 years has been relatively unmanaged. As shown in the following pictures, during storm events, the Murphy Creek channel fills quickly and then flow moves in a lateral direction allowing sediment-laden waters to make contact with adjacent wetlands and riparian areas that serve as depositories for sediment and nutrients.

**Murphy Creek**



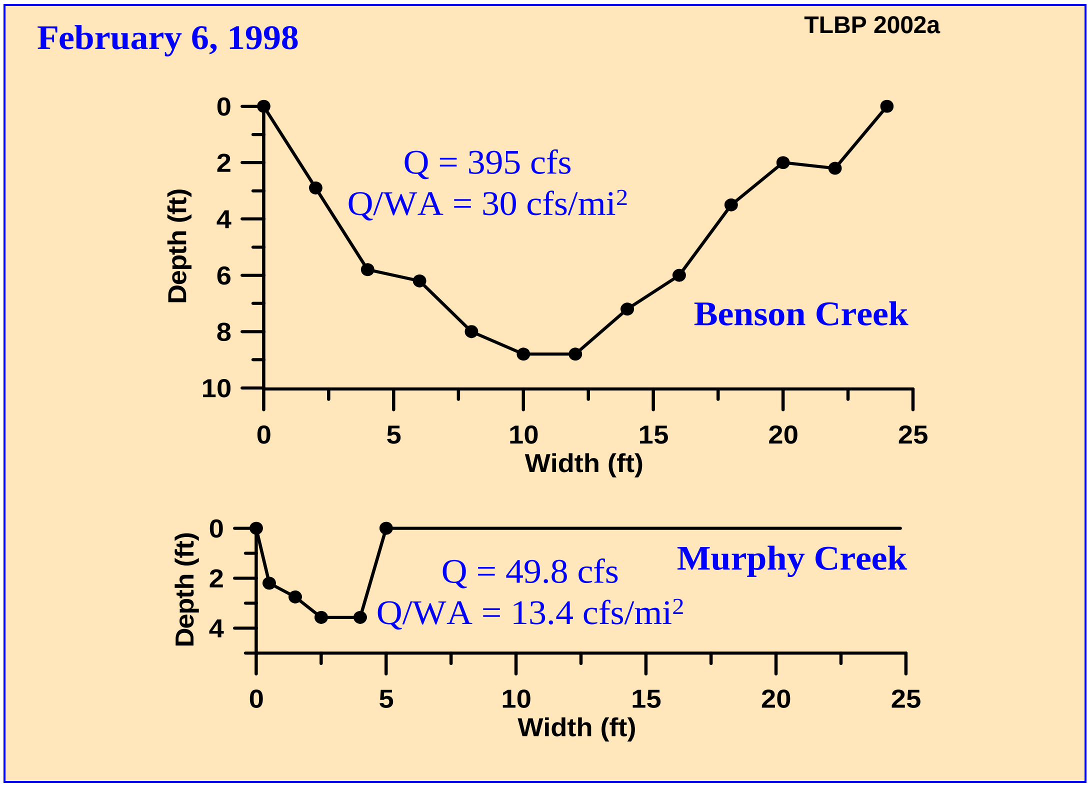
### *5.4.2.1 Channel Dimension and Discharge Comparison*

The discharge response in Murphy Creek was in sharp contrast to that observed in Big and Benson Creeks. The stream channel for Murphy Creek adjacent to the sampling site was narrow (5 feet wide) and relatively deep (3.5 feet) and highly vegetated. Its capacity to carry discharge was very limited and consequently stream discharge would often exceed the stream channel carrying capacity, resulting in sheet flow extending across the broad marsh (5-25 feet).

Benson Creek has a much larger and deeper channel (25 feet wide and 9 feet deep) and velocities were measured to be nearly eight times higher. The stream remains confined in the larger channel for a longer period of time. Because of the channel geometry, maximum stream velocity in Murphy Creek was about 2 feet/second, compared to values up to 4 feet/second in Big and Benson Creeks. When in channel flows are adjusted based upon watershed area (Q/WA) flows confined to the Benson Creek channel are over twice those measured within the Murphy Creek. The transport of total suspended solids to the lake from Benson Creek is much larger under these conditions that from Murphy Creek.

The following figure compares Murphy Creek channel features to those of Benson Creek.

**Figure 17 - Comparison of In Channel Flow (Q) of Benson and Murphy Creeks in Low Gradient Reaches (Plotted as depth of stream to width of stream)**

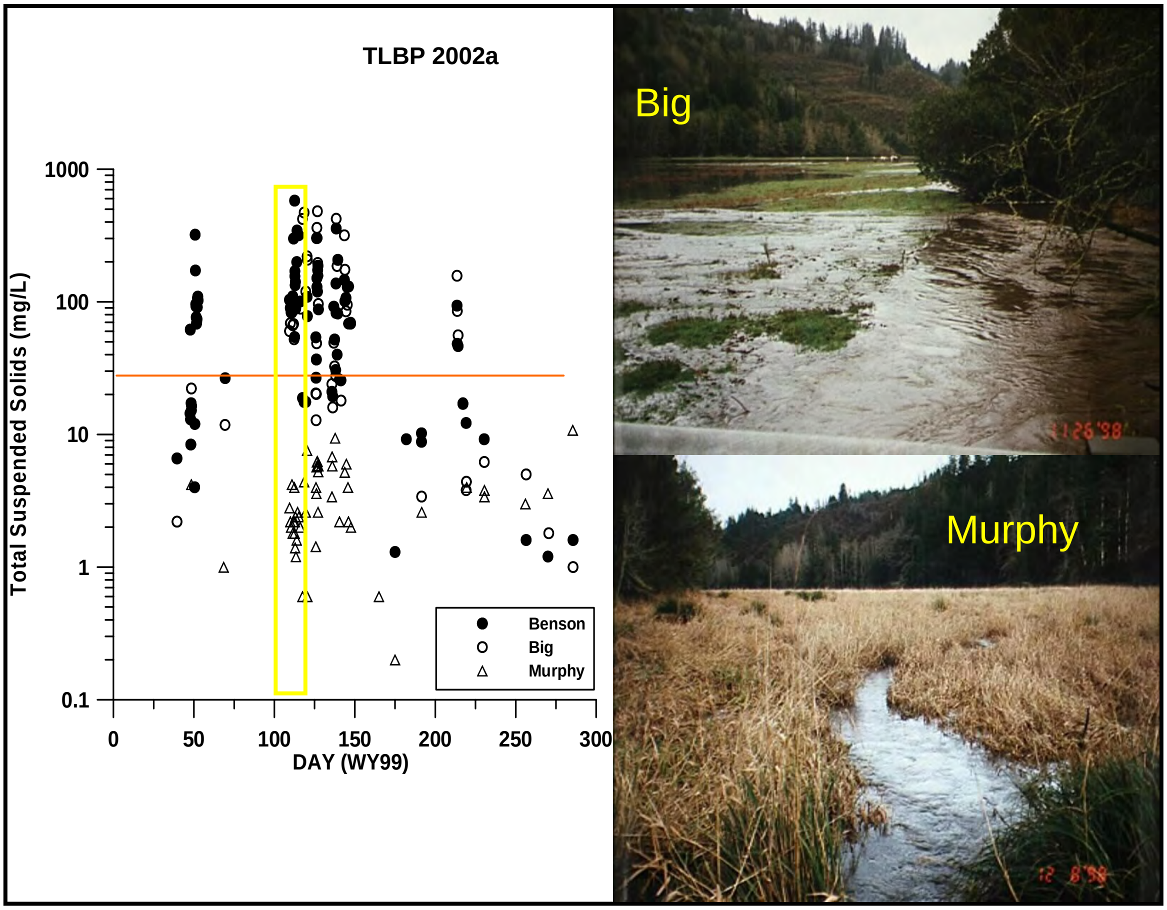



The figure below shows total suspend solids mg/L (TSS) data collected from the lower stations in Benson, Big, and Murphy Creeks. Note that the concentrations of TSS for Murphy Creek are much lower than those for Benson and Big Creeks. Modified channels have resulted in increased channel velocities and transport of suspended sediment from upland sources to the lakes during high flow events. This increased sediment transport results in part from loss of overbank contact with historic wetlands where velocities were low and sediments were filtered by vegetation.

Data for Murphy and Adams Creek reveals that TSS levels measured above the wetland are reduced by 80% for Murphy and 95% for Adams after passing through the wetland stream reach prior to discharge to the lake. As little data is currently available future data collection efforts should incorporate additional monitoring of TSS in stream reaches prior to and after leaving wetland landscapes. This data was utilized in modeling to support load derivation in this TMDL. The restored wetland modeled scenario and subsequent catchment loading ties directly to loading from modified stream channels.

It should be noted that the Adams Creek stream channel has recently been channelized (managed) in a very traditional manner and wetland function has been diminished.

**Figure 18 - TSS - Benson, Big, and Murphy Creeks**
*(Water year 1999 - October 1, 1998 to September 30, 1999)*

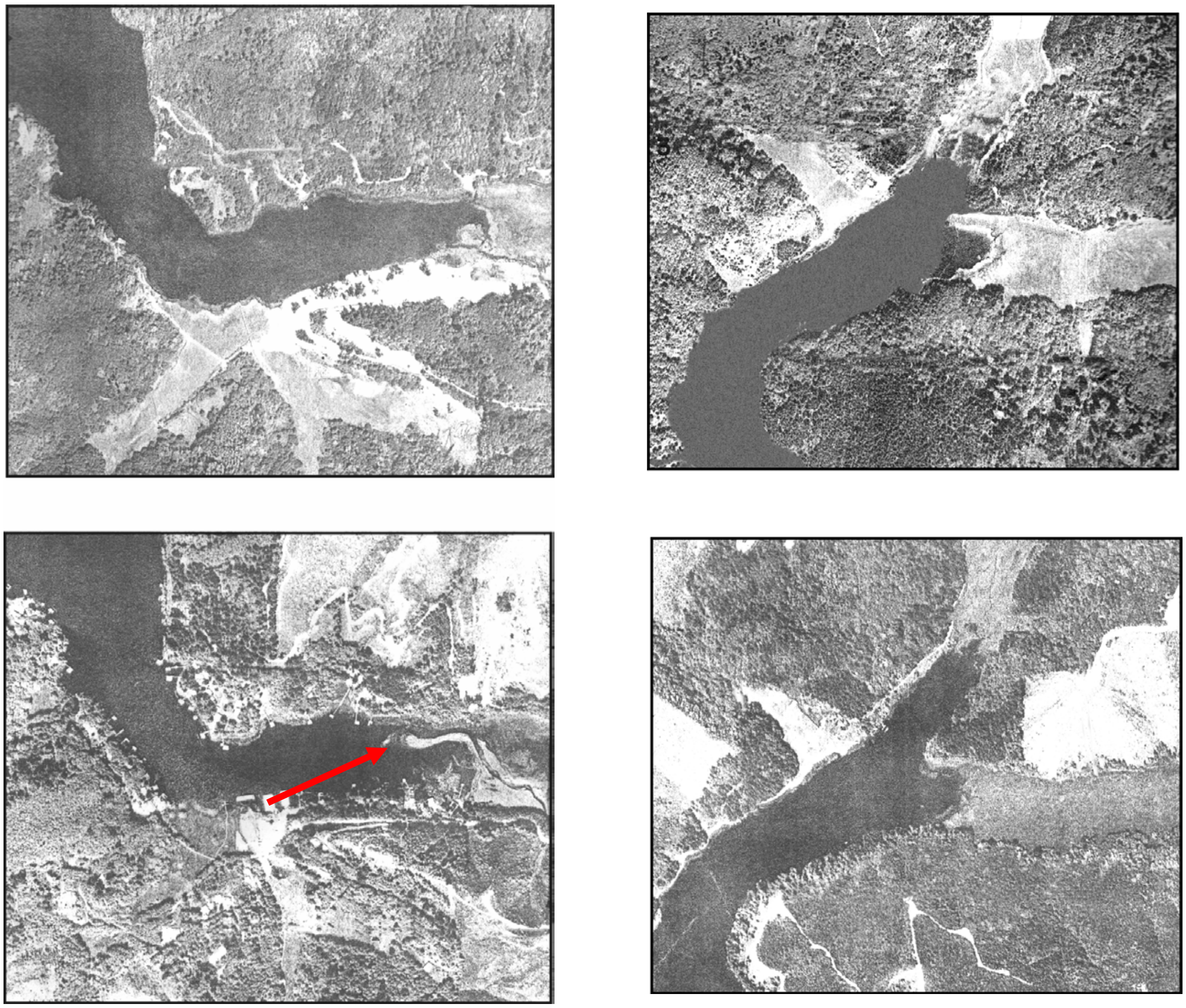


The left side of the figure below depicts aerial photographs North Tenmile Lake in 1967 (above) and 1994 (below) illustrating the encroachment of the Big Arm Creek delta into the embayment. Note the increase in boat docks established along the shoreline.

The right side of Figure 16 depicts Carlson Arm (North Tenmile Lake) in 1967 and 1994 showing the inlets for Wilkins Creek (north) and Murphy Creek (east). Little delta building is visible in contrast to the Big Arm Creek embayment.

**Figure 19 - Aerial Photographs of Delta Formation at Big Arm (L) and Murphy Creek (R)**

1967 Top Photographs (Before)



1994 Bottom Photographs (After)

The rate of delta building observed at the mouths of tributaries provides further support for the finding of accelerated sediment delivery from modified systems. These deltas can be viewed, in part, as the system reconstructing the wetland interface between the lake and tributaries lost though stream channelization. It should be noted that functional wetlands have a finite carrying capacity for sediments. If upland sediment abatement is not implemented wetlands at the lake interface would also begin to fill.

In 1967 Murphy Creek lowlands were being used for cattle grazing, much as other lowland areas in the watershed are currently being used. At that time, the uplands were fully forested in Douglas fir. By 1994, both the lowlands and uplands had changed. The cattle were removed from the lowlands circa 1980 (Sally Thomas, pers. comm. 2002) and have remained off the land through the present. However, the northern uplands portion of the catchment was clear-cut in 1993/1994. Despite this timber harvest, there was little change in the shape or extent of wetlands at the mouth of Murphy Creek.

In 1967, the Big Creek lakeshore embayment was largely undeveloped, with only two docks visible in the aerial photograph. By 1994, approximately 18 private docks are visible and a commercial marina is present. Although some recent timber harvest was evident on the south side of the embayment in 1967, a much more extensive clear-cut was present on the north side in 1994. In addition, the mouth of Murphy Creek showed little change in the intervening 27 years while an extensive delta formed at the mouth of Big Creek. The Big Creek stream channel had changed locations to the north side of the embayment as a result of either management or as a consequence of the elevated sediment load. The docks on the east end of the embayment (from Sun Lake Marina eastward) are now experiencing rapid shoaling and difficulty in accessing the lake. Ongoing survey work is being conducted to better quantify delta building rates.

# CHAPTER 6 - POLLUTANT LOADING ASSESSMENT

## *6.1 TOTAL SUSPENDED SOLIDS (LAKE TRIBUTARIES)*

### 6.1.1 The Relationship of Total Suspended Solids to Weeds and Algae

Although macrophytes (rooted plants) require nutrients for growth, the immediate origin of those nutrients is still a matter of some controversy. Originally it was thought that macrophytes may compete with algae for nutrients in the water; this may be the case for floating species, such as duckweed or coontail. Evidence suggests that rooted aquatic plants draw most, if not all, of their nutrients from the sediments, not from the water. In this manner, they can access nutrients from the sedimented historical phosphorus. This use of historical nutrients obscures or even eliminates correlations and predictions of macrophyte biomass based on contemporary nutrient loading. It also discourages the management of macrophyte-based eutrophication by nutrient loading control because the macrophytes may persist, and most likely even spread, after nutrient reduction.

Phosphorus in soils is almost entirely associated with soil particles. When erosive forces carry sediment to water, phosphorus is contained in this sediment. The rate of sediment delivery can be quantified by measuring water column total suspended solids. Sediments in a lake bottom may act as a sink and store phosphorus or as a source of phosphorus in solution. Phosphorus in solution is readily available for use by algae. Control of sedimentation from tributaries to the lakes, as reflected in reduction in the delivery of total suspended solids (TSS), is likely a better measure of the reduction of the creation of physical conditions which favor macrophytes rather than that of reducing their nutrient supply.

Phosphorus present in the lake during the summer months is primarily dissolved orthophosphorus or phosphates ($P0_4$). The availability of phosphate governs the rate of growth of many organisms, including plants and algae. Elevated levels of phosphate in lakes contributes to ecological disequilibrium, and often leads to booms in the population of some organisms and subsequent busts in the populations of others deprived of other nutrients or essential elements by the rapid growth and consumption by the booming population. Lake bottom sediments provide stored phosphorus to the lake water column by a variety of mechanisms. Dissolved phosphorus in the lake water column directly links to algae composition and nuisance algae blooms.

## *6.2 SEASONAL VARIATION AND CRITICAL CONDITIONS CWA §303(D)(1)*

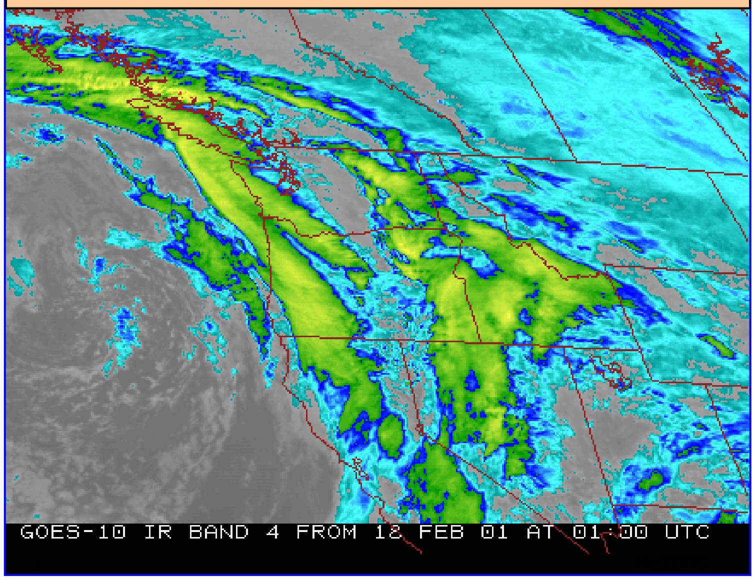
TMDLs by law and regulation must describe how seasonal variations were considered. There is inherent annual and seasonal variation in the delivery of sediment to stream systems.

Regulations (40 CFR 130.7) state that TMDLs shall take into account critical conditions for stream flow, loading, and water quality parameters.

## 6.2.1 Hydrological Events Triggering Sediment Loading

Sediment loading discussions relating to any given water body must be placed in the context of the magnitude of the hydrological event being monitored and/or modeled. When comparing various studies it is important to assure that hydrologic events of similar magnitude are being compared. Both field collected flow information as well as information quantifying storm magnitudes has been utilized in the development of this TMDL assessment.

**Nutrient Loading Is Often Triggered By Storm Events**




Precipitation Frequency is a term commonly used in the same manner as flood frequency (e.g. 100-year flood). The American Meteorological Society Glossary of Meteorology defines rainfall frequency as; "The probability distribution specifying the exceedance probability of different rainfall depths for a given duration. The exceedance frequency is often reported as a return period in years, which is the reciprocal of the annual exceedance frequency."

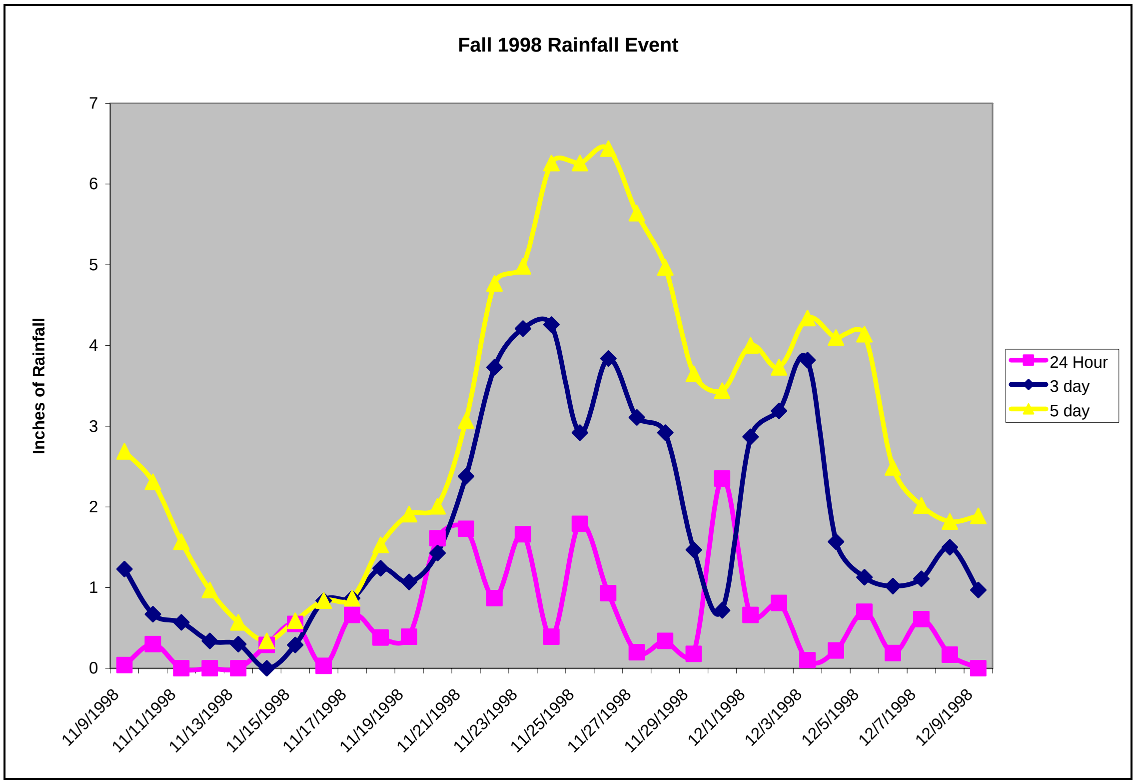
A useful example that might be helpful in understanding return period is the case of a 100 year event. A 100 year event is an event which has a 1 percent chance of being exceeded in any year; it is not one event every 100 years.

Precipitation frequency estimates are used as basic design criteria for a wide variety of hydraulic structures such as culverts, roadway drainages, bridges and small dams. Current precipitation frequency studies for the continental United States are contained in studies that were completed from the early 1960s to the mid-1970s. These references provide information for durations from 5 minutes through 10 days, and for return periods of 2 years through 100 years.

For this TMDL, precipitation frequency estimates were utilized to allow the comparison of loading studies and predictive modeling projects generated in various locations. Precipitation frequency was utilized for the North Bend Airport weather site. This site has an extensive period of record. The recent installation of a precipitation monitoring site in the Tenmile Lakes Watershed will allow the development of area specific rainfall information. Information generated from this site will be incorporated into future iterations of this assessment.

Data collection for use in the Tenmile Lakes Watershed TMDL assessment occurred between 1998 and 2001. This data was utilized to calibrate a predictive model. The largest pollutant loading event which occurred during this period happened in November, 1998, during a storm event where 6.44 inches of rain fell in a five day period. This event represented a 2-year rainfall return interval, a relatively moderate event representing a rainfall event expected to occur 98% of the time on a yearly basis. More data will need to be collected over time to verify pollutant loading rates through a wider representation of rainfall events.

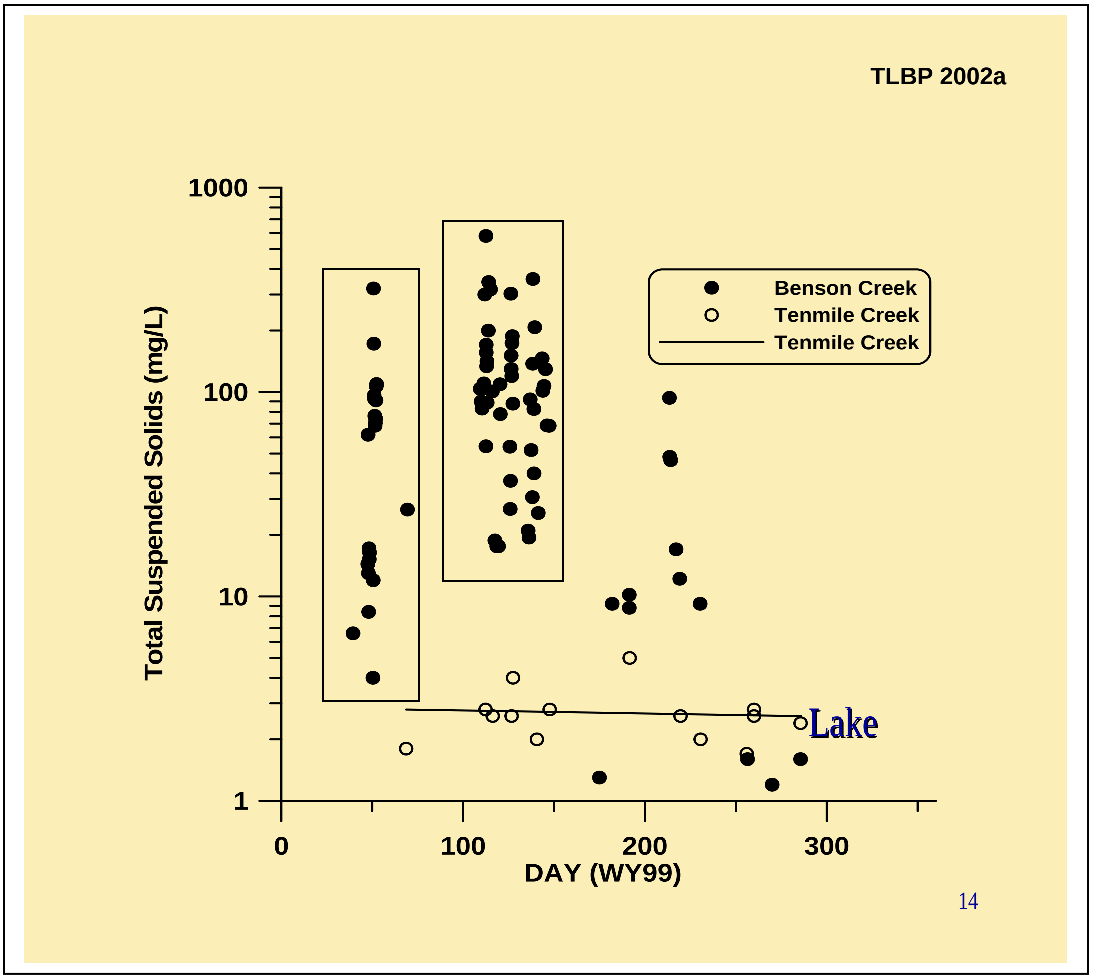
**Figure 20 – November of 1998 Rainfall Event Hydrograph**




Predictive modeling for the Tenmile Lakes Watershed TMDL was conducted for the five year period 1990 through 1995 when weather was rather mild. There were only two discrete occurrences where monthly rainfall exceeded twenty inches during this period. The predominant storm events **represent the two to five year return interval** range for this area. These are storm events which have a 95-98% chance of being exceeded in a given year.

The boxes in the figure below highlight TSS data from Benson Creek and illustrate increased sediment delivery in response to two storm events. Exports from the lake via Tenmile Creek remain low as a result of the settling of suspended solids in the lake. Pollutants delivered by storm events are retained in the lake because of the “slack” water conditions and 15 to 30 day residence time under winter conditions.

**Figure 21 - Total Suspended Solids (TSS) Response During Storm Events**
*Water year 1999 - October 1, 1998 to September 30, 1999*



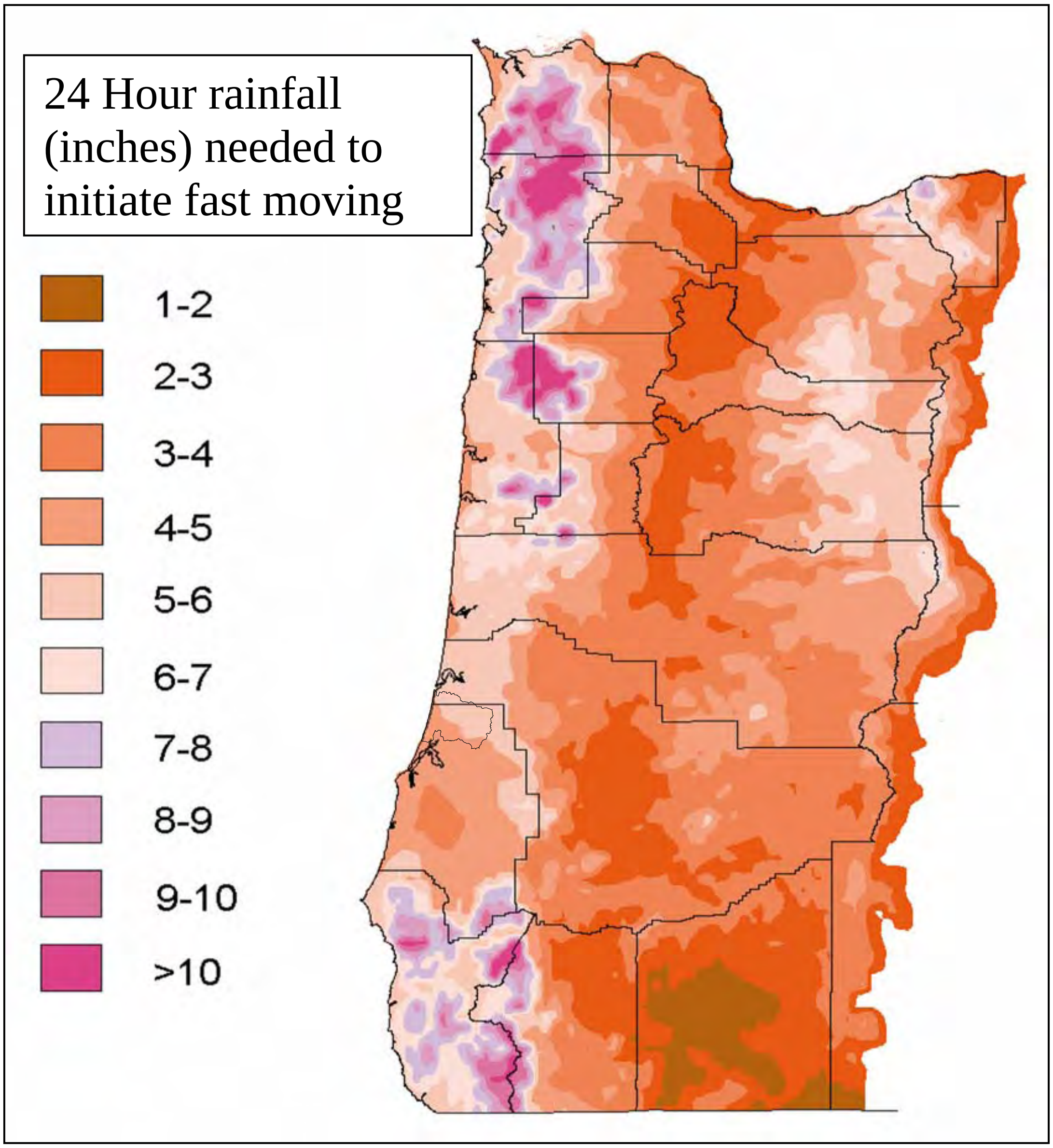

## 6.2.2 Hydrological Events Triggering Landslides and Debris Torrents

This TMDL does not explicitly estimate sediment loads during critical flow conditions for several reasons. It is often impractical to accurately measure sediment loading, transport, and short term effects during high magnitude flow events usually responsible for producing most sediment loading and channel modifications.

A fifteen year study conducted in the Alsea River watershed examined sediment production under a variety of land management and hydrological conditions beginning in the fall of 1958 through 1972 (Bestcha, 1978). The study indicated that two large storm events (25 year return interval) accounted for 36% of the total suspended sediment yield and over one half of the average suspended sediment yield for January over the fifteen year period. Debris avalanches in one watershed moved considerable volumes of sediment and inorganic material downstream during these storm events. In several instances, the paths of these mass failures scoured drainages down to bedrock, and much of the material was deposited in low gradient stream channels. These events resulted in stream channel changes and significantly increased suspended sediment yields. Several mass failures within patch cuts were observed and show that clear-cutting affects mass soil erosion rates. Such effects were found to be most pronounced in areas with steep slopes with shallow soils. Heavy rainfall events were necessary to trigger mass failures indicating that a watershed must have not only the potential for mass failures but also a hydrologic event of sufficient magnitude before an increase in sediment production occurs. A significant increase in sediment production was documented in one watershed after burning of slash where the burn was conducted in a manner which resulted in the exposure of mineral soils.

The figure below depicts rainfall intensities generally required to initiate landslides and debris torrents in western Oregon. (Wiley, 2000)

**Figure 22 - 24 Hour Rainfall Needed to Induce Landslides.**




In 2002 the Oregon Department of Forestry (ODF) and ODEQ, completed a sufficiency analysis titled A Statewide Evaluation of Forest Practices Act Effectiveness in Protecting Water Quality (ODF, ODEQ, 2002). The study included a comprehensive literature review and information compilation regarding the parameter sediment.

### *6.2.2.1 Road Related Slope Failures*

The following are conclusions from drawn from an Oregon Department of Forestry study of forest road related landslides (ODF 1996) and Robison et al. (1999), road and stream crossing restoration guide. These findings include some of the most current information addressing the adequacy of the forest practice rules related to landslides and forest roads:

- Landslides associated with forest roads made up a smaller percentage of the total landslides in the ODF study than in most previous studies.
- Road-associated landslides identified during the ODF study were smaller, on average, than road-associated landslides in past studies. However, these road-associated landslides were four times larger, on average, than those landslides not associated with roads.
- Landslides that delivered sediment to stream channels rarely occurred on roads crossing slopes of less than 50 percent, especially when those roads had well spaced drainage systems and fills of minimal depth.
- Road fill placed on steep slopes created an increased landslide hazard, even where no drainage water is directed to those fills.
- Road-drainage waters directed onto very steep slopes created an increased landslide hazard, even when there was no road fill placed on those very steep slopes.
- In the ODF study, washouts were a significant problem in Tillamook and, to a lesser extent, in Vida study areas. Washouts were often related to undersized culverts (installed prior to current rule requirements).
- Based on the lower numbers of road-associated landslides surveyed in the ODF study and on the smaller sizes of these landslides (as compared with previous studies), current road management practices are likely reducing the size of road-associated landslides and the number of landslides.

In addition to the conclusions from Robison et al. (1999), there are three other studies that examined current road construction standards. A road damage inventory conducted in Washington found that roads constructed in the last 15 years survived a landslide-inducing storm with minimal damage, while roads constructed earlier had very high damage rates (Toth, 1991). ODF landslide monitoring has made similar findings in Oregon (Mills, 1991). Although most surface erosion tends to occur in the first few years after construction, or during periods of heavy traffic use, landslides can occur many decades after original construction. Roads built using current construction practices (steep grades, full-bench design, and end haul construction) have been found to reduce landslide frequency and size compared to roads constructed using pre-1984 practices (Sessions, 1987).

### *6.2.2.2 Harvest Related Slope Failures*

In regard to harvesting-related landslides and forest stand condition the following are conclusions from Robison et al. (1999). These findings include the most current information addressing the adequacy of the forest practice rules related to landslides and debris flows.

- Timber harvesting can initiate landslides in areas with moderate to high landslide risk. In three out of four ODF storm monitoring study areas, higher landslide densities and erosion volumes were found in stands that had been harvested in the previous nine years, as compared to forests older than one hundred years. Forested areas between the ages of 10 and 100 years typically had lower landslide densities and erosion volumes than those found in mature forest stands (Robison et al., 1999).
- There is significant landslide risk on very steep slope regardless of the age of vegetation, especially in certain geologic formations, where major storms and landslide processes are the dominant means by which the landscape is shaped.
- Landslides from recently harvested and older forests can have similar dimensions, including depth, initial volume and debris flow volume (Robison et al., 1999).
- Variability in both storm and site characteristics can be a dominant influence on landslide occurrence.

- Any disturbance that removes vegetation on steep, landslide-prone locations results in increased landslide occurrence. Both the length of time these locations experience periods of reduced forest cover and the extent of lands with reduced vegetative cover can affect landslide density and erosion rate.
- Landscape-level disturbances can result in large, contiguous areas in a condition susceptible to landslides.
- Alternative management strategies for high-risk sites should be carefully monitored. This will take considerable time, since landslides are a geologic process (variable in both time and space). The effectiveness of specific practices, therefore, will be difficult to evaluate until the landscape has experienced major storms and/or prolonged exposure to geologic processes.

### *6.2.2.3 Stream Channel Impacts*

The following are conclusions from Robison et al. (1999) in regard to landslide-related stream channel impacts. These findings include the most current information addressing landslide-related stream channel impacts on forestlands in Oregon. It should be noted that forest streams included in this study are mid to high gradient stream channels. They do not reflect the channelized streams found in Tenmile Lakes Watershed finger valleys.

- In the ODF study, stream channel impacts varied greatly by study area and were not directly related to the number of landslides. Large, up-slope landslides originating above small channel junction angles ($<70^o$) and steep channel gradient slopes resulted in the greatest stream channel impacts.
- Debris torrents reduce stream shading, especially when they travel through younger stands.
- Debris torrents have only a minor effect on active channel width.
- The Benda-Cundy model provides a reliable tool for determining maximum potential travel distances of “typical” debris flows and torrents from forested slopes. Less than 10 percent of the total landslides in the ODF study traveled farther than predicted by the Benda-Cundy model (Benda and Cundy, 1990). The debris torrents that traveled farther than predicted were, on average, larger and had younger riparian vegetation near their terminus. Thus, when determining landslide run-out distance, channel junction angles and channel gradient are the primary factors, while landslide volume and composition of the riparian area along debris torrent-prone channels may also be important secondary factors.
- In the ODF study, slash in the channel was different by stand age class for the Elk Creek and Scottsburg areas. However, whether these differences in slash resulted in increased travel distances by debris torrents could not be determined.

### *6.2.2.4 Tenmile Lakes Watershed Landslide Survey (Noble Creek)*

In the Tenmile Lakes Watershed, slope failures were documented to be widespread during a rainfall event which occurred in December of 2002 wherein 9” of rainfall occurred within a three day period (12”+ within a 6 day period). This storm event represented a 25 year return interval storm event. A Noble Creek landslide survey documents slope failures that occurred in recently harvest draws located adjacent to finger valleys managed for agricultural production (TLBP, 2002b).

Many of these landslides resulted in debris torrents, originating from intermittent stream draws located adjacent to valley bottoms in the Tenmile Lakes Watershed. These debris torrents have been documented to deliver significant amounts of sediment and wood to managed agricultural lands and in some instances to receiving streams where wood retention is not likely to occur. Wood delivered to managed receiving streams in this low gradient portion of the landscape often does not successfully provide the desired fish habitat. Further, large wood and sediment in debris torrents often disturb low gradient stream bank stability.

Management practices should be evaluated to avoid disturbance of stream banks, riparian vegetation, and ultimately sediment delivery to the Tenmile Lakes. Although debris torrents can have positive effects when wood is delivered to areas where it can be successfully recruited and held in streams, sediment delivery also accompanies these events. If successful wood recruitment is not likely, the management of large wood in steep slope drainages adjacent to low gradient channelized or managed streams may not provide the desired ecological benefit. Timber operators are being encouraged to evaluate the ability of the stream to receive and retain woody debris prior to conducting management practices designed to promote the delivery of these materials. The picture below depicts a draw slide which occurred in the Noble Creek drainage and "blocked" the creek with sediment and debris delivered from this slope failure.

**Figure 23 – Noble Creek Draw Slide**

In the pictures below Noble Creek is running bank full and over banking during the 2002 rainfall event. Turbid waters bring sediments from upland sources to the lake. Although debris makes it to the stream from upland sources during this large 2002 storm, log jams are often removed by agricultural landowners almost immediately. This practice is common in channelized/modified streams in the watershed. Wood retention in this portion of Noble Creek is not occurring under current management scenarios.

**Figure 24 – Noble Creek – Up and Muddy**

**Figure 25 - Debris Torrent Destined for Removal from Noble Creek**

Elements included in the margin of safety will help to ensure that the TMDL will result in beneficial use protection during and after critical flow periods associated with maximum sedimentation events. A critical condition is represented by major storms (e.g., storms with a recurrence interval of approximately 25 years or more). Such storms and the associated floods and huge sediment loads can affect watershed conditions dramatically and may support the re-evaluation of sediment accrual rate (SAR) monitoring frequencies.

The approach used in this TMDL to account for critical conditions is the use of indicators that identify address sediment sources at risk of delivery during large magnitude storm events. This will allow landscape management actions to be correlated with water quality measurements to assist in the tracking of both the implementation and effectiveness of measures to improve water quality conditions and reduce sediment loading.

Water quality indicators may be effectively measured during the lower flow conditions (2-5 year return intervals) that align with loading targets determined in this TMDL. Future monitoring efforts should seek to incorporate monitoring in response to larger storm events as possible. Additional loading data, representative of both routine and larger storm events, will be a valuable asset during future reviews of this TMDL and its Load Allocations.

## 6.3 REFERENCE CONDITION DETERMINATION

Three approaches are generally considered when establishing reference conditions and load allocation targets.

1) *Direct observation (data collection) of sites and estimation or inference of reference conditions*. This may take two forms: (1) observation of sites that meet reference site requirements and (2) observation (data) of an entire population of lakes. It is assumed that some percentile of either distribution represents a reference condition.

2) *Model-based prediction or extrapolation of reference conditions from related data sets or related knowledge*. The predictions may come from statistical models (usually regression models), mass balance models, or combinations of the two.

3) *Paleolimnological reconstruction of past conditions*. This means inference of reference conditions from observations of non-reference sites. It requires statistical models based on large data sets and a sample of dated sediment cores for the lake classes in question.

## 6.3.1 Direct Observations – Sedimentation

Very few sediment loading studies are available for Pacific Northwest stream systems. Thus, the use of direct observations for the development of reference loading conditions for suspended sediment is data limited.

The Hinkle Creek study currently underway is a nested paired watershed study of a watershed located 25 miles northeast of Roseburg, Oregon in the foothills of the Cascades. The watershed is almost wholly owned by Roseburg Forest Products and supports a stand of 55-year-old, harvest-regenerated Douglas fir. The forest stand is typical of the kind of forests and forestland currently owned and managed by private, industrial, timberland owners in western Oregon. Thus, it represents an excellent place to test the efficacy of contemporary forest practices with regard to impacts on water quality. Because year one of the study has just been completed, the study area is not located in the coast range, and because of the management history and potential for legacy conditions, this study provides limited utility within this reference condition discussion.

### *6.3.1.1 Sedimentation Studies - Units of Measurement*

There are various units of measurement commonly utilized to depict sediment loading. Three units of measure are referenced in this document. The Alsea study references loading based upon area measured in square kilometers ($km^2$). The Nutrient Study (TLBP, 2002a) references loading based upon area measured in hectares. For your convenience excess loads are depicted based upon area measured in square miles ($mi^2$) later in this document. The reader should take care when comparing loading statements to assure that the units of measurement for area are comparable. Conversions can be made based upon the following relationships.

- Square kilometer ($km^2$) = 100 Hectares = 0.39 Square miles ($mi^2$)
- Sediment yields are reported as metric tones (t). A metric ton is equal to 1000 kg and a ton is equal to 907 kg or 1 tone is equal to 1.1 ton.

### *6.3.1.2 Tenmile Lakes Watershed and Alsea Watershed Comparisons*

A fifteen year study conducted in the Alsea River Watershed examined sediment production under a variety of land management and hydrological conditions beginning in the fall of 1958 through 1972 (Bestcha, 1978). The study provides a significant data set which was utilized to assess sediment loading for a regionally specific water body. In two treatment watersheds, road building commenced in 1965 and between 25 and 82 percent of the landscape was harvested. The study period prior to management activities is particularly useful when discussing reference condition sediment loading. The study concludes that sediment discharge rates are affected by land management, watershed condition, and flow rates, but was not designed to assess sediment loading specific to various rainfall magnitudes or return intervals.

Rainfall records for the Alsea weather station were reviewed to assess five day rainfall accumulations consistent with the seven year period of the baseline/pretreatment study (1959-1965). The baseline (pretreatment) study represented landscape conditions prior to road building and timber harvest. During this period, five storm events occurred wherein five-day rainfall accumulations exceeded ten inches (25-50 year storm events), four storm events occurred wherein five-day rainfall accumulations exceeded eight and one half inches (5+ year storm events), and there were six discrete occurrences where monthly rainfall exceeded twenty inches. A January 1965, storm event produced over six inches of rainfall in 24 hours qualifying as a 24-hour 25-year storm event.

Modeling for the Tenmile Lakes Watershed TMDL was conducted for the five year period 1990 through 1995 when weather was rather mild. Only one storm event occurred wherein five day rainfall accumulations exceeded ten inches (close to a 25 year storm event in January, 1995). Other relatively mild storm events occurred during this period wherein five day rainfall accumulations exceeded seven inches only once in December of 1993. There were only two discrete occurrences where monthly rainfall exceeded twenty inches. Storms of this period predominantly **represent the two to five year return interval** range for this area. Sediment loads reflected for the Tenmile Lakes' tributaries represent the average annual loading for this five year period.

Because large storm events trigger increased sediment loading, loading assessments and load allocations must be reviewed within the context of defined hydrologic regimes. Use of predictive modeling would be needed to fully equilibrate hydrological conditions allowing comparison of loading information presented in the Alsea study with data and loading assessments generated for the Tenmile Lakes Watershed TMDL project. Hydrological conditions over the fifteen year period of record for the month of December in the Alsea River study are more comparable to peak rainfall events represented in the Tenmile Lakes Watershed datasets and subsequent modeling effort. Average yearly sediment yield in three Alsea River watersheds, without inclusion of sediment loading triggered by larger storms, ranged from 18-35 t/km$^2$.

Phosphorus concentrations and sediment yields were most intensively measured in Big, Benson, and Murphy Creeks, tributaries to the Tenmile Lakes. Modeling was then utilized to derive annual phosphorus and sediment loads for lake tributaries (catchments). Because mixed land use activities are present in close proximity, datasets did not provide sufficient rigor to allow the derivation of load allocations specific to individual land uses. Future monitoring efforts should seek to better define phosphorus and sediment loading from specific land uses (e.g. forested landscape, agriculture, rural residential).

The significantly reduced sediment loading for Tenmile Lakes Watershed reference streams appears to be in large part attributable to the filtering of upland sediments by a functional wetland. This filtering effectively reduces sediment loading to the Tenmile Lakes under these conditions. Sediment management in low gradient, mixed land use valleys, and adjacent steep slopes appear to be critical areas where reductions in sediment loading to the lakes might be achieved.

**Table 20 - Sediment Loading Information for Alsea River as Compared to Tenmile Lakes Watershed**

| Watershed | Land Use | Sediment Loading (tonnes/km$^2$/year) |
|---|---|---|
| Alsea River Tributaries | Forest | 18-35 (estimated) |
| Big Creek | Forest/Agriculture | 36 (measured/modeled) |
| Benson | Forest/Agriculture | 26 (measured/modeled) |
| Tenmile Reference Streams | Forest/Wetland | **7 (measured/modeled)** |

### 6.3.2 Direct Observations – Phosphorus Loading

In other studies, phosphorus exports from forested lands are typically low, on the order of 10 to 15 kg phosphorus/km$^2$/yr (Reckhow and Simpson, 1980; Verry and Timmons, 1982).

| Table 21 - Phosphorus Export Coefficients | | | |
|---|---|---|---|
| | Phosphorus (kg/km$^2$yr) | | |
| | HIGH | MID | LOW |
| **Urban** | 500 | 80-300 | 50 |
| **Rural/Agriculture** | 300 | 40-170 | 10 |
| **Forest** | 45 | 14-30 | 2 |
| **Precipitation** | 60 | 20-50 | 15 |

Based on data from the predominantly forested Northern Lakes and Forest ecoregion of Minnesota, stream TP concentrations typically range from 20 to 50µg/L (McCollor and Heiskary, 1993). This range of exports and concentrations is often applicable for marsh land use as well, although phosphorus export will vary seasonally in marshes (USEPA, 2000). Pastured and open park land exports often range from about 20 to 40 kg phosphorus/km$^2$/yr. For example, two monitored sub watersheds in southwest Minnesota, with 60 percent or more of the watershed in Conservation Reserve Program, had phosphorus exports of 25 to 40 kg phosphorus//km$^2$/yr (Schueler, 1995). Phosphorus export studies specific to Western Oregon were not available. EPA, Ambient Water Quality Criteria Recommendations, Rivers and Streams in Nutrient Ecoregion II did provide suggested TP background levels for streams within the western forested mountain area (USEPA, 2000b).

The table below reflects annual phosphorus loads and TP concentrations cited in literature as compared to values derived for selected Tenmile Lakes' tributaries. Reference stream values approach background conditions as defined in available literature.

**Table 22 – Phosphorus Loading Information from Literature as Compared to Tenmile Lakes Watershed Current Conditions**

| Watershed | Land Use | Annual Phosphorus Loading (kg/km$^2$/year) | TP Concentrations ug/L |
|---|---|---|---|
| Literature | Forest/Marsh | 10-15 | 20-50 |
| Literature | Pastured/Open Parks | 20-40 | NA |
| USEPA Criteria Recommendation | River and Streams (Western Forested Mountains) | NA | 10 |
| Big Creek | Forest/Agriculture | 230 | 90 |
| Benson | Forest/Agriculture | 182 | 100 |
| Tenmile Lakes Watershed Reference Streams | Forest/Wetland (Marsh) | 45 | 20 |

Delta building observed at the mouths of tributaries can be viewed as the system reconstructing the wetland interface between the lake and tributaries lost though stream channelization. It should be noted that functional wetlands have a finite carrying capacity for sediments. If upland sediment abatement is not implemented wetlands at the lake interface would also begin to fill.

## 6.3.3 Soil and Water Assessment Tool (SWAT) - Predictive Modeling

The USDA model called SWAT (Soil and Water Assessment Tool) is a model that is widely utilized in estimating sediment and nutrient loads in large watersheds where nonpoint sources of pollution play a role. Documentation for the SWAT model can be reviewed at http://www.brc.tamus.edu/swat/. Detailed information regarding the SWAT modeling for this project can be found in the Tenmile Lakes Nutrient Study and the reader is encouraged to reference this document. Information in this section provides an overview and results derived from this modeling effort.

SWAT has eight major components: hydrology, climate, sedimentation, soil temperature, crop growth, nutrients, pesticides, and agricultural management practices. Data was developed to represent identified sub watersheds or SWAT catchments. Sources of the data sets which were utilized to represent the conditions in each sub watershed are described below.

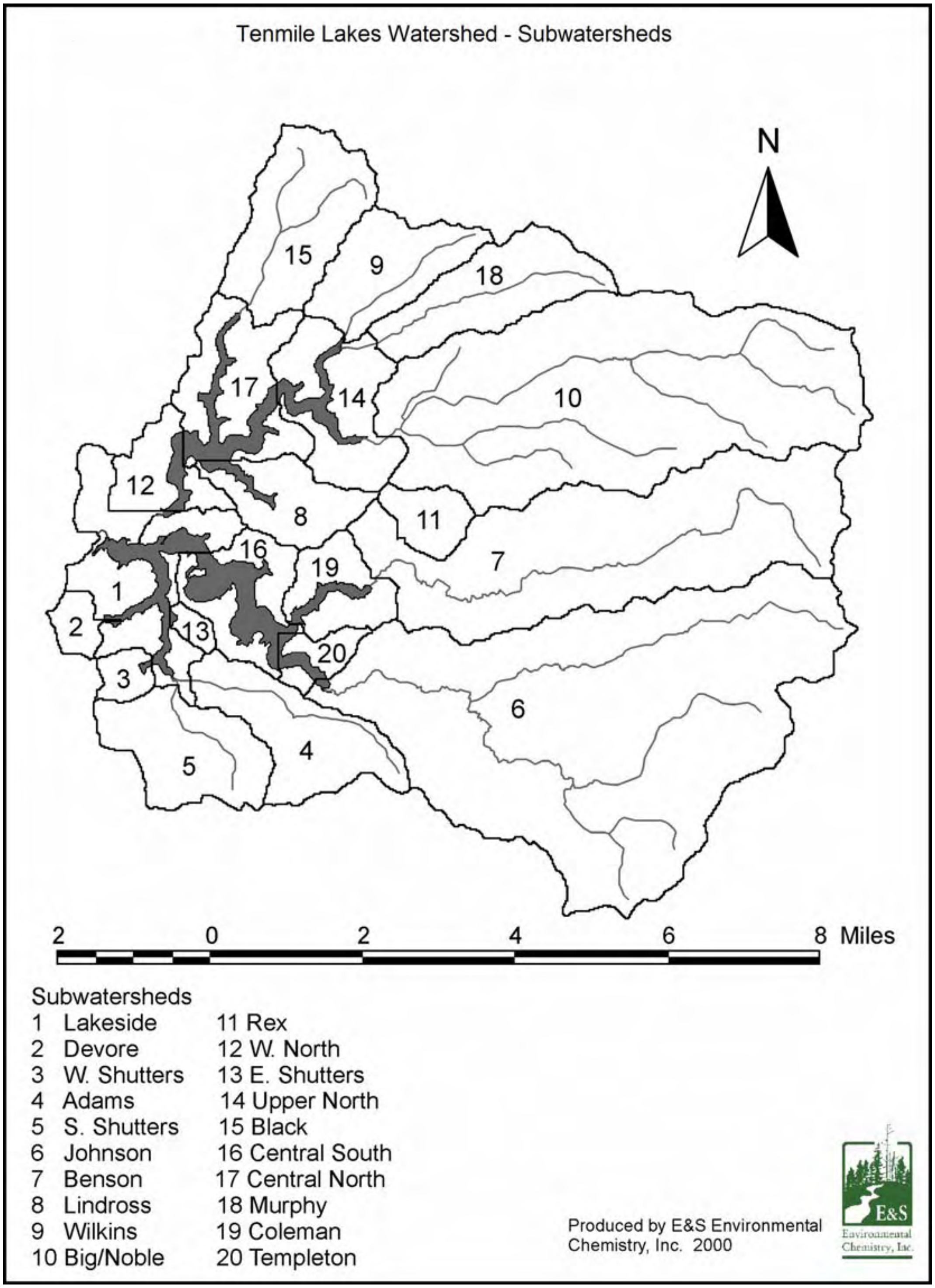
- Soils: Natural Resources Conservation Service (NRCS) SSURGO data (1:24000) were used as the basic soils data. Data from Coos and Douglas counties was gathered and clipped to the Tenmile Lakes Watershed. Currently, data from Coos County is still considered provisional by NRCS. A series of spot checks of the digital data against the hardcopy Soils Survey of the county was used as verification of the provisional data.

- Land use: The composite land use data was developed from two separate data sources. Where available, detailed information from the Oregon Department of Forestry (ODF) was utilized. The dataset, called STANDS98, is available from the Oregon State Service Center for Geographic

Information Systems (SSCGIS). In areas where this coverage was unavailable, land use information was photo interpreted from 1994 aerial photographs.

- Elevation: A 30 meter digital elevation model (DEM) was developed as input for the SWAT model. The data originated at the SSCGIS as 18 United States Geologic Survey (USGS) quadrangle coverages. These datasets were integrated to generate a complete coverage for the watershed.
- Climate: Model calibration was performed using daily rainfall and air temperature data collected near the Big and Benson Creek water quality monitoring stations. Precipitation was collected using a tipping bucket attached to a digital data logger. Air temperature was collected at approximately hourly intervals using HoboTemp data recorders. Precipitation for Phase II was derived from the North Bend Airport NOAA weather site.

**Figure 26 – Partitioning of the Tenmile Lakes' Subwatersheds as SWAT Model Catchments**



### 6.3.3.1 SWAT Model Calibration

The SWAT model was calibrated using multi parameter water quality data and flow information collected from three principal tributary monitoring sites; Big, Benson, and Murphy Creeks. Other stream supporting data was also utilized. The model was calibrated first for hydrology before proceeding with calibration of sediment, phosphorus, and nitrogen parameters.

**Table 23 - Distribution of Tributary Water Quality Samples Collected to Support SWAT Modeling**

| Stream Sites | Year | | | | Total |
|---|---|---|---|---|---|
| | 1998 | 1999 | 2000 | 2001 | |
| Benson (BEN) | 21 | 63 | 39 | 1 | 124 |
| Big (BIG) | 4 | 52 | 26 | 1 | 83 |
| Murphy (MUR) | 2 | 51 | 1 | 1 | 55 |
| Johnson (JON) | | | 21 | | 21 |
| Benson - trib. (REX) | | 12 | 5 | 1 | 18 |
| Tenmile Creek (TCO) | 1 | 14 | | | 15 |
| Others (N=13) | 5 | 15 | 1 | | 21 |

The SWAT model was calibrated to individual storm flows which had occurred during the period of data collection. The calibrated model was then utilized to extrapolate pollutant loading for actual daily flows over a five-year period (1990 -1995).

The simulated versus measured discharge at the three primary stations is shown in the figure below. The model was able to simulate discharge at Big and Benson Creeks reasonably well. The hydrologic simulation for Murphy Creek was not as precise as the other two sites. We attribute this to the large proportion of unmeasured overbank discharge which occurred at the Murphy Creek site during high flow events. Traditional gauging techniques (stage-discharge rating curves) are problematic in these wetland stream systems. Nevertheless, the difficulty in the hydrologic calibration for Murphy Creek is minimized because of the low concentrations of the parameters of interest. Water quality simulations proceeded following the hydrology calibration. Results from calibration of TSS, TP, and $NO_3$-N for Murphy, Big, and Benson Creeks are presented in the following figures as mean monthly loads for the period January 1999 to April 1999 (TLBP, 2002a).

**Figure 27 - Simulated Versus Measured Stream Discharge (cfs)**
**Big, Benson, and Murphy Creeks**

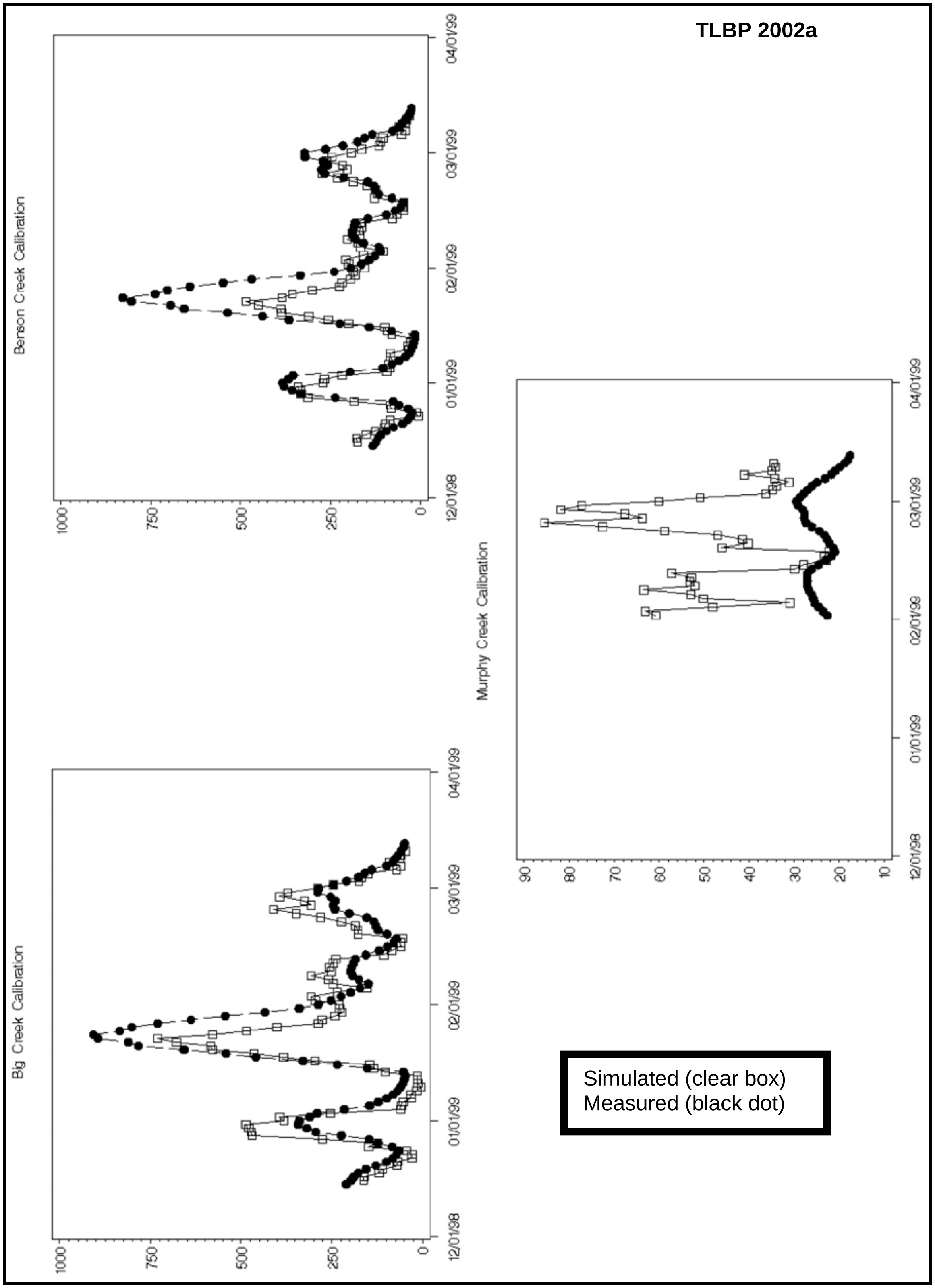


**Figure 28 - Simulated Versus Measured Total Suspended Solids (mg/L) (Sediment) Concentrations**

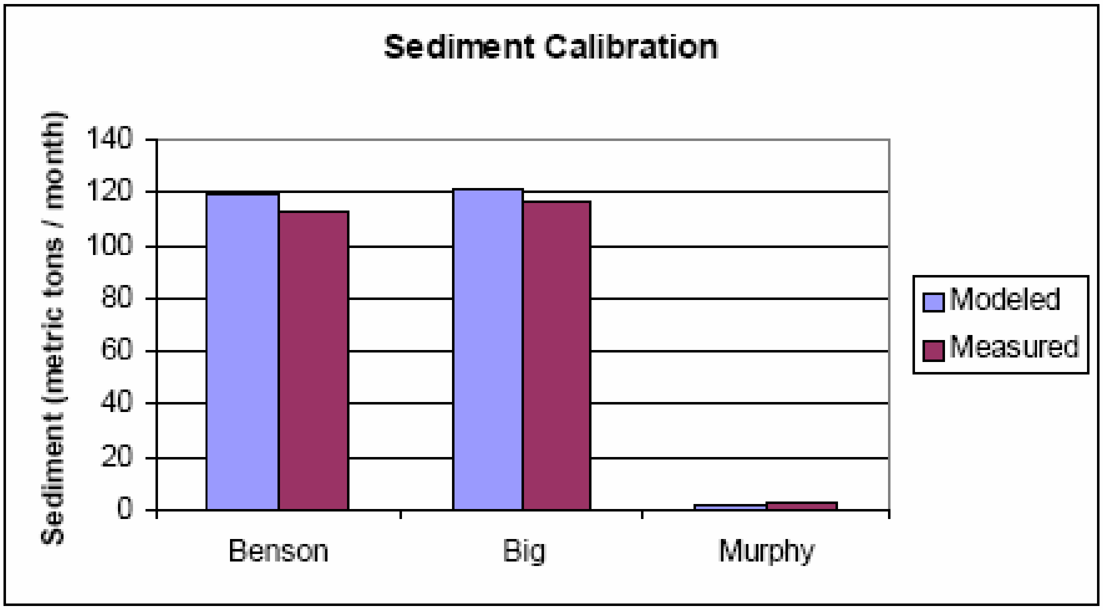



**Figure 29 - Simulated Versus Measured Concentrations of TP (mg/L)**

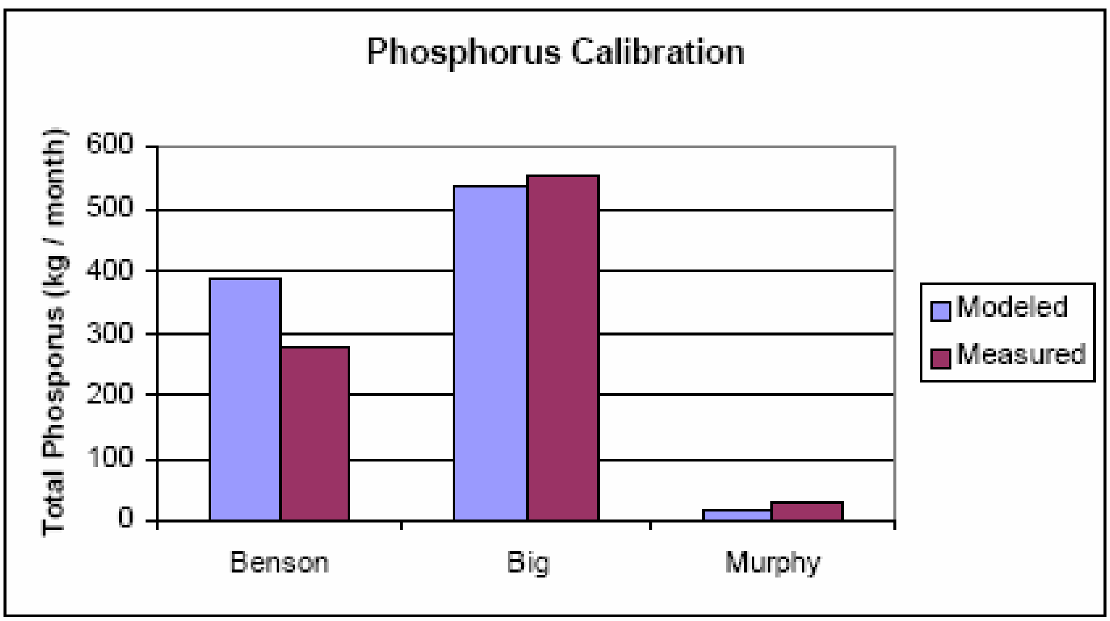
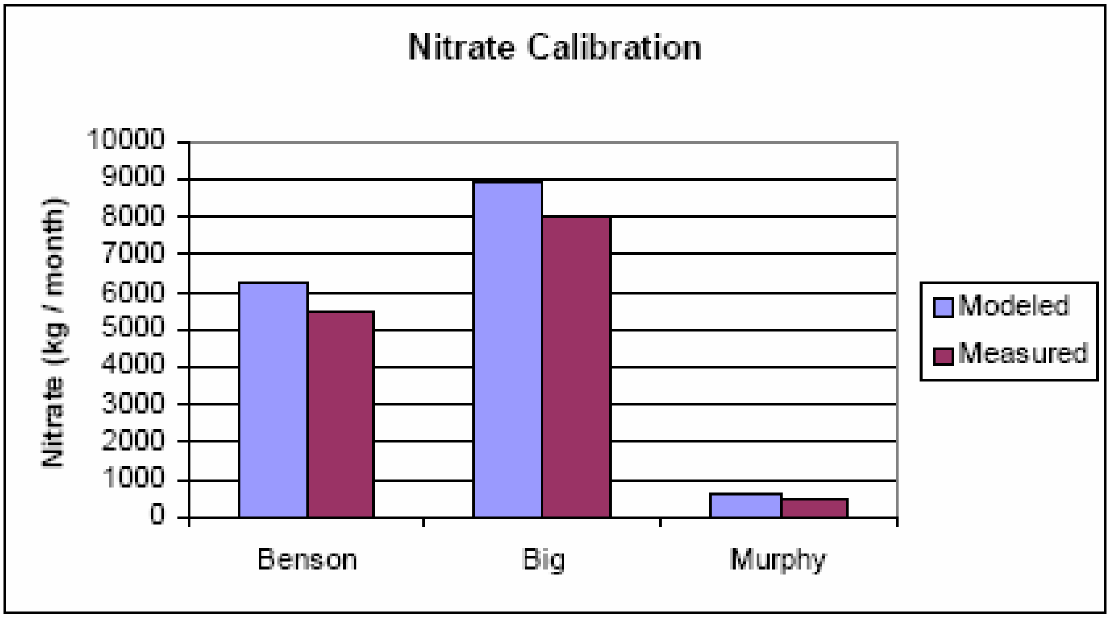


**Figure 30 - Simulated Versus Measured Concentrations of Nitrate (mg/L)**




### *6.3.3.2 SWAT Modeling Scenarios*

Using the calibrations, model estimates of water, sediment, nitrogen, and phosphorus yields for each of the 20 catchments within the Tenmile Lakes Watershed were derived for three landscape scenarios. Model estimates for volume-weighted concentrations and annual loads are presented on a unit-area basis for each catchment.

- Current land use and landscape condition existing in 1994 (“current”)
- Historical landscape condition (“historical”)
- Current land use and landscape condition with wetland restoration 1000M meters from the lakeshore – (“wetlands”). In this scenario the City of Lakeside remains urbanized.

The model simulations indicate that water yield (the amount of total discharge from a catchment) varies by nearly a factor of two among catchments. Catchments such as Murphy Creek exhibit a low yield of water runoff. Other sites such as West Shutters and Devore also had similarly low runoff values. These three sites all have wetlands in the lower part of their respective watersheds which either causes an underestimation of the actual amount of measured runoff or the presence of the wetlands at the base of the watersheds actually alters the amount of runoff. Regardless of whether the amount of watershed discharge is altered or whether the flow becomes rerouted to the extent that it can’t be easily measured, the effects appear to be similar.

Watersheds with high water yields include Johnson Creek, South Shutters, and Adams Creek. Some of the elevated runoff for Johnson Creek may reflect the orographic influence from high precipitation in the upper (eastern) portion of the watershed. However, Johnson Creek also exhibits a high rate of timber harvest and grazed wetlands that contribute to the modeled response. South Shutters catchment is notable for the high percentage of grazed uplands which, combined with grazed wetlands, promote a high degree of runoff.

Clearly, the greatest confidences in model results are associated with catchments for which detailed water quality data were collected. The results indicate that the larger catchments such as Big and Benson Creeks drive the results for the watershed as a whole. Higher exports of TSS, $NO_3$ -, and $PO_4$ from smaller catchments such as Benson Creek are balanced by low exports from wetland dominated sites such as Murphy Creek. The current loads of modeled parameters for the Tenmile Lakes Watershed exceed historical (historical) loads of TSS by at least an order of magnitude. The differential between historical and current loads of $PO_4$ are estimated to differ by a factor of three, whereas $NO_3$ - appears to differ by a factor of two

### 6.3.3.3 Current Land Use and Landscape Condition Simulations

The “current” simulations are based upon landscape conditions derived from aerial photography collected in 1994 and updated with an aerial survey in 1999. The actual spatial information on land use and landscape condition is constantly changing and will not correspond precisely with current distributions of land disturbing activities. One of the most variable factors in the watershed landscape condition is timber harvest. Areas which were harvested in the early 1990s have since experienced appreciable timber re-growth, which should result in declining sediment and nutrient loads. Conversely some areas, which were mature timber in 1994, have since been harvested likely causing loads to increase in those areas.

Three tributaries to the Tenmile Lakes were monitored on an intensive basis from November 1998 through May 1999. Stream flow declined after May and tributary inputs became relatively insignificant (on a lake-wide basis). During this period, Big and Benson Creeks delivered measured sediment and nutrients at a rate far greater than those measured in Murphy Creek. Loads, expressed on a per hectare basis, show that sediment yields from Big and Benson Creeks are at least ten times greater than the yield from Murphy Creek. The loads of nitrogen and phosphorus from Big and Benson Creeks are at least three times those from Murphy Creek. Although Big and Benson Creeks are degraded relative to Murphy Creek, these two catchments may not represent worse-case conditions in the watershed. The modeling results indicate that nearly one-half of the remaining catchments may have higher yields (on a per hectare basis) than Big and Benson Creeks.

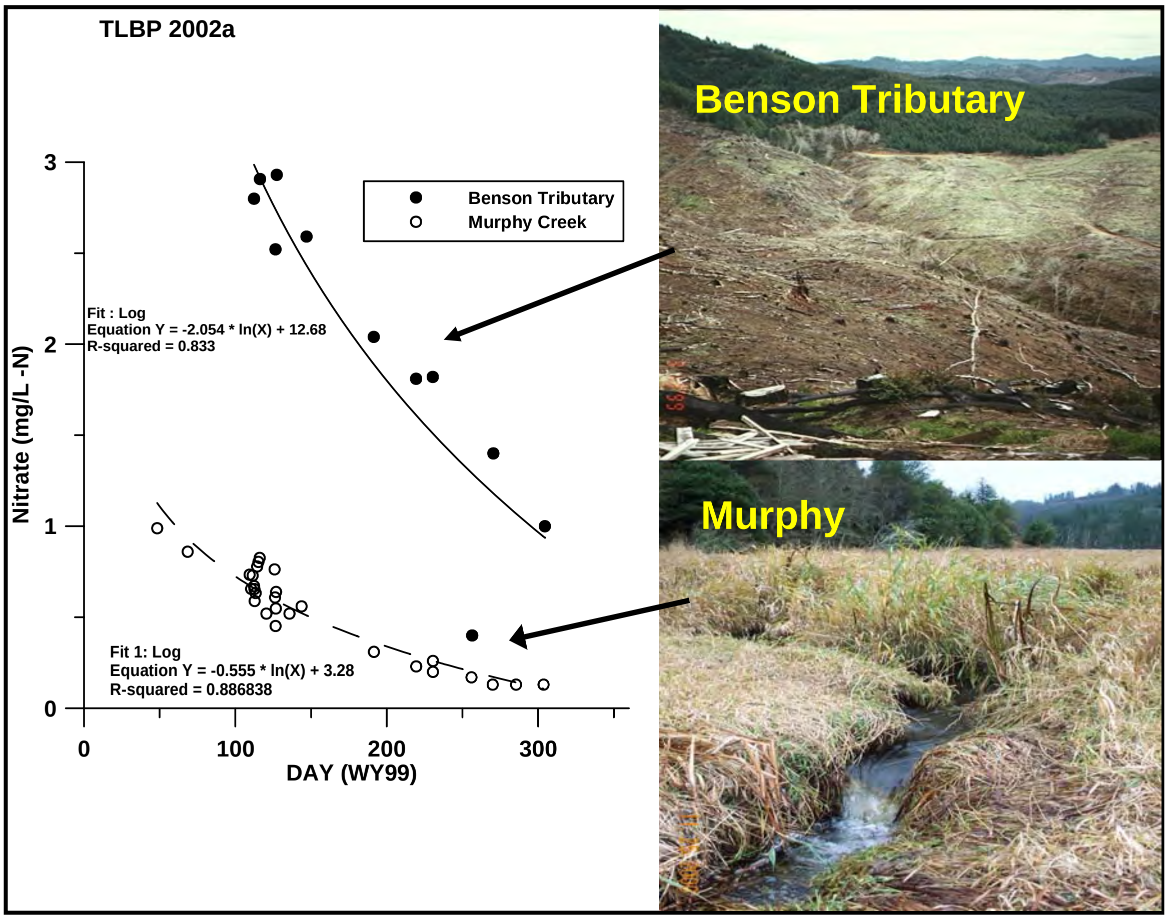
Simulated sediment yield varied by two orders of magnitude ranging from less than 0.1 t/ha/yr in catchments such as Templeton, Murphy, Adams, and West Shutters to values over 1.0 t/ha/yr in catchments such as Lakeside, Central South, West North, and South Shutters. Murphy, Adams, and West Shutters had wetlands at the base of the catchments in 1994 which served to filter upland sediments. The low simulated sediment load in Templeton is, in part, an artifact of having to include part of the lake surface in partitioning the catchment (22 percent is listed as water surface). It should be noted that the Adams Creek stream channel has recently been channelized (managed) in a very traditional manner and wetland function has been diminished.

On the high end of sediment production for non-urban areas are South Shutters, Big, Benson, Johnson, and Black creeks. All of these catchments have a comparatively high percentage of clearcut land, but other factors such as channelized stream management are involved as well. Although Black Creek has a wetland present at its interface with the lake, the wetland is smaller than that of Murphy and West Shutters creeks and appears to be less effective at removing sediments. The catchment with the greatest percentage of clearcut is Devore Arm (48 percent), yet the model simulation shows that sediment production is only a small fraction of that found in the high-sediment yield catchments. The primary difference is the location of the land use disturbance with respect to the receiving water. The clearcutting in the Devore catchment is mostly upland with a buffer of established forest, whereas the timber harvest in the other catchments occurred on steep slopes closer to the lake. Additionally, the high sediment production catchments all have grazed wetlands, whereas the Devore catchment contains intact wetlands in the lowlands. One factor influencing the modeled sediment production in South Shutters is the high percentage of grazed uplands and wetlands.

Catchments with a large component of urban land use (West North and Lakeside) had high yields of nitrogen (1.34 and 1.30 kg N/ha/yr, respectively). The general ranking of phosphorus loads from the catchments was similar to that of nitrogen, whereby high loads were associated with urban and grazing activities and low loads were associated with catchments with a high percentage of mature forest and intact wetlands at the base of the watershed.

The location of wetlands and recent clearcuts affects all phases of the modeling. Not only are sediment and total phosphorus production increased during logging, but nitrogen export is also affected. Nitrogen export ranged by nearly two orders of magnitude from 0.07 kg N/ha/yr in Wilkins Creek to 1.29 kg N/ha/yr in South Shutters and 1.92 kg N/ha/yr in a clearcut tributary to Benson Creek. About 80% of the Benson Creek tributary catchment had been logged the previous year. In the figure below a comparison of nitrate concentrations in Murphy Creek and the Benson Creek tributary show elevated nitrogen yield after harvest. Nitrogen export in coast range streams is influenced by red alder densities and can have a relatively short term response to harvest as a result of leaf and needle decomposition. The effects of forest harvesting on stream water chemistry have been investigated in a wide range of small watersheds. Most of these have documented increases in stream water $NO_3$ - concentrations, but others have found no effect or even a decline in concentrations (Binkley et al, 2004)

**Figure 31- Nitrate ($NO_3$-N, mg/L) Concentrations**
*1999 Water year (October 1, 1998 to September 30, 1999*




Williams and Melack (1997) found significant increases in stream water $NO_3$ - concentrations following prescribed fires in mixed conifer forests of the Sierra Nevada in California. Nitrate concentrations in stream water increased dramatically in the first two years after fire, rising from near zero before the fire to annual averages of about 0.5 mg N/L. The concentrations declined in the third year after burning, returning to background levels in the fourth year.

The comparatively high water quality delivered to North Tenmile Lake from Murphy Creek, both measured and modeled, under the current condition scenario is attributed largely to the functional wetland on the lower 2.5 km of the stream. This wetland filters pollutants delivered from the uplands in the Murphy Creek watershed. Using Murphy Creek as one indicator of historical stream water quality infers that nutrient loads from most of the tributaries have increased under the current management conditions.

The SWAT model output for volume-weighted concentrations of TSS indicates that Big Creek, Rex Creek, tributary to Benson, and catchments immediately adjacent to South Tenmile Lake in and near the city of Lakeside, contribute a disproportionately greater amount of TSS to the lake. Catchments with significant wetlands such as Murphy Creek, Adams Creek, West Shutters, and Devore contribute runoff with lower TSS concentrations. It should be noted that the Adams Creek stream channel has recently been channelized (managed) in a very traditional manner and wetland function has been diminished. The Lindros catchment presumably contributes relatively low sediment loads because of low stream development. Land disturbing activities such as those that occur during timber harvest or development can result in increased sediment and total phosphorus production due to erosion. The table below summarizes SWAT model load estimates under the current land use (TLBP, 2002a).

**Table 24 - SWAT Model Estimates Under the C*urrent* Land Use**

| | | Annual Loads | | | Average Concentrations | | |
|---|---|---|---|---|---|---|---|
| Name | Area (ha) | Sediment (t/ha) | Nitrate (kg/ha) | Phosphorus (kg/ha) | Sediment (mg/L) | Nitrate (mg/L) | Phosphorus (mg/L) |
| Lakeside | 792 | 2.35 | 1.30 | 16.80 | 45.54 | 0.37 | 0.25 |
| Devore | 116 | 0.15 | 0.08 | 0.83 | 14.52 | 0.08 | 0.36 |
| W. Shutters | 109 | 0.08 | 0.10 | 0.05 | 8.05 | 0.08 | 0.02 |
| Adams | 693 | 0.09 | 1.32 | 2.89 | 9.04 | 0.56 | 0.12 |
| S. Shutters | 644 | 1.06 | 1.29 | 6.29 | 99.64 | 0.65 | 0.26 |
| Johnson | 4473 | 0.28 | 0.84 | 2.34 | 26.00 | 0.39 | 0.09 |
| Benson | 2411 | 0.26 | 0.69 | 1.82 | 28.46 | 0.37 | 0.10 |
| Lindros | 426 | 0.05 | 0.13 | 1.19 | 5.61 | 0.15 | 0.06 |
| Wilkins | 478 | 0.18 | 0.07 | 0.50 | 17.59 | 0.06 | 0.02 |
| Big | 3412 | 0.36 | 0.81 | 2.30 | 32.95 | 0.36 | 0.09 |
| Rex | 218 | 0.85 | 1.92 | 5.60 | 79.03 | 1.02 | 0.23 |
| W. North | 357 | 3.38 | 1.34 | 13.78 | 38.08 | 0.30 | 0.20 |
| E. Shutters | 105 | 0.44 | 0.22 | 1.80 | 39.25 | 0.03 | 0.07 |
| Upper North | 751 | 0.12 | 0.90 | 4.35 | 25.65 | 0.34 | 0.12 |
| Black | 819 | 0.26 | 0.06 | 0.66 | 25.30 | 0.06 | 0.03 |

**Table 24 Continued - SWAT Model Estimates Under the C*urrent* Land Use**

| | | Annual Loads | | | Average Concentrations | | |
|---|---|---|---|---|---|---|---|
| Name | Area (ha) | Sediment (t/ha) | Nitrate (kg/ha) | Phosphorus (kg/ha) | Sediment (mg/L) | Nitrate (mg/L) | Phosphorus (mg/L) |
| Central South | 553 | 1.35 | 0.74 | 8.59 | 33.67 | 0.39 | 0.19 |
| Central North | 678 | 0.07 | 0.39 | 3.29 | 23.46 | 0.30 | 0.15 |
| Murphy | 713 | 0.07 | 0.17 | 0.45 | 6.13 | 0.07 | 0.02 |
| Coleman | 343 | 0.13 | 0.62 | 4.19 | 27.17 | 0.40 | 0.14 |
| Templeton | 231 | 0.08 | 0.77 | 2.50 | 25.35 | 0.40 | 0.13 |

### *6.3.3.4 Historical (Historical) Land Use and Condition Scenario*

The historical simulations were based on landscape conditions where mature timber would be present throughout the uplands, and wetlands analogous to those existing in Murphy Creek would be present in the lowlands. The historical time period represented by the model would probably be that present at circa 1850. This was prior to a major fire that destroyed the timber in a significant portion of the eastern watershed in the 1860s. It was also prior to any stream channelization and wetland drainage that occurred after 1890. The modeling analysis of sediment and nutrient loads under Historical conditions indicates that historical loads delivered to the Tenmile Lakes from tributaries would have been much lower relative to current conditions.

The table below presents predicted annual loads for sediment, nitrate, and phosphorus for a Historical landscape condition scenario (TLBP, 2002a). The watershed is not realistically expected to reach pre development loading levels because of continuing land management activities.

**Table 25 - SWAT Model Estimates Under the *Historical* Land Cover**
(TLBP 2002a)

| | | Annual Loads | | | Average Concentrations | | |
|---|---|---|---|---|---|---|---|
| Name | Area (ha) | Sediment (t/ha) | Nitrate (kg/ha) | Phosphorus (kg/ha) | Sediment (mg/L) | Nitrate (mg/L) | Phosphorus (mg/L) |
| Lakeside | 792 | 0.23 | 2.57 | 9.65 | 2.91 | 0.22 | 0.06 |
| Devore | 116 | 0.01 | 0.16 | 0.10 | 1.07 | 0.05 | 0.00 |
| W. Shutters | 109 | 0.03 | 0.15 | 0.23 | 2.75 | 0.05 | 0.01 |
| Adams | 693 | 0.01 | 0.20 | 0.10 | 1.01 | 0.07 | 0.00 |
| S. Shutters | 644 | 0.01 | 0.18 | 0.10 | 0.86 | 0.06 | 0.00 |
| Johnson | 4473 | 0.02 | 0.66 | 0.22 | 1.33 | 0.24 | 0.01 |
| Benson | 2411 | 0.01 | 0.41 | 0.13 | 0.99 | 0.14 | 0.01 |
| Lindros | 426 | 0.00 | 0.15 | 0.09 | 0.30 | 0.05 | 0.00 |
| Wilkins | 478 | 0.03 | 0.19 | 0.23 | 2.85 | 0.06 | 0.01 |
| Big | 3412 | 0.01 | 0.55 | 0.16 | 0.76 | 0.20 | 0.01 |
| Rex | 218 | 0.01 | 0.16 | 0.07 | 0.87 | 0.05 | 0.00 |
| W. North | 357 | 0.22 | 2.33 | 4.65 | 2.12 | 0.23 | 0.05 |
| E. Shutters | 105 | 0.01 | 0.03 | 0.07 | 1.03 | 0.00 | 0.00 |
| Upper North | 751 | 0.02 | 2.03 | 1.13 | 1.06 | 0.24 | 0.01 |
| Black | 819 | 0.03 | 0.23 | 0.25 | 2.75 | 0.08 | 0.01 |
| Central South | 553 | 0.18 | 1.45 | 4.28 | 2.24 | 0.24 | 0.03 |
| Central North | 678 | 0.01 | 1.36 | 0.69 | 1.23 | 0.23 | 0.03 |
| Murphy | 713 | 0.01 | 0.23 | 0.06 | 0.42 | 0.08 | 0.00 |
| Coleman | 343 | 0.02 | 1.90 | 1.08 | 1.12 | 0.20 | 0.02 |
| Templeton | 231 | 0.02 | 1.81 | 0.75 | 1.34 | 0.26 | 0.01 |

The table below shows metric tones (t) of sediment loading under the current landscape condition, loads predicted under the Historical landscape, and the difference between current and Historical sediment loads depicted as a percentage.

**Table 26 – Modeled Sediment Load Comparison – Current vs. Historical Condition**

| Name | Area (ha) | Pre Development Annual Loads Sediment (t/ha) | Current Annual Loads Sediment (t/ha) | Potential Annual Load Reduction Sediment (t/ha) | Difference as % (Sediment increase under current condition scenario) |
|---|---|---|---|---|---|
| Lakeside | 792 | 0.23 | 2.35 | 2.12 | 90 |
| Devore | 116 | 0.01 | 0.15 | 0.14 | 93 |
| W. Shutters | 109 | 0.03 | 0.08 | 0.05 | 63 |
| Adams | 693 | 0.01 | 0.09 | 0.08 | 89 |
| S. Shutters | 644 | 0.01 | 1.06 | 1.05 | 99 |
| Johnson | 4473 | 0.02 | 0.28 | 0.26 | 93 |
| Benson | 2411 | 0.01 | 0.26 | 0.25 | 96 |
| Lindros | 426 | 0.00 | 0.05 | 0.05 | 100 |
| Wilkins | 478 | 0.03 | 0.18 | 0.15 | 83 |
| Big | 3412 | 0.01 | 0.36 | 0.35 | 97 |
| Rex | 218 | 0.01 | 0.85 | 0.84 | 99 |
| W. North | 357 | 0.22 | 3.38 | 3.16 | 93 |
| E. Shutters | 105 | 0.01 | 0.44 | 0.43 | 98 |
| Upper North | 751 | 0.02 | 0.12 | 0.1 | 83 |
| Black | 819 | 0.03 | 0.26 | 0.23 | 88 |
| Central South | 553 | 0.18 | 1.35 | 1.17 | 87 |
| Central North | 678 | 0.01 | 0.07 | 0.06 | 86 |
| Murphy | 713 | 0.01 | 0.07 | 0.06 | 86 |
| Coleman | 343 | 0.02 | 0.13 | 0.11 | 85 |
| Templeton | 231 | 0.02 | 0.08 | 0.06 | 75 |
| **Totals** | 18,322 | 0.89 | 11.61 | 10.72 | 92 |

### *6.3.3.5 Wetland Buffer Scenario*

The SWAT model was used to simulate watershed response to a change in current land use. The simulation was based on the assumption that all lowland tributary sites were allowed to be re-established as mature wetlands (with features comparable to Murphy Creek) for 1000 meters extending from the lakeshore upstream.

Even a scenario that proposed to restore all lowlands to their original wetland condition will not return the watershed export rates to their historical levels because of expected continued activity in the uplands. Some catchments are forecasted to remain high because the model simulation is based on continued upland disturbance and direct inputs from areas where the extent of historical wetlands was limited. Some urban and shoreline development areas are examples of areas where wetland enhancement opportunities can be limited.

The vegetation and hydrology of the present Murphy Creek drainage was utilized. Wetlands in Murphy Creek extend through the entire valley floor. Murphy Creek was formerly channelized, but for the last 20 years has been relatively unmanaged. The "natural" wetland recovery that has evolved at this site is probably unlike the historical wetlands which appeared to consist of lowland hardwoods (c.f., description by S. Cathcart).

> *"Land very rough and mountainous. Soil principally clay bottom through which the different streams meander although not generally wide very rich; and covered with dense growth of timber principally Ash, Maple and Alder. The mountains between Streams very steep so much so could only measure with a one pole chain. Timber on almost all of them burnt and its place being taken with Thimbleberry and young Alders. This Twp. Contains numerous lakes and considerable land that is overflowed with water which all can be drained at the present time."*
>
> Simon Cathcart, Surveyor, 1890

Murphy Creek is in the process of re-establishing a more natural meander, and as previously discussed, channel dynamics encourage over bank flows quite often. Some stream reaches in Murphy Creek have retained features of a channelized stream. Without access to an undisturbed native wetland as a reference site, the Murphy Creek wetland was selected as a reasonable approximation from which to derive hydrology and vegetative features for use in this (wetland buffer) modeling scenario.

The SWAT model represents loads as material moving from a specific hydrologic resource unit (HRU). Because of this, under this scenario, the annual watershed loads are identical to the current scenario annual watershed loads. The wetland scenario predicts load reductions resulting from the filtering and denitrifying of water passing through the wetland. The "wetland" model scenario attempts to simulate this process by superimposing a filter over the loads of TSS, $NO_3$ -, and $PO_4$ entering the wetland. For example, monitoring showed that TSS was reduced by 79% after traveling through the Murphy Creek wetland. Thus, the change in sediment loading between these scenarios must be made by comparing stream water column concentrations.

The SWAT model simulates export of water column dissolved orthophosphate ($PO_4$) rather than TP. The simulated change in $PO_4$ export is relatively modest for the wetland scenario. However, a greater reduction in TP would be expected because of the relationship between TSS and TP. When paired TP and $P0_4$ datasets are evaluated, the ratio of TP to $PO_4$ is quite variable ranging from as high as 20:1 to as low as 1:1. The generalized relationship of 3:1 was identified in the Nutrient Budget for the Tenmile Lakes Watershed.

The table below summarizes SWAT model load estimates under the current land use compared to loads predicted under the wetland buffer scenario (TLBP, 2002a).

**Table 27 - SWAT Model Estimates Current Land Use Compared with Wetland Buffer Scenario**
Wetland Buffer 1000 Meters from the Lakeshore

| | | Average Concentrations Current Condition Scenario | | | Average Concentrations Wetland Buffer Scenario | | |
|---|---|---|---|---|---|---|---|
| Name | Area (ha) | Sediment (mg/L) | Nitrate (mg/L) | Phosphate ($P0_4$) (mg/L) | Sediment (mg/L) | Nitrate (mg/L) | Phosphate ($P0_4$) (mg/L) |
| Lakeside | 792 | 45.54 | 0.37 | 0.25 | 29.45 | 0.23 | 0.19 |
| Devore | 116 | 14.52 | 0.08 | 0.36 | 7.80 | 0.04 | 0.02 |
| W. Shutters | 109 | 8.05 | 0.08 | 0.02 | 4.26 | 0.04 | 0.11 |
| Adams | 693 | 9.04 | 0.56 | 0.12 | 9.04 | 0.56 | 0.12 |
| S. Shutters | 644 | 99.64 | 0.65 | 0.26 | 10.74 | 0.06 | 0.01 |
| Johnson | 4473 | 26.00 | 0.39 | 0.09 | 6.89 | 0.22 | 0.05 |
| Benson | 2411 | 28.46 | 0.37 | 0.10 | 12.12 | 0.19 | 0.05 |
| Lindros | 426 | 5.61 | 0.15 | 0.06 | 2.60 | 0.05 | 0.02 |
| Wilkins | 478 | 17.59 | 0.06 | 0.02 | 11.08 | 0.06 | 0.02 |
| Big | 3412 | 32.95 | 0.36 | 0.09 | 8.72 | 0.18 | 0.04 |
| Rex | 218 | 79.03 | 1.02 | 0.23 | 79.03 | 1.02 | 0.23 |
| W. North | 357 | 38.08 | 0.30 | 0.20 | 25.15 | 0.20 | 0.15 |
| E. Shutters | 105 | 39.25 | 0.03 | 0.07 | 39.25 | 0.03 | 0.06 |
| Upper North | 751 | 25.65 | 0.34 | 0.12 | 9.12 | 0.22 | 0.07 |
| Black | 819 | 25.30 | 0.06 | 0.03 | 18.42 | 0.06 | 0.02 |
| Central South | 553 | 33.67 | 0.39 | 0.19 | 17.44 | 0.23 | 0.12 |
| Central North | 678 | 23.46 | 0.30 | 0.15 | 9.90 | 0.21 | 0.10 |
| Murphy | 713 | 6.13 | 0.07 | 0.02 | 6.23 | 0.07 | 0.02 |
| Coleman | 343 | 27.17 | 0.40 | 0.14 | 12.37 | 0.24 | 0.09 |
| Templeton | 231 | 25.35 | 0.40 | 0.13 | 6.99 | 0.23 | 0.07 |

These results suggest that the wetland scenario would reduce concentrations of TSS in the average catchment from 30.5 mg/L to 16.3 mg/L, and the corresponding reductions in concentration of $NO_3$ - and $PO_4$ would be 0.32 mg/L to 0.21 mg/L and 19 µg/L to 10 µg/L respectively. These changes represent a 47% decrease in TSS and $PO_4$ and a 34% decrease in $NO_3$ -. Export of $PO_4$ from wetlands can remain quite high because of the solubilization of P under reducing conditions in the wetland soils. Total phosphorus loads, on the other hand, would be greatly reduced under a wetland scenario because of the strong association of TSS and TP.

For phosphate ($PO_4$), the patterns among the three model scenarios are more strongly related to soil properties. The predominant silt loam soils in the far western portion of the watershed will continue to leach at rates greater than the eastern portion of the watershed. The wetlands scenario is not highly successful in reducing $PO_4$ concentrations in the western portion because this land will remain urbanized and restoring a 1000 meter wetland would not be feasible. These catchments will continue to export high concentrations of $PO_4$ to South Tenmile Lake.

This reduction in watershed exports would be expected to further decrease if the extent of the lowland wetland buffers was increased over 1000 meters. Murphy Creek wetland buffer extends up the channel from the lake about 2.5 km.

The figures below compare current and Historical (historic) sediment (t/ha/yr), nitrate (kg/ha/yr), and phosphorus (kg/ha/yr) average annual loads and water column concentrations of sediment (TSS mg/L), nitrate (mg/L), and phosphorus (mg/L) by catchment.

**Table 28 - Catchment Names and Numbers**

| Catchment Name | Catchment Number | Catchment Name | Catchment Number |
|---|---|---|---|
| Lakeside | 1 | Rex | 11 |
| Devore | 2 | W. North | 12 |
| W. Shutters | 3 | E. Shutters | 13 |
| Adams | 4 | Upper North | 14 |
| S. Shutters | 5 | Black | 15 |
| Johnson | 6 | Central South | 16 |
| Benson | 7 | Central North | 17 |
| Lindros | 8 | Murphy | 18 |
| Wilkins | 9 | Coleman | 19 |
| Big | 10 | Templeton | 20 |

**Figure 32- Current vs. Historical Sediment Loading by Catchment**

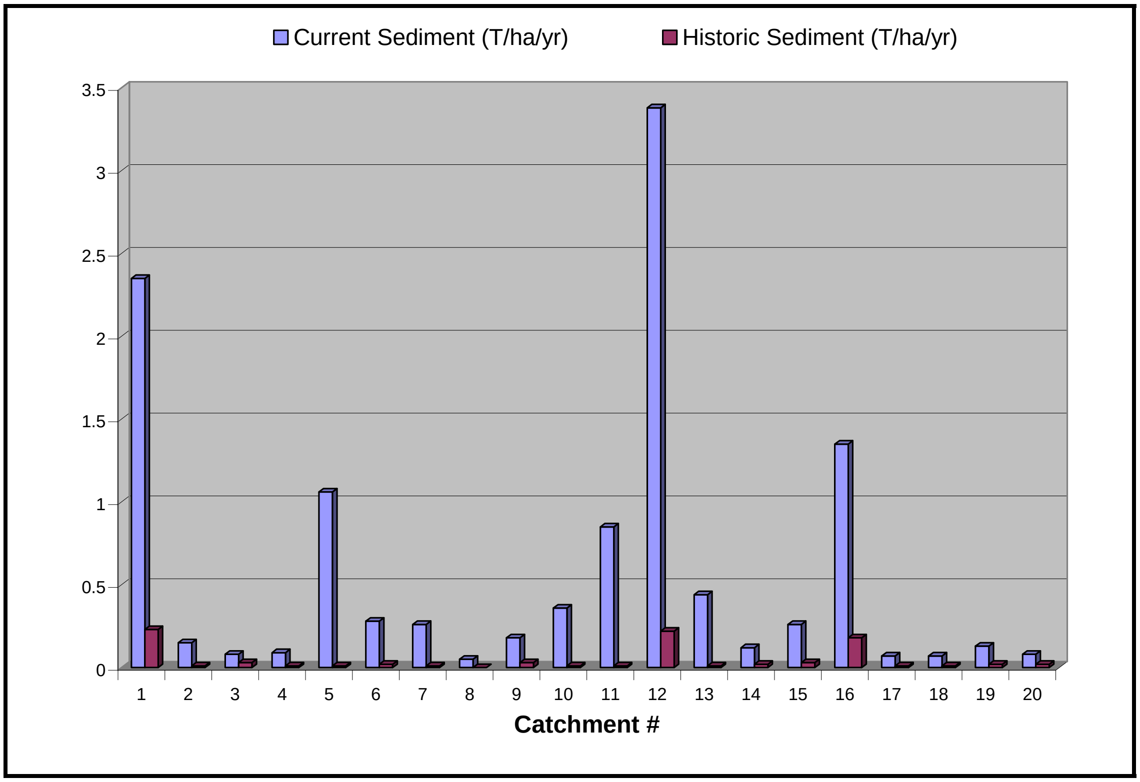



**Figure 33 - Current vs. Historical Nitrate Loading by Catchment**

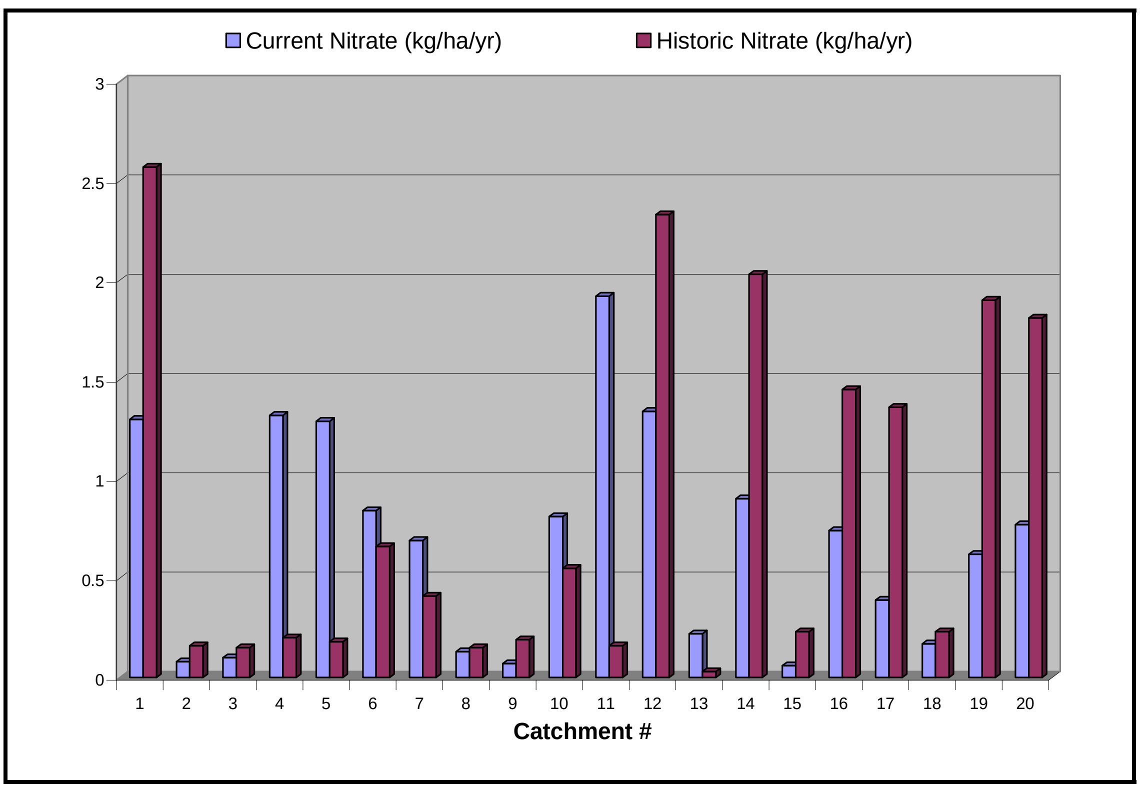


**Figure 34 - Current vs. Historical Total Phosphorus (TP) Loading**

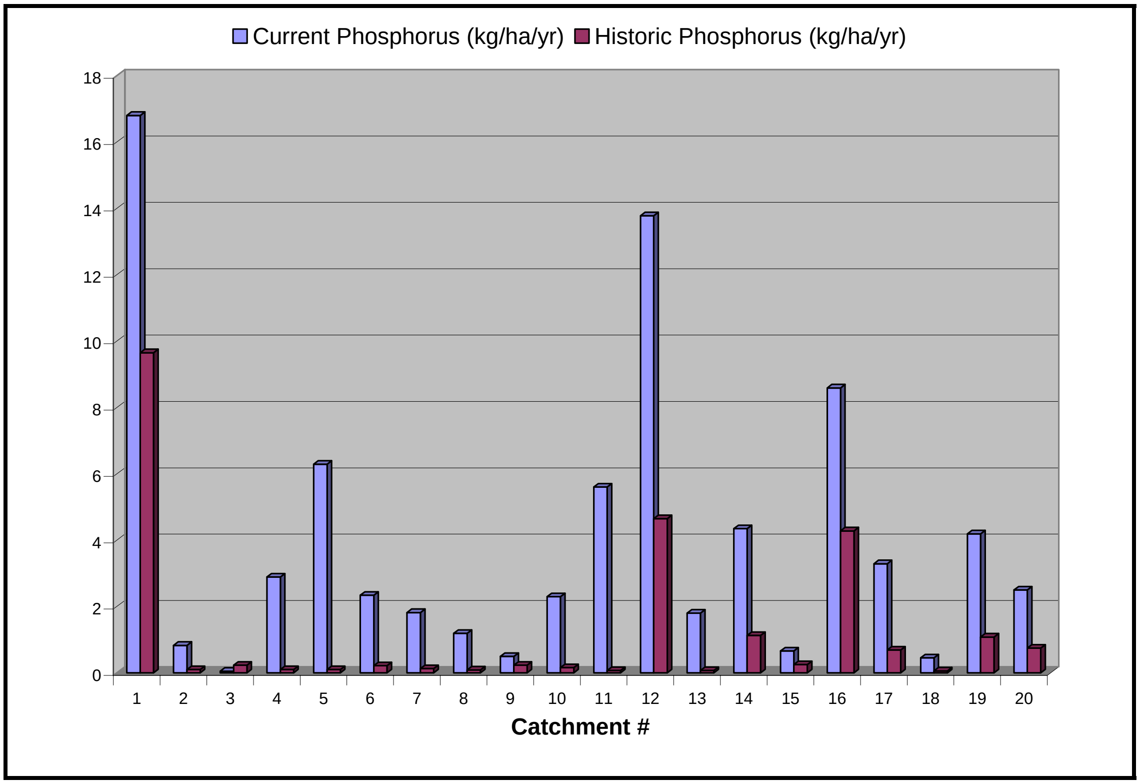



**Figure 35 - Average Annual Sediment Concentrations (TSS) Under Three Modeling Scenarios**

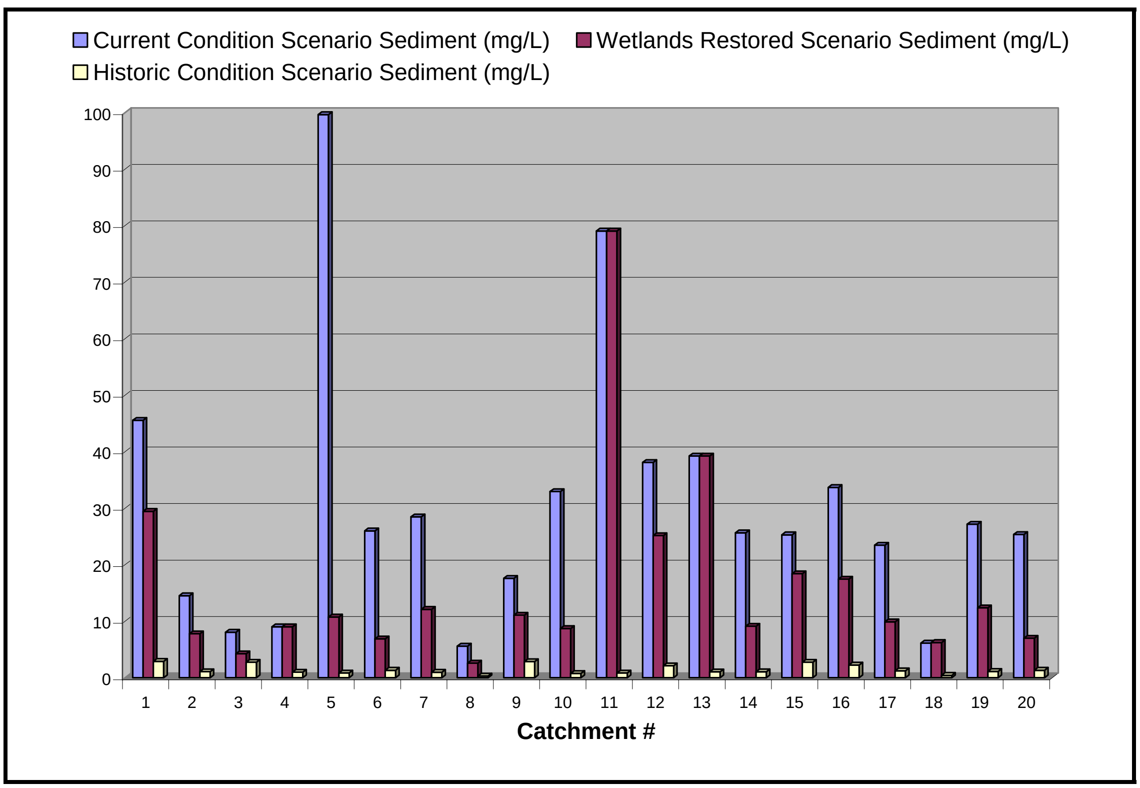


**Figure 36 - Average Annual Phosphate ($PO_4$) Concentrations for Three Modeling Scenarios**

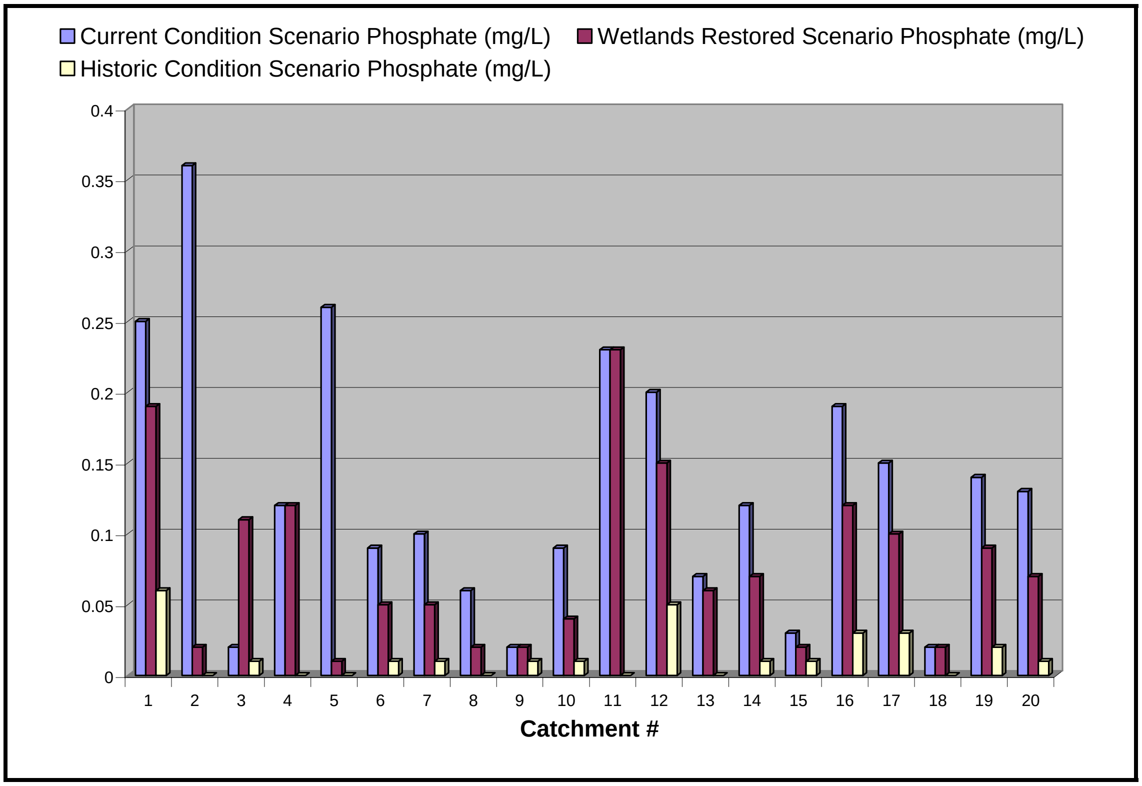
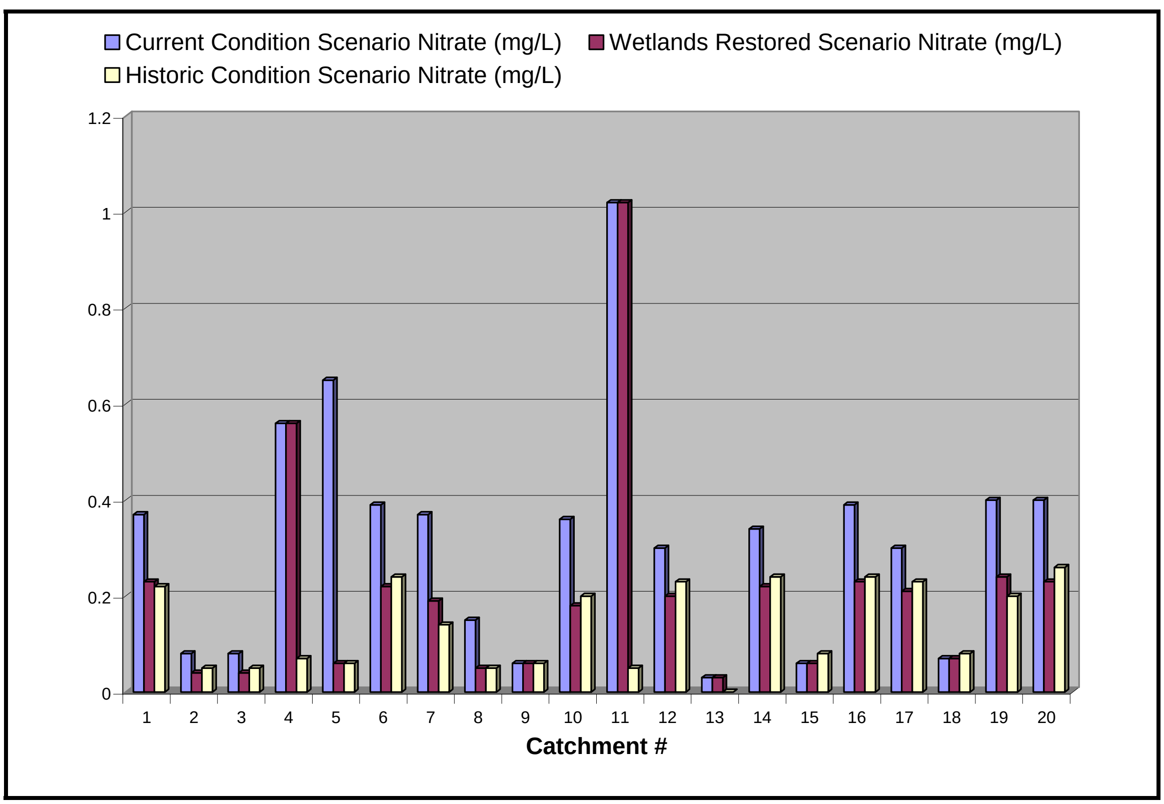



**Figure 37 - Average Annual Nitrate ($NO_3$) Concentrations for Three Modeling Scenarios**



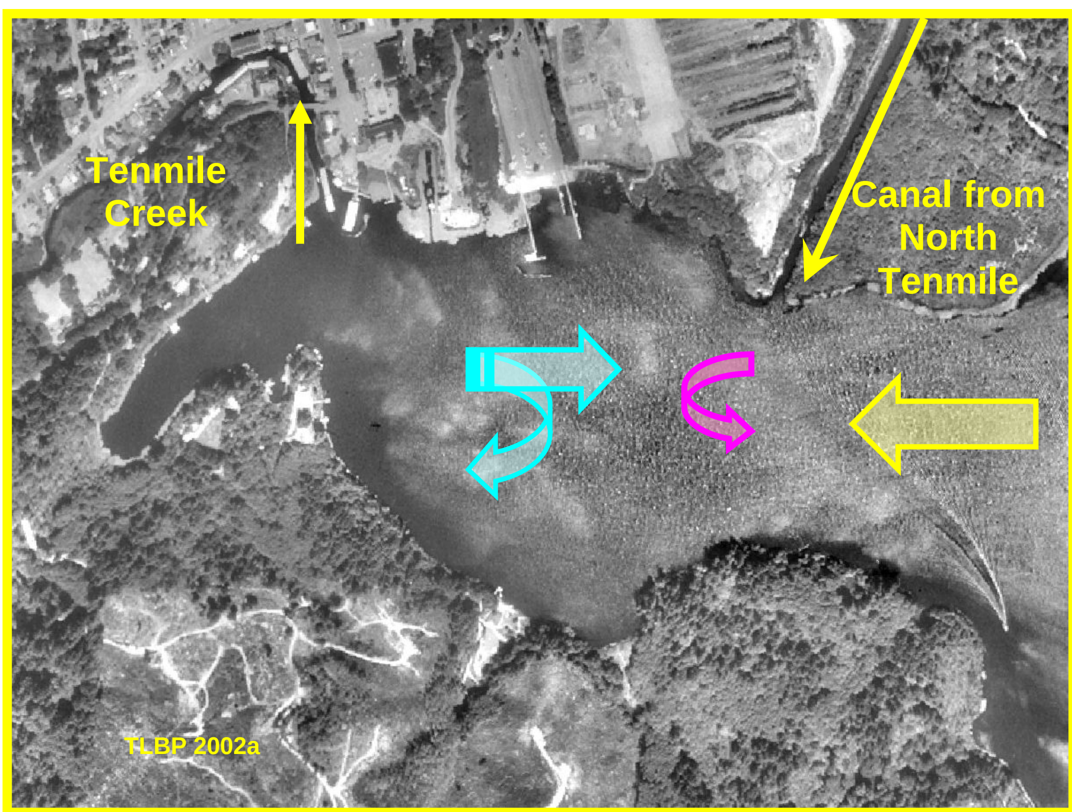
## 6.3.4 Urban Sediment Loading

Hydrological changes in watersheds are often magnified in urban areas. Impervious surfaces, such as rooftops, roads, parking lots, and sidewalks, decrease the infiltrative capacity of the ground and result in greatly increased volumes of runoff. Elevated flows also necessitate the construction of runoff conveyances or the modification of existing drainage systems to avoid erosion of streambanks and steep slopes. Changes in stream hydrology resulting from urbanization include the following (Schueler, 1987):

- Increased peak discharges compared to Historical levels (Leopold, 1968; Anderson, 1971);
- Increased volume of urban runoff produced by each storm in comparison to Historical conditions;
- Decreased time needed for runoff to reach the stream (Leopold, 1968), particularly if extensive drainage improvements are made;
- Increased frequency and severity of flooding;
- Reduced stream flow during prolonged periods of dry weather due to reduced level of infiltration in the watershed; and
- Greater runoff velocity during storms due to the combined effects of higher peak discharges, rapid time of concentration, and the smoother hydraulic surfaces that occur as a result of development.

As a result urban land uses tend to export phosphorus at rates often equivalent to or higher than other land uses. The extent of impervious surfaces is a primary reason for higher export rates. These impervious surfaces are very efficient conduits for exporting water and contaminants off the landscape. Because flows from the western portion of the watershed dominate the hydrology of the lake, it is the western portion of the watershed that must continue to receive the greatest effort at nutrient reduction.

**Figure 38– Predominant Hydrology in South Tenmile Lake at the City of Lakeside Interface**



The City of Lakeside storm water drainage is delivered to South Tenmile Lake and to North Tenmile Lake via Bowron Creek. The City is not currently required to operate this drainage system under an NPDES permit because the population is below the current thresholds which require permitting. The City of Lakeside will need to address storm water management within their required Water Quality Implementation Plan. Upon future review of this TMDL, the City of Lakeside storm water collection system may be required to secure and NPDES permit which could identify discharge permit limits.

## 6.3.5 Direct Lakeshore Sediment Loading

Because the focus of this TMDL study has been largely on watershed processes and stream monitoring, it should not be inferred that the degradation of the lake has been solely caused by upland management practices within the watershed such as timber harvest, livestock grazing, and stream channelization. Indeed, it is clear that watershed activities have altered the loads of sediment and nutrients to the lake. However, a lake improvement program based solely on improving land use practices in the upper watershed will likely not yield the desired improvements in lake water quality. Although decreasing the sediment and nutrient loads from the watershed is a necessary element of improving the Tenmile Lakes, there are other factors that have not been fully addressed in this study that influence lake water quality. As a result it is extremely important that all sources within the watershed (land management, rural residential, urban, fisheries, etc) seek to reduce nutrient loading to North and South Tenmile Lakes.

The Nutrient Study (TLBP, 2002a) was less able to quantify sediment loads from lakefront development. Although not fully quantified, reducing pollutant loading from these sources is an important part of improving water quality in the Tenmile Lakes. The Water Quality Management Plan for this water body will emphasize the importance of the inclusion and implementation of management practices designed to reduce nutrient loading from rural residential sources.

Land development activities along the lakeshore are quite variable and often episodic in nature. Developmental activities associated with lake shorelines include road construction, home site development, and grounds development like lawns and landscaping.

Longer term nutrient contributions can come from on-site waste water treatment and grounds management activities that require fertilizer input. These activities can continue to supply the lake with increased loading of nitrogen and phosphorus for the duration of occupancy and beyond. Because of the episodic nature of lakefront development, the SWAT model, in its present formulation, has limited capability for including nutrient inputs from these activities.

These activities often result in ground disturbing activities exposing soils to erosive forces and are often accompanied by removal of natural lakefront vegetation to accommodate views and moorage. Removal of riparian vegetation can result in the loss of natural nutrient buffering. The loss of littoral wetlands (lake perimeter vegetation) also results in reductions in nutrient uptake and buffering. The loss of littoral wetlands and lakefront riparian areas makes exposed soils along the lakeshore more susceptible to erosion from wave and wake action caused by boat traffic and wind.

Housing development can and often does increases sediment production during construction. Lakefront landslides are often seen in conjunction with driveway and home site development often resulting from the side casting of unconsolidated soils onto steep slopes.

**Figure 39 – Lakefront Development Slope Failure**

# *6.4 PALEOLIMNOLOGICAL RECONSTRUCTION OF PAST CONDITIONS*

## 6.4.1 Historical Conditions Inferred from Analysis of Sediments

***Please refer to the Nutrient Budget (TLBP 2002a) for a more detailed discussion of sediment core sample results.***

**Figure 41 – Diatom Cell Structure in Sediment**

Sediment cores were collected from four sites (South Lake (STA), North Lake (NTA), North Lake Arm (NTB), and Lindros Arm (LIN) were dated using 210Pb. The 210Pb information allows estimation of the age of the sediments and allows the computation of the sediment accumulation rate (SAR). The sediment core from the south lake station (STA) was also analyzed for fossil diatoms, nitrogen, Nitrogen-15 (15N), and cyanobacteria akinetes. Diatom taxa preserve well in lake sediments because the cell wall is composed of silica. Diatoms have specific environmental requirements and the type of species in the sediments can provide considerable information about the historical water quality in the lake.

15N is a naturally-occurring isotope of nitrogen (atomic weight 14). A shift in the 15N/14N ratio can provide insight into shifts in sources of nitrogen to the lake. An elevated ratio can be associated with high inputs of marine-derived N from anadromous fish. It also can be caused by a shift in the proportion of N-fixing phytoplankton (E.g. cyanobacteria) had increased.
Akinetes are structures found on N-fixing cyanobacteria that can be preserved in the sediments. An increase in akinetes can signal an increase in cyanobacteria.

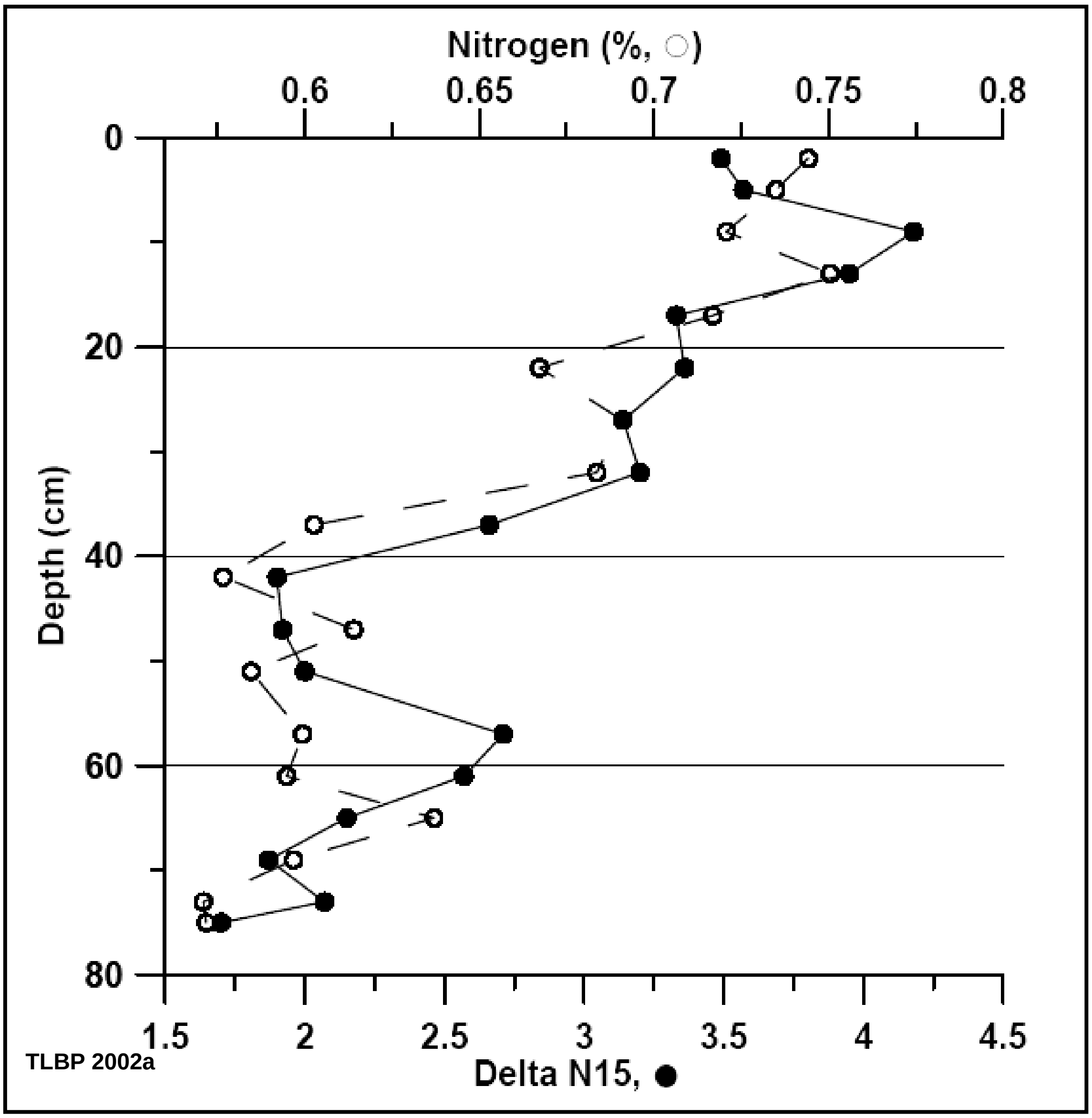
Sediment core results revealed that:

- STA Nitrogen and the ratio of 15N/14N show increases in the upper sediments, consistent with an increase in lake productivity and an increase in the biomass of nitrogen-fixing cyanobacteria.
- STA sediment akinete results also suggest that there has been a several-fold increase in the biomass of cyanobacteria in South Tenmile Lake in recent decades (since the early 1900's).
- STA diatom results show a significant increase in the relative abundance of taxa that favor eutrophic waters.
- Sediment Accrual Rates (SAR) has increased two to four-fold over Historical conditions.

### 6.4.1.1 Nitrogen

Sediment at station STA was analyzed for nitrogen, to determine ambient concentrations and to examine the ratio of naturally occurring isotopes. The results depicted in the figure below show that the upper sediments have nearly twice as much nitrogen as the bottom sediments and the proportion of 15N increased in the upper sediments. The sediment nitrogen profile may be in part an artifact of in-lake processes but it is difficult to attribute the increasing ratio of 15N to diagenesis. The 15N/14N ratio may also be changing as benthic organisms differentially accumulated the heavier isotope (cf., Adams and Sterner 2000). Taken in conjunction with diatoms and the akinete results, it is difficult to attribute both sets of sediment nitrogen results to sediment processes. The increase in 15N would be expected if the population of N-fixing cyanobacteria (blue-green algae) had increased. The increase in 15N would have had to be large in order to overcome the expected loss of marine-derived 15N associated with the decline in the salmon runs into South Tenmile Lake.

**Figure 40 - Nitrogen and 15N Versus Depth in Sediments, South Tenmile Lake**

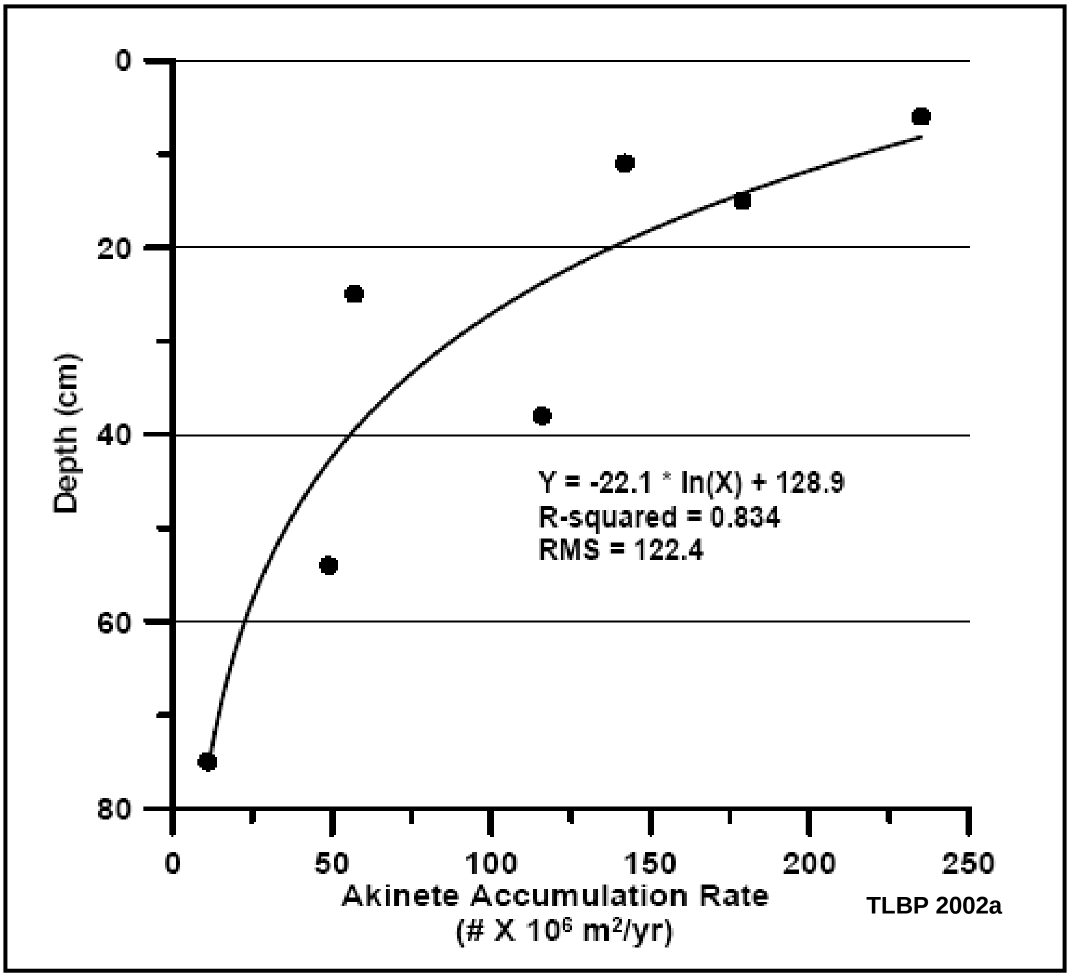



*Nitrogen (N, % N by dry weight) and 15N as delta 15N/14N*

### 6.4.1.2 Cyanobacterial Akinetes

The results of an examination of akinetes present in the sediments at station STA are depicted in the figure below. These results show that the rate of cyanobacterial akinetes accumulation is increasing and trending upward. The greater deposition of akinetes is indicative of an increase in cyanobacteria, particularly those taxa that fix nitrogen. These results further support those of diatom stratigraphy which also show an increase in lake productivity. The results are also consistent with the nitrogen data showing increasing biological productivity N-fixing cyanobacteria. Although a moderate population of cyanobacteria have been present in the lake for at least the last several hundred years, the rate of change in the 20th century is highly consistent with increased nutrient availability in the lake.

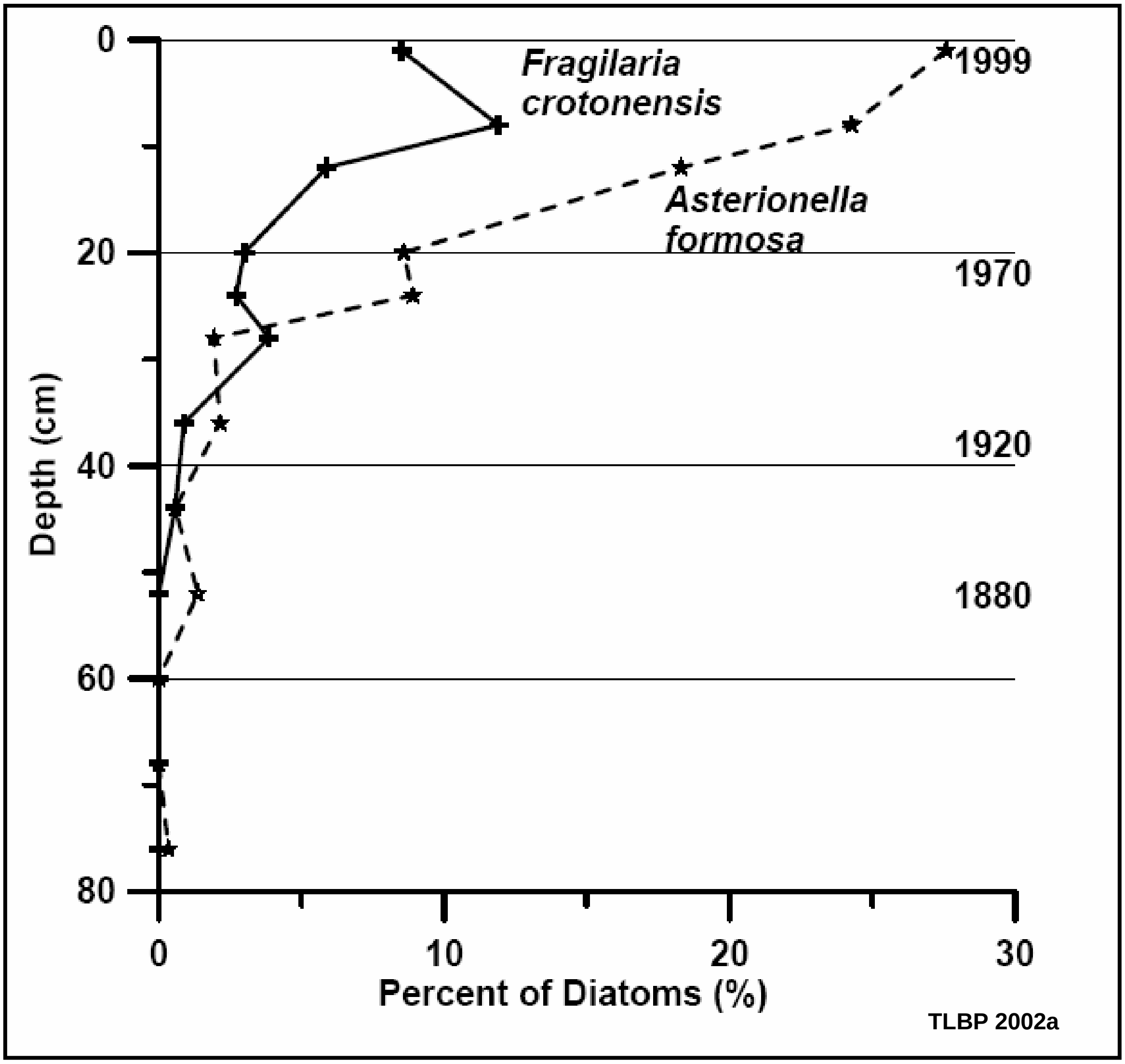
**Figure 41 - Accumulation Rate of Cyanobacterial Akinetes in South Tenmile Lake (STA).**




### 6.4.1.3 Diatoms

There has been a major increase in *Asterionella formosa* and a smaller increase in *Fragilaria crotonensis*, taxa commonly associated with eutrophic lakes. A diatom bloom observed in April, 1999 was comprised largely of *A. formosa*. These nitrogen dependant early season (spring) blooms consume available nitrogen and create conditions that may favor nitrogen fixing, blue-green algae blooms later in the summer season. Benthic (bottom-dwelling) diatoms have decreased in the lake and the diatom community is now largely planktonic. These changes are consistent with a decrease in transparency in the lake, most likely caused by an increase in planktonic algae and cyanobacteria.

**Figure 42 - Relative Percentage of *Fragilaria crotonensis* and *Asterionella formosa* in Sediments (STA).**



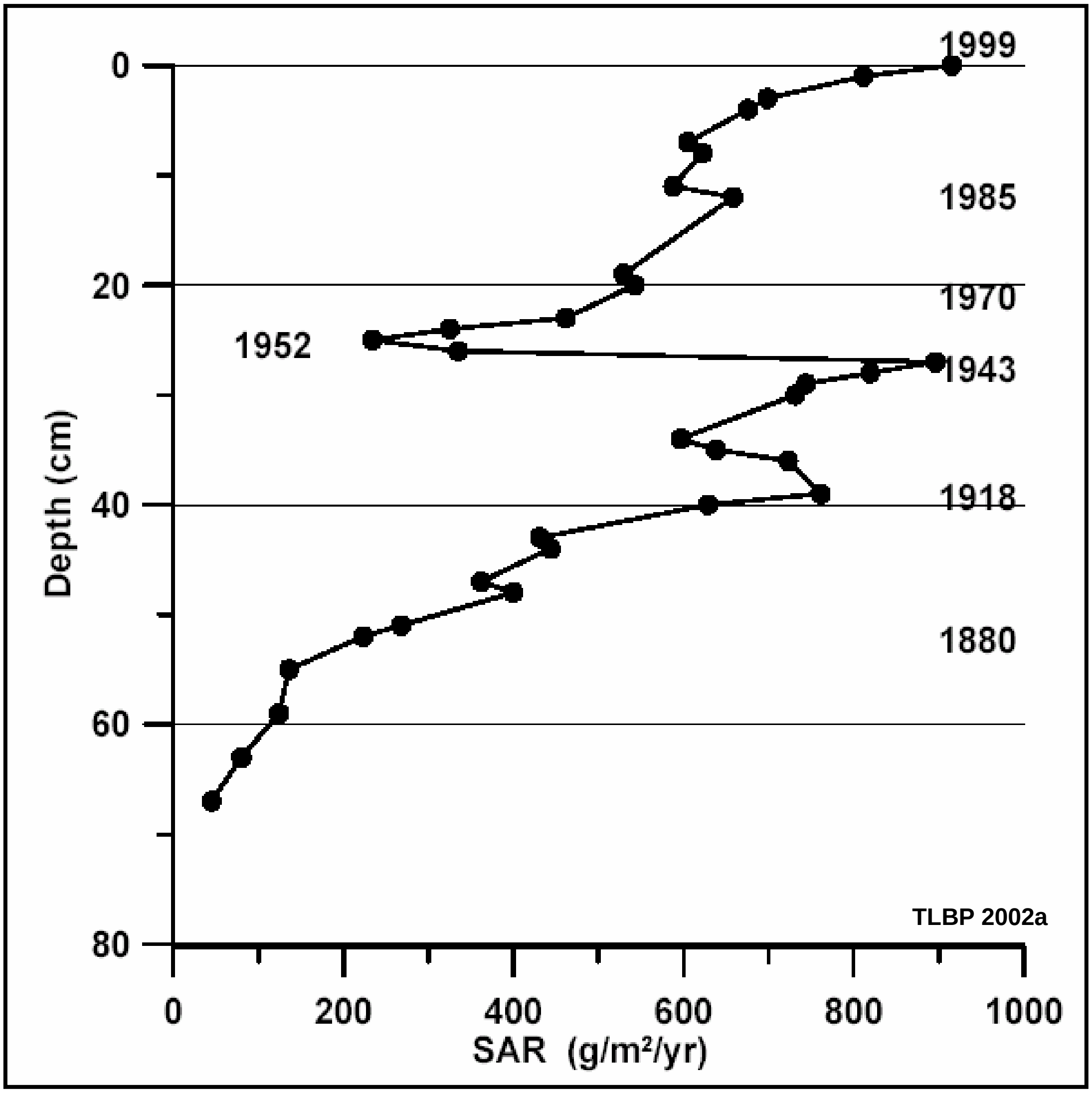

### *6.4.2 Sediment Accumulation Rate (SAR) – Timeline of Events Comparison*

Sediment cores were collected from four sites (South Lake (STA), North Lake (NTA), North Lake Arm (NTB), and Lindros Arm (LIN). Increases in SAR were noted in the late 19th century, corresponding with the early land clearing and settlement in the area. A major increase in SAR occurred in the period 1910-1920, at a time when road building and commercial logging activities were high. These activities were conducted using management practices commonly applied prior to water protection measures now required for these activities.

SAR declined circa 1950, likely as a result of diverted resources and manpower related to WWII. The figure below graphically shows a continuous increase in SAR since the end of WWII. The general shape of the SAR record (i.e., increase in SAR, a mid-century partial recovery followed by an accelerated increase in SAR) is similar to that observed in Devils Lake, located on the Oregon central coast (Eilers et al. 1996b). Devils Lake underwent a similar development timeline as occurred in the Tenmile Lakes Watershed. The increased SAR is consistent with monitoring and watershed modeling results which point to elevated rates of sediment yield from the watershed.

An example of one of the four sediment cores is graphically depicted below. This sediment core was collected at station STA, the South Tenmile Lake open water site.

**Figure 43 – Sediment Accumulation Rate at South Tenmile Lake Site (STA)**




**Anthropogenic Events Timeline**

***1910 – 1920***

Railroad and road building

Early logging prior to riparian and water protection measures

***1920 – 1940***

Agricultural wetland conversion, continued upland timber harvest

***1939 - 1945***

World War II

***1955 to Present***

Accelerated urban and residential lakeshore development

Upland timber harvest (Forest Practices Act 1972)

Continued stream channelization and maintenance

Increased low gradient channel instability

Loss of wetlands

Both pre-settlement and current sediment accrual rates are presented in the table below. Because sediment core data is limited, ODEQ will seek to work with partners to expand this baseline network. SAR is proposed as a measure of long term sedimentation trends.

| Table 29 - Sediment Accumulation Rates (SAR) Summary | | |
|---|---|---|
| **Location** | **Pre-settlement** | **Current** |
| South Lake (STA) | 200g/m$^2$/yr. | 900 g/m$^2$/yr. |
| North Lake (NTB) | 400g/m$^2$/yr. | 1300 g/m$^2$/yr. |
| North Lake (NTA) | 400g/m$^2$/yr. | 800 g/m$^2$/yr. |
| Lindros (LIN) | 300g/m$^2$/yr. | 700 g/m$^2$/yr. |

SAR is proposed for use as a long term measure of the effectiveness of sediment and nutrient abatement measures. It is recommended that SAR core sites should be expanded to other lake sites and then should be re-evaluated again within twenty five years. Because the measurement of sediment loading during critical flow periods associated with maximum sedimentation events and mass wasting events is often not feasible, SAR is a good long term that will help to ensure that this TMDL will result in beneficial use protection. The sediment accrual record may provide a better representation of the overall watershed response to increased sediment loading because it integrates inputs over time and space rather than event related stream monitoring. A critical condition is represented by major storms (e.g., storms with a recurrence interval of approximately 25 - 50 years or more). Such storms and the associated floods and huge sediment loads can affect watershed conditions dramatically and may support the re-evaluation of SAR on a more frequent basis.

As the natural aging process for lakes results in a filling trend, increased SARs reflect the accelerated aging of these lakes. Reduced depths provide habitat favoring weed colonization and increases in available nutrients favor algae growth.

## *6.5 EXCESS LOADS - SEDIMENTATION*

### 6.5.1 Interim Sediment Load Targets

#### *6.5.1.1 Reference Streams*

Pollutant loads for the tributaries in the table below were measured and/or modeled and have supported selection of these reference streams or drainage areas for this TMDL. Phosphorus exports are low and compare well with other studies regarding phosphorous inputs from forested landscapes as well as pastured and open parks. Sediment loading from these drainages is close to that of Murphy Creek, where sediment loads to the lake were measured and found to be low. These values have been utilized to derive the sediment loading capacity of the Tenmile Lakes and watershed tributaries.

| Table 30 – "Reference Streams"<br>Streams Where Sediment Loading is at or Near Reference Condition | | | |
|---|---|---|---|
| Name | Area (ha) | Reference Feature | Current Annual Sediment Loads (tones/ha) |
| W. Shutters | 109 | Intact Wetland | 0.08 |
| Adams* | 693 | *Intact Wetland | 0.09 |
| Central North | 678 | 23% Lake Surface Area | 0.07 |
| Lindros | 426 | Low Stream Development | 0.05 |
| Murphy | 713 | Intact Wetland | 0.07 |
| Templeton | 231 | 22% Lake Surface Area | 0.08 |
| | **2850 Total** | | **0.07 Weighted Average** |

Watershed landscape conditions were derived from aerial photography collected in 1994 and updated with an aerial survey in 1999. Conditions in these drainages may have changed significantly.

*For example, it should be noted that the Adams Creek stream channel has recently been channelized (managed) in a very traditional manner and wetland function has been diminished.

| **Table 31 – Phosphorus Loading Information from Literature as Compared to Tenmile Lakes Watershed Reference Streams** | | | |
|---|---|---|---|
| **Watershed** | **Land Use** | **Annual Phosphorus Loading (kg/km$^2$/year)** | **TP Concentrations ug/L** |
| Literature | Forest/Marsh | 10-15<br>(Reckhow and Simpson, 1980; Verry and Timmons, 1982). | 20-50<br>(McCollor and Heiskary, 1993) |
| Literature | Pastured/Open Parks | 20-40<br>(Schueler, 1995). | NA |
| USEPA Criteria Recommendation | River and Streams (Western Forested Mountains) | NA | 10<br>(USEPA, 2000b |
| Tenmile Lakes Watershed Reference Streams (6) | Forest/Wetland | 32 | 8 |

### 6.5.1.2 Watershed Tributaries

For Tenmile Lakes Watershed tributary streams and drainages, sediment load reduction targets are based upon reference stream loading of 0.07 t/ha/yr (7.3 t/km$^2$). It should be noted that the SWAT modeled, historical weighted average sediment loads for these watersheds was 0.01 t/ha/yr (4.8 t/km$^2$). This is the predicted load with an undisturbed landscape, prior to anthropogenic ground disturbing activities.

Although there may be many questions about processes utilized to select reference water quality and landscape conditions from which to derive loading allocations, clearly improvements can be made to reduce sediment and nutrient loading in the Tenmile Lakes Watershed. The use of selected stream within the watershed as reference for the first iteration of this TMDL sets clear and attainable load reduction targets. Because TMDLs are an iterative process, additional data should be gathered through time to help refine model calibration and to adjust reference loading targets as necessary in the future, support adaptive management, and to ensure the protection of beneficial uses.

The tables below show current sediment loading values for eleven catchments, reductions needed to attain reference conditions, and reductions needed to meet the target of 50% reduction in annual sediment loads in 25 years. The load reduction target is shown in the units of tones of sediment per hectare and per square mile.

**Table 32 – Interim Sediment Load Reduction Targets (t/ha)**

| Name | Catchment # | Area (hectare) | Annual Loads Sediment Current Condition | Annual Load Reduction Sediment Reference Condition | ***Target 50% Reduction Within 25 Years*** |
|---|---|---|---|---|---|
| Devore | 2 | 116 | 0.15 | 0.08 | 0.08 |
| S. Shutters | 5 | 644 | 1.06 | 0.99 | 0.53 |
| Johnson | 6 | 4473 | 0.28 | 0.21 | 0.14 |
| Benson | 7 | 2411 | 0.26 | 0.19 | 0.13 |
| Wilkins | 9 | 478 | 0.18 | 0.11 | 0.09 |
| Big | 10 | 3412 | 0.36 | 0.29 | 0.18 |
| Rex | 11 | 218 | 0.85 | 0.78 | 0.43 |
| E. Shutters | 13 | 105 | 0.44 | 0.37 | 0.22 |
| Upper North | 14 | 751 | 0.12 | 0.05 | 0.06 |
| Black | 15 | 819 | 0.26 | 0.19 | 0.13 |
| Coleman | 19 | 343 | 0.13 | 0.06 | 0.07 |
| **Totals** | **11 total** | **13,770** | **4.09** | **3.32** | **2.06** |

| Table 33 - Annual Sediment Load Reduction Targets (t/mile$^2$) | | | | | |
|---|---|---|---|---|---|
| Name | Catchment # | Area (square miles) | Current Condition | Reference Condition | ***Target 50% Reduction Within 25 Year*** |
| Devore | 2 | 0.44 | 17 | 8 | 8.5 |
| S. Shutters | 5 | 2.49 | 683 | 45 | 342 |
| Johnson | 6 | 17.27 | 1,252 | 313 | 626 |
| Benson | 7 | 9.31 | 627 | 169 | 314 |
| Wilkins | 9 | 1.85 | 86 | 33 | 43 |
| Big | 10 | 13.17 | 1,228 | 239 | 614 |
| Rex | 11 | 0.84 | 185 | 15 | 93 |
| E. Shutters | 13 | 0.41 | 46 | 7 | 23 |
| Upper North | 14 | 2.90 | 90 | 53 | 45 |
| Black | 15 | 3.16 | 213 | 57 | 107 |
| Coleman | 19 | 1.32 | 45 | 24 | 23 |
| **Totals** | **11** | **53.16** | **4,472** | **963** | **2,236** |

A target of attaining a 50% reduction in annual sediment loads within the next 25 years has been incorporated. The target of 25 years was selected by the local advisory group as a timeframe wherein significant sediment abatement activities could occur and allow for a positive response of in lake processes (e.g. stored sediment), and improvements in lake water quality might be realized. The advisory group felt that the 50% reduction target represent significantly less lake sedimentation and sets a clear attainable goal for land managers. It is not intended to limit sediment reductions should the opportunity to reduce loading beyond 50% occur.

### *6.5.1.3 Urbanized Landscape*

The SWAT model output for volume-weighted concentrations of TSS indicates that catchments immediately adjacent to South Tenmile Lake in and near the city of Lakeside, contribute a disproportionately greater amount of TSS to the lake even under the pre development scenario. These areas did not historically have wetlands to the extent of some of the other catchments in the watershed. Reference streams with significant wetlands contributed runoff with low TSS concentrations. The use these reference stream load allocations for catchments 1 (Lakeside), 12 (W North), and 16 (Central South) would reflect pollutant reductions above those seen for these areas under the historical modeling scenario. Interim sediment loading targets for these catchments are reflected in the tables below. Load reductions targets for these areas are based upon historical loads and are shown in the units of tones of sediment per hectare and per square mile.

Prior to 1999, the City of Lakeside Public Works Department utilized urban wetlands to manage stormwater runoff. These “drainage” wetlands are being impacted as a result of development and drainage maintenance projects. Protection and enhancement of wetland areas present in the urban landscape is critical to controlling stormwater runoff, protecting water quality, and achieving load reduction targets. We missed those wetlands in the TMDL or in the write-up.

**Table 34 – Annual Sediment Load Reduction Targets (t/ha)**

| Name | Catchment # | Area Hectare | Current Condition | Model Derived Historical Sediment Loads | Sediment Load Reduction |
|---|---|---|---|---|---|
| Lakeside | 1 | 792 | 2.35 | 0.23 | 2.12 |
| W. North | 12 | 357 | 3.38 | 0.22 | 3.16 |
| Central South | 16 | 553 | 1.35 | 0.18 | 1.17 |
| Total | 3 Total | 1,702 | 7.08 | 6.45 | 3.55 |

**Table 35 – Annual Sediment Load Reduction Targets (t/mile$^2$)**

| Name | Catchment # | Area Square Miles | Current Condition | Model Derived Historical Sediment Loads | ***Target 50% Reduction Within 25 Years*** |
|---|---|---|---|---|---|
| Lakeside | 1 | 3.06 | 1,861 | 182 | 930 |
| W. North | 12 | 1.38 | 1,207 | 79 | 604 |
| Central South | 16 | 2.14 | 747 | 100 | 374 |
| **Totals** | **3 Total** | **6.57** | **3,815** | **361** | **1908** |

## 6.5.2 Lake Sedimentation Targets

The table below presents sediment accrual rates (SAR) results for four sediment cores. Pre-settlement SAR and current SAR are presented. The percentage of increase over historic SAR is also shown. Increase SAR observed at the site called NTB is consistent with observed and anecdotal information indicating that delta building and extreme filling is occurring at the mouths of some tributaries.

**Table 36 – Sediment Accrual Rate Results**

| Location | Pre-settlement | Current | % Increase |
|---|---|---|---|
| South Lake (STA) | 200g/m$^2$/yr. | 900 g/m$^2$/yr. | 78% |
| North Lake (NTB) | 400g/m$^2$/yr. | 1300 g/m$^2$/yr. | 70% |
| North Lake (NTA) | 400g/m$^2$/yr. | 800 g/m$^2$/yr. | 50% |
| Lindros (LIN) | 300g/m$^2$/yr. | 700 g/m$^2$/yr. | 57% |

SAR directly links to lake water quality. It is not currently proposed for use to set a load capacity or load allocation in this TMDL. SAR is proposed for use as an overall measure of physical lake sedimentation rates over time. Sedimentation connects directly to the delivery and storage of the nutrient phosphorus and ties directly to lake filling, a primary driver for the expansion of nuisance weeds. The reduction of the lake sediment accrual rate by 50% within the next 25 years is identified as a target.

## *6.6 LAKE WATERS TOTAL PHOSPHORUS TARGET*

This TMDL identifies the nutrient phosphorus (P) as a water quality parameter which contributes to conditions which impair beneficial uses in Tenmile Lakes. Nutrient loading studies have identified elevated phosphorus level in lake waters. Because the primary nuisance algae are nitrogen fixing and cannot be limited by nitrogen, lake water column total phosphorus (TP) is proposed as a target directly linking to nuisance algal blooms.

### 6.6.1 The Relationship of Total Phosphorus to Algae

The element phosphorus became the focus of study because overwhelming evidence suggested that phosphorus limited algal growth in many aquatic systems (Schindler, 1977). Phosphorus values were highly correlated with algal biomass in lakes (Sakamoto, 1966); in turn, water clarity was shown to vary with algal levels (Edmondson, 1972). With these linkages quantified, the science of lake management arose around the premise that reductions in nutrient loads would reverse eutrophication, as measured by reduced nutrient concentrations, algal levels, and greater water clarity.

Phosphorus loading via sediments during storm events can be dominated by particulate phosphorus. Phosphorus present in the lake during the summer months is primarily dissolved orthophosphorus or phosphates ($P0_4$) the more readily available, dissolved faction. The availability of phosphate governs the rate of growth of many organisms, including plants and algae. Elevated levels of phosphate in the lakes contributes to ecological disequilibrium, and often leads to booms in the population of some organisms and subsequent busts in the populations of others deprived of other nutrients or essential elements by the rapid growth and consumption by the booming population.

Several forms of phosphorus can be measured. Total phosphorus (TP) is a measure of all forms of phosphorus, both dissolved and particulate, found in a sample. TP is relatively easy to measure and during analysis all forms of phosphorus are converted into orthophosphorus. TP generally reflects the amount of orthophosphorus plus some polyphosphates in the sample. TP has been used throughout North America as a basis for setting trophic state criteria and in developing related models. Because of the relationship between chlorophyll and phosphorus and its linkage to algae biomass, chlorophyll is often a major component of trophic state indices (Carlson, 1977) and water quality criteria. Oregon has set an endpoint of 10µg/L for chlorophyll a (chl a) for natural lakes that thermally stratify and 15µg/L for chl a for natural lakes that do not thermally stratify (NALMS, 1992).

Chlorophyll is the major photosynthetic pigment in plants, both algae and macrophytes. As such, Chlorophyll is probably most often used as an estimator of algal biomass. There are actually two types of chlorophyll, named *a* and *b*. They differ only slightly, in their chemical composition. Both of these two chlorophylls are very effective photoreceptors that have very strong absorption bands in the visible regions of the light spectrum, allowing the plant to absorb the energy from sunlight.

Data collected as part of the Nutrient Study (TLBP, 2002a) revealed that episodically high chlorophyll a values occur in conjunction with nuisance algal blooms. Future monitoring efforts will seek to pair algae and chlorophyll a sampling when ever possible.

## 6.6.2 Target Determination

Because coastal lakes in Oregon are significantly altered, it was impossible to select an appropriate reference site to represent pre management conditions. Use of lakes from neighboring regions as reference sites did not seem a viable option with respect to impacts and overall comparability to the Tenmile Lakes Watershed. Because a good reference lake was not identified reference conditions were inferred from other information, including models, historical data sets, presented in USEPA criteria recommendations.

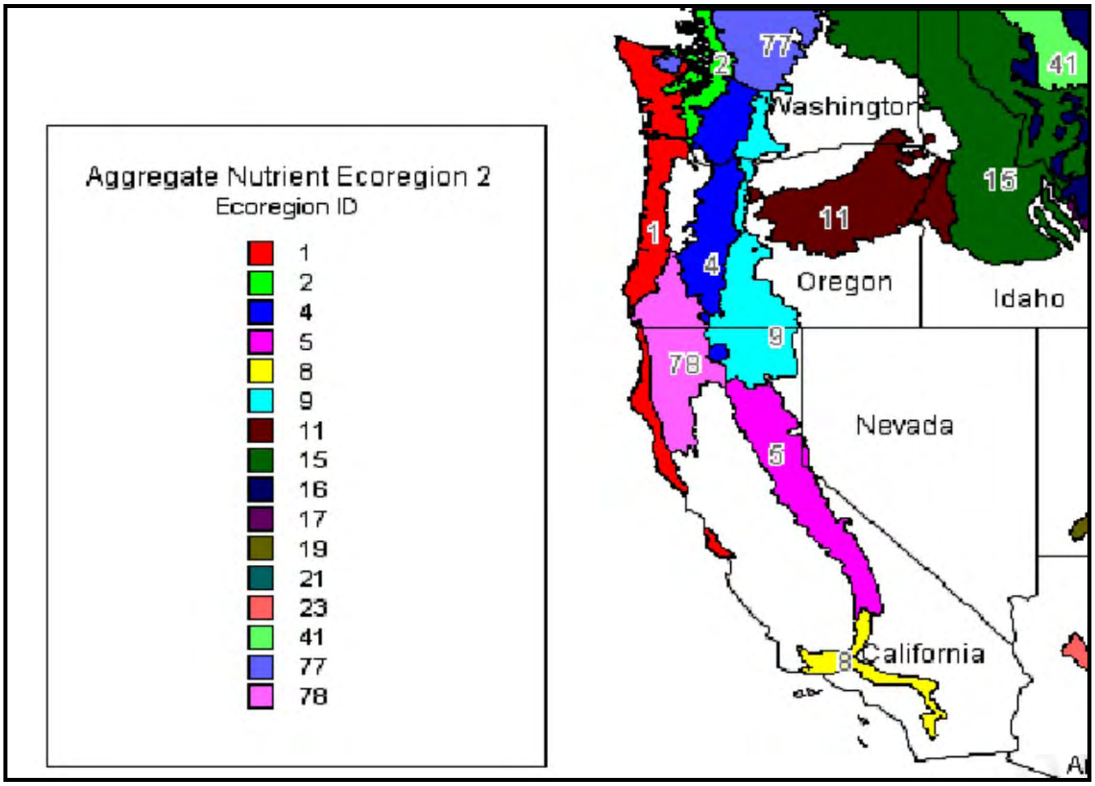
USEPA has developed the National Strategy for the Development of Regional Nutrient Criteria (National Strategy) (USEPA, 1998) and technical guidance manuals for lakes, reservoirs, wetlands, rivers, and streams, inclusive of reference criteria guidance for specific nutrient ecoregions (USEPA, 2000). Because some parts of the country have naturally higher soil and parent material enrichment, and different precipitation regimes, the application of the criterion development process has to be adjusted by region. Therefore, an ecoregional approach was chosen to develop nutrient criteria appropriate to each of the different geographical and climatological areas of the country. Soils, vegetation, climate, geology, land cover, and physiology that are associated with spatial differences in the quantity and quality of ecosystem components are relatively similar within each ecoregion.

Setting ecoregional criteria for the large scale aggregates is not without its drawbacks as variability is high. USEPA recommends that States and Tribes develop nutrient criteria at the level III ecoregional scale and at the waterbody class scale where those data are readily available. An Oregon Regional Technical Assistance Group (RTAGs) is working to develop recommendations for reference criteria at the more localized geographic scale for lakes within Oregon.

USEPA's criteria recommendations are based upon a process whereby historical and recent nutrient data in Nutrient Ecoregion II were utilized to assess nutrient conditions. This ecoregion has a highly heterogeneous coverage with regard to nutrient data. In the northwest area increased logging has likely increased sedimentation which is often associated with nutrient leaching and run-off to lakes and streams. Urbanization around large metropolitan areas has likely contributed to nutrient additions to streams and directly to some lakes. Grazing is another activity that may have played a role in increased nutrient loading. Wildfires likely cause considerable yearly variation in nutrient loading.

Tenmile and Eel Lakes are considered part of the region called Level III Ecoregion II, Western Forested Mountains. Reference sites and reference conditions were evaluated based on the lake population distribution approach which uses a representative sample of all lakes within the Ecoregion to derive reference values based upon the lower 25th percentile value of all data available for the region. The procedures for determining reference recommendations are described in more detail in the Nutrient Criteria Technical Guidance Manual Lakes and Reservoirs (USEPA, 2000). USEPA presented recommended criteria for total phosphorus, total nitrogen, chlorophyll a, and turbidity for lakes and reservoirs for this ecoregion. These nutrient criteria are intended to address cultural eutrophication and the adverse effects of excess nutrient inputs. The criteria are empirically derived to represent conditions of surface waters that are minimally impacted by human activities and protective of aquatic life and recreational uses.

**Figure 44 - Aggregate Ecoregion II with Level III Ecoregions Shown**




| Table 37 – Summary of USEPA Recommendations for Lakes Reference Conditions | |
|---|---|
| Reference Parameter | Level 3 Subecoregion 1 |
| TKN (mg/L) | 0.11 |
| $NO_2$ -+$NO_3$ - (mg/L) | 0.02 |
| TN (mg/L) | 0.19 |
| TP (ug/L) | 7.1 |
| Chlorophyll a (ug/L) *(fluorometric)* | 2.3 |
| Secchi depth (meters) | 5.1 |

USEPA's recommended criteria are utilized to set a preliminary target for total phosphorous (TP) in the Tenmile Lakes. These criteria are proposed as a starting point pending the states development of more refined nutrient criteria. TP is proposed as a good general indicator of phosphorous loading as an all season average. The use of an all season average over time incorporates winter loading events as well as summer conditions (the period of algal blooms). The large seasonal fluctuation in lake stage corresponds with considerable variation in the hydraulic residence time in the lake. High discharge from the tributaries in the winter reduce the hydraulic residence time in the Tenmile Lakes to approximately 15 days, compared to a residence time of 30 days in the spring and 300 days in the summer

Phosphorus is present in the lake during the summer months when nuisance algae blooms occur from multiple sources including; seasonal lakefront activities as well as internal lake cycling (sediments, fishery, weeds, etc). Because discrete loads from these sources are elusive to define, TP is proposed as a target, to work towards, rather than a load allocation for the following reasons;

- No point sources discharge into the water quality limited waterbody and no WLAs are currently proposed
- Although the derivation of a mass load (LA) for TP is possible, no precision is added to the project
- A LA for TP would be solely allocated to internal lake processes
- Setting a LA, or developing further modeling at this time, would not change NPS implementation priorities
- Setting of the TP target allows more monitoring to occur through time and supports an adaptive management approach
- Additional nutrient data is needed for Oregon lakes to support future nutrient criteria discussions

**Table 38 – Lake Water Quality Target**

| | | | |
|---|---|---|---|
| Lake Water Column | Total Phosphorus (TP) | All Season Average | ≤7.1ug/L |

## 6.6.3 Current Lake Water Total Phosphorus Conditions

The tables below summarize the Tenmile Lakes' core sampling sites, all season average nutrient data and compare those values with the USEPA reference conditions for total phosphorus (7.1ppb), and identify reduction targets for phosphorus loading in the Tenmile Lakes.

**Table 39 – The Tenmile Lakes Nutrient Data Summary November 1998 – January 2001 All Season Averages for Core Sites**

| Station | TP ug/l | N03-N02 mg/l | NH4 mg/l | TKN mg/l | Secchi disc Transparencies | Chlorophyll a ug/l |
|---|---|---|---|---|---|---|
| NTA | 25 | 0.28 | 0.02 | 0.19 | 2.6 meters | 7.0 FW* |
| NTB | 38 | 0. 29 | 0.02 | 0.17 | 2.0 meters | 8.4 Fall* |
| STA | 27 | 0.20 | 0.02 | 0.19 | 2.8 meters | 4.9 FW* |
| STB | 23 | 0.29 | 0.02 | 0.14 | 2.4 meters | 25.8 Fall* |
| TCO | 21 | 0.65 | 0.01 | 0.13 | NA | NA |

*Seasons based upon traditional quarters of the year

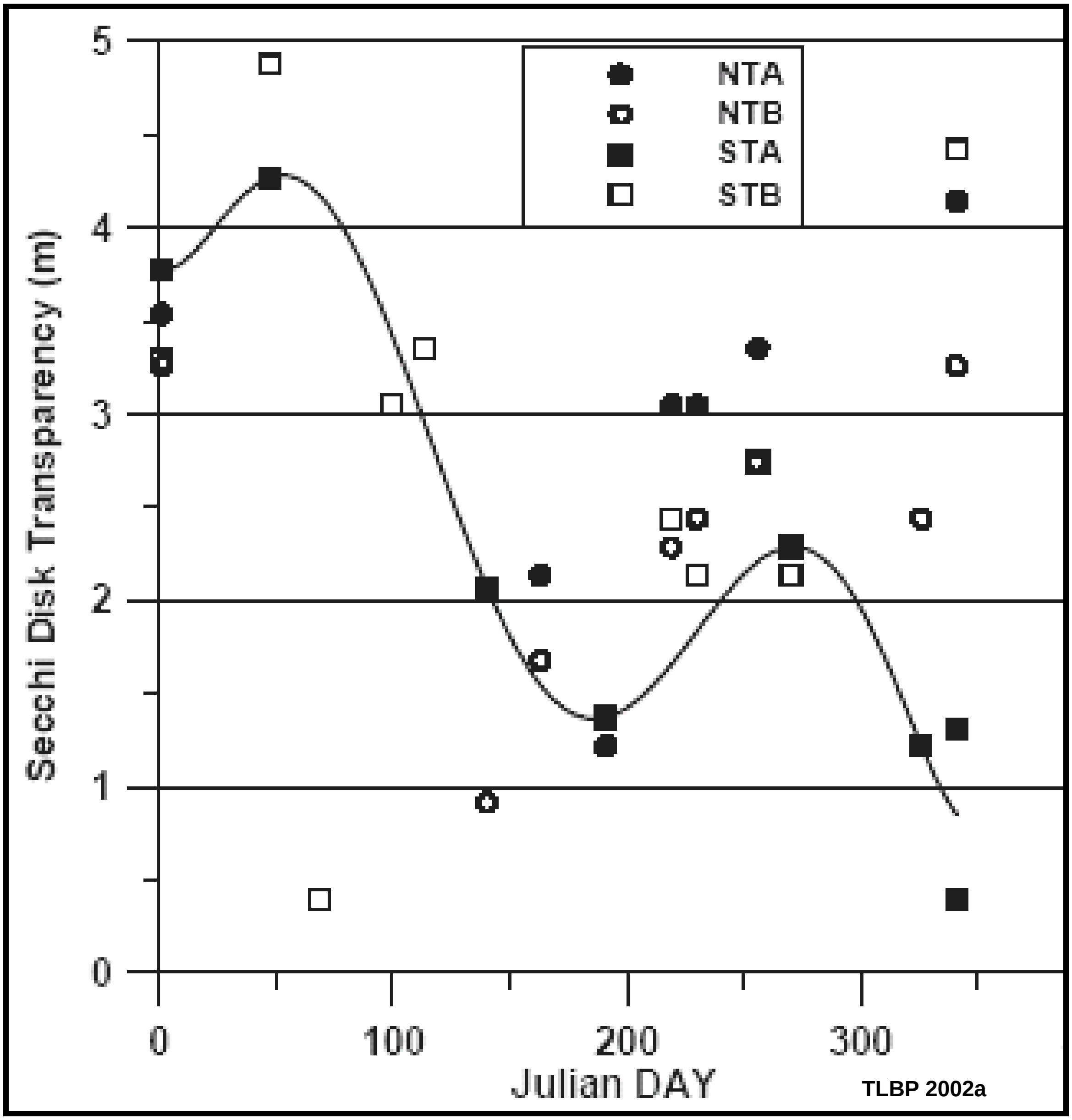
| Table 40 - Lake Water Column TP Load Reduction Targets | | |
|---|---|---|
| **Station** | **Measured TP Ave ug/L** | **% Reduction in Ambient Water Concentration Required to Meet Target** |
| NTA | 25 | 72 % |
| NTB | 38 | 81 % |
| STA | 27 | 73 % |
| STB | 23 | 69 % |
| TCO | 21 | 66 % |

The table below identifies the level of improvement needed to meet USEPA's suggested reference criteria for secchi disc transparencies. Load reductions based upon secchi disc transparencies are not specifically proposed at this time.

| Table 41 - Secchi Disc Transparencies Compared to Reference Values | | | |
|---|---|---|---|
| **Station** | **Secchi disc Transparencies** | **Secchi Disc Transparency (+meters needed to meet reference)** | **% Secchi Disc meters increase needed to meet reference** |
| NTA | 2.6 | +1.9 | 73 |
| NTB | 2.0 | +2.5 | 125 |
| STA | 2.8 | +1. | 35 |
| STB | 2.4 | +2.1 | 88 |

The figure below depicts secchi disc transparency data summarized for the Tenmile Lakes. The Tenmile Lakes' secchi disc readings decrease as suspended sediments are transported to the lake via winter storms and again as algal counts increase in summer and fall.

**Figure 45 - Secchi Disc Transparency Data Summarized for the Tenmile Lakes**
*(1999 Water Year - October 1, 1998 through September 30, 1999)*




## 6.6.4 Lakefront and In Lake Sources of Phosphorus

The Tenmile Lakes are highly valued for the recreational and aesthetic opportunities offered to residents and lake visitors. Residential occupancy, as well as lakefront activities including boating, swimming, skiing, and fishing, increases during the summer months. Higher levels of boat traffic result in an increase in wake and waves that have an erosional effect on the lakeshore in some areas. Increased residential yard and garden activities likely provide some seasonal nutrient loading to the lakes. The increased occupancy of lakefront homes with poorly functioning waste water treatment systems also have the potential to provide nutrient loading at this critical time of year

Modeling for this project has focused on developing estimates of sediment and nutrient inputs to North and South Tenmile Lakes based on watershed processes and land use patterns. Discrete loads from summertime, lakefront sources, and in lake processes are elusive to define and hard to quantify. TP is proposed as a target, to work toward and can serve as in indicator parameter, directly related to the summer algal blooms which adversely impact summer and fall beneficial uses. Three other factors, beyond watershed inputs, that significantly influence nutrient concentrations in the Tenmile Lakes discussed in the subsequent sections include:

- Septic tank inputs,
- Internal nutrient cycling in the lake
- Biomanipulation of trophic structures.

### *6.6.4.1 On-Site Septic Systems*

Studies have been less able to quantify loads from septic systems and associated lakefront development. Although not fully quantified, reducing pollutant loading from these sources is an important part of improving water quality in the Tenmile Lakes. The Water Quality Management Plan for this water body will emphasize the importance of the inclusion and implementation of management practices designed to reduce pollutant loading from rural residential sources including house boats and boat houses.

In 1999 ODEQ conducted a records review of nearly 500 homes on the Tenmile Lakes. Of these, approximately 350 were dependant on septic systems for their waste disposal. Permits for the installation of septic systems have been required in Oregon since 1974. Homes in the watershed were divided into three categories: (1) those built after 1974 that did not have permits, (2) those that were remodeled or expanded without permits and (3) those built before permits were required by ODEQ. ODEQ began working with 70 owners of homes built after 1974 without permits. ODEQ staff contacted these individuals and offered them an opportunity to voluntarily comply by obtaining a permit for their septic system. These systems were evaluated and many homeowners upgraded or installed new systems. ODEQ also worked with 51 owners of homes that had been remodeled without the necessary permits. These systems were also evaluated for adequacy, and many of these individuals also improved their on site waste treatment systems.

ODEQ recently partnered in funding programs to conduct on site system education and outreach activities to work with homeowners who have on site systems built before 1974. These older systems have a higher risk of failure as a result of septic tanks beyond their expected lifetime, lack of system solids management, and because many of these older systems would not meet today's design requirements for the protection of water quality. These efforts seek to provide landowners education and outreach focusing on system maintenance and gray water, and solids management and programs encouraging group septic tank pumping and system assessment are underway. These programs encourage homeowners to "get to know their systems" will help homeowners locate their systems. Basin partnership staff are also working to facilitate a group rate for contractor site visits so that systems can be evaluated and recommendations made regarding septic system maintenance and/or upgrade options. Improvement of many of these older individual on-site waste water treatment systems could significantly reduce lake nutrient loading.

In an attempt to quantify the relative contributions of N and P from septic systems, a spreadsheet analysis was utilized to estimated nutrient loading. Because of the seasonal nature of lakefront home usage, occupancy estimates were developed by month. Loading estimates were based upon 250 homes per lake with occupancy varying from two to four individuals, based upon time of year for 365 days of the year. Lower percent occupancies and density (number of persons) were projected during off season winter and spring month. July and August were predicted to have the highest occupancy rates. Using published estimates of nutrient generation per capita a range of monthly phosphorus load estimates were derived. The upper and lower estimates are derived from assumptions regarding the degree of attenuation (retention) of N and P in the soils under conditions where soil anions are saturated and unable to retain additional phosphorus. .

| Table 42 – The Tenmile Lakes Septic Tank Loading Estimates | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Month | Percent Occupancy/ Density | Homes/ lake | TN (a) g/cap/d * | TP (a) | TN Load g/year | TP Load g/year | High Estimate (b) | | Low Estimate (c ) | |
| | | | | | | | TN Load kg | TP Load kg | TN Load kg | TP Load kg |
| Jan | 20/2 | 250 | 23 | 2.3 | 71300 | 7130 | 71.3 | 7.1 | 30.3 | 3.03 |
| Feb | 30/2 | 250 | 23 | 2.3 | 96600 | 9660 | 96.6 | 9.7 | 41.1 | 4.11 |
| Mar | 40/2 | 250 | 23 | 2.3 | 142600 | 14260 | 142.6 | 14.3 | 60.6 | 6.06 |
| Apr | 50/2 | 250 | 23 | 2.3 | 172500 | 17250 | 172.5 | 17.2 | 73.3 | 7.33 |
| May | 60/2 | 250 | 23 | 2.3 | 213900 | 21390 | 213.9 | 21.4 | 90.9 | 9.09 |
| Jun | 70/3 | 250 | 23 | 2.3 | 362250 | 36225 | 362.25 | 36.2 | 154.0 | 15.40 |
| Jul | 80/4 | 250 | 23 | 2.3 | 570400 | 57040 | 570.4 | 57.0 | 242.4 | 24.24 |
| Aug | 80/4 | 250 | 23 | 2.3 | 570400 | 57040 | 570.4 | 57.0 | 242.4 | 24.24 |
| Sep | 60/3 | 250 | 23 | 2.3 | 310500 | 31050 | 310.5 | 31.0 | 132.0 | 13.20 |
| Oct | 40/2 | 250 | 23 | 2.3 | 142600 | 14260 | 142.6 | 14.3 | 60.6 | 6.06 |
| Nov | 30/2 | 250 | 23 | 2.3 | 103500 | 10350 | 103.5 | 10.4 | 44.0 | 4.40 |
| Dec | 20/2 | 250 | 23 | 2.3 | 71300 | 7130 | 71.3 | 7.13 | 30.3 | 3.03 |
| | | | | | | | | | | |
| Per Lake | | | | | 2827850 | 282785 | 2828 | **283** | 1161 | **116** |
| Per watershed (2 lakes) | | | | | 5655700 | 565570 | 5656 | 566 | 2322 | 232 |

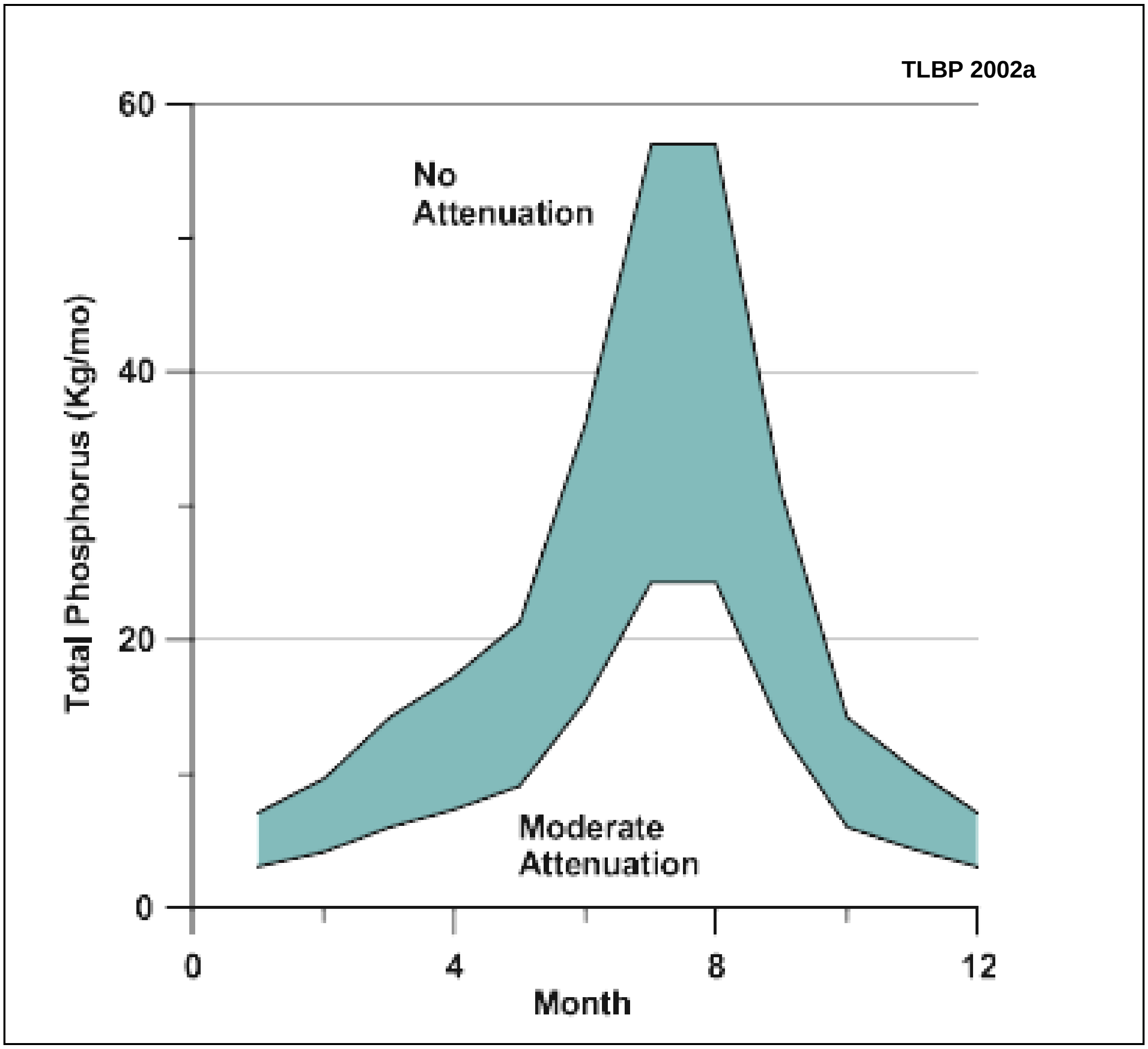
a Derived from Chapra (1997)
b Assumes no attenuation of nutrients in the soils and that all nutrients are delivered to the lake
c Assumes a retention/reduction of septic loads based on soil interactions
* grams /capita/day

Estimated lake-wide annual septic inputs of TP derived from the spreadsheet analysis range from 116 to 283 kg (high attenuation = 116 - low attenuation = 283) as compared to the SWAT model nutrient loading estimate for this source of 384 kg/yr of $PO_4$. When paired TP and $P0_4$ datasets are evaluated the ratio of TP to $PO_4$ is quite variable ranging from as high as 20:1 to as low as 1:1. The generalized relationship of 3:1 was identified in the Nutrient Budget for the Tenmile Lakes Watershed. Based upon this relationship and the SWAT modeling results the annual load of TP is about 1150 kg/yr.

A soils ability to attenuate contaminants is very site specific. In general the Tenmile Lakes Watershed has soils with the ability to highly attenuate waste water contaminants. Soils are variable in the basin and each site can be different. In general a soils texture, organic matter content, pH, depth, permeability, and drainage class determine a soils ability to attenuate nutrients. The amount of soil and distance from a waterway are also important factors. Soils closer to the lake generally attenuate nutrient less effectively than upland soils. In addition, areas with more sandy soils will provide less attenuation. The ability for soils to attenuate nutrients can be negatively impacted by solids delivered through lack of maintenance. These solids can both plug soils and adversely impact soils microbes.

The high (b) and low (c) low loading estimates are graphically depicted in the figure below. This visually reflects uncertainty in attenuation of nutrients in the soil. Note that during high occupancy and density periods (summer), phosphorus loading to the lakes from on site systems generally increases, regardless of soil attenuation.

**Figure 46 - Estimates of Monthly Loading of TP From Septic System Inputs.**



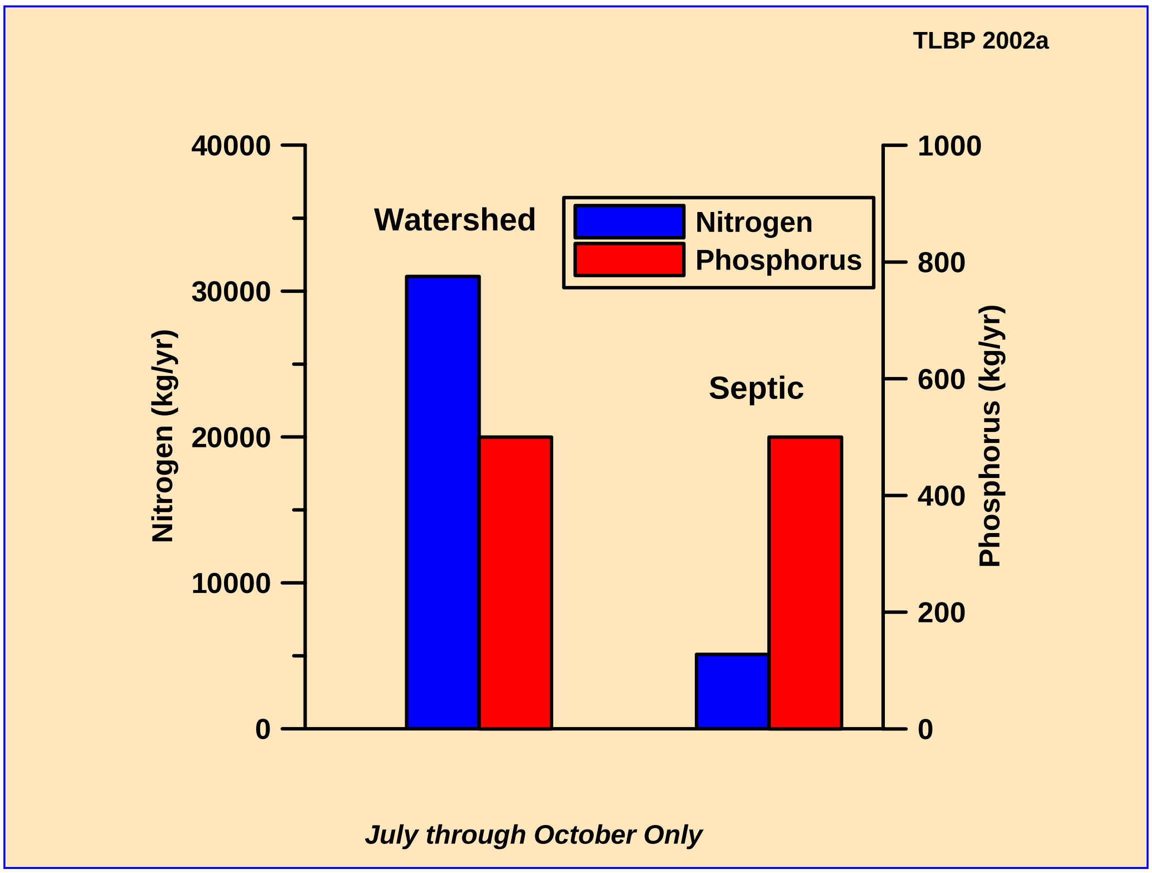

These nutrient loading estimates provide a starting point for assessing the role of on-site waste water treatment systems in the total watershed nutrient load. Additional efforts are needed to understand the operating condition and treatment effectiveness of older on site systems and to better define nutrient loading from on site treatment systems in the watershed.

The table below summarized water chemistry data collected from the mid to upper arms of the Tenmile Lakes for a three year fall period. This represents a high use recreational period and high lakefront home occupancy. Nitrogen is quickly utilized by algal communities during this high light intensity and warm water late summer period. Nitrogen levels are relatively low when compared to phosphorus. This relationship creates conditions that favor nitrogen fixing blue-green algal communities.

**Table 43 – The Tenmile Lakes Nutrient Ambient Data Summary**
All Station Averages 1995, 1997, 1998 (All August/September)

| Station | TP ug/l | Dissolved $PO_4$ ug/l | $NO_3$-$NO_2$ mg/l | $NH_4$ mg/l | TKN mg/l | Chlorophyll a ug/l |
|---|---|---|---|---|---|---|
| North Lake | 37 | 11.6 | 0.02 | 0.04 | 0.52 | 12 (range 1.4 - 33) |
| South Lake | 57 | 9 | 0.07 | 0.14 | 0.6 | 16 (range <0.1 – 47) |

**Figure 47 –Watershed Nutrient Contributions Compared to Septic Nutrient Contributions**




The annual septic system contribution of TP is estimated at about 10-22% of the total watershed inputs. Septic system contributions are expected to be greatest in the summer and early fall and it is likely that septic inputs constitute an important component supplying nutrients to support blooms of cyanobacteria from late July to October when runoff from the upper watershed is minimal.

### *6.6.4.2 Aquatic Macrophytes Nutrient Cycling*

Both North and South Tenmile Lakes are heavily infested with the exotic *Egeria densa*. It is unknown if the *E. densa* has simply replaced the native *Elodea*, or whether the current spatial distribution and density of *Egeria* exceeds the historical condition of *Elodea*. The Tenmile Lakes Basin Partnership (TLBP) recently completed a weed mapping project designed evaluate changes in spatial distribution and densities.

Anecdotal information provided by long term lake users indicate that both the spatial extent and density of submergent weeds has increased dramatically. Weed densities are reported to be extremely heavy in the upper arms of the lake at confluence with tributaries where sedimentation rates are highest. Delta building observed at the mouths of tributaries can be viewed as the system reconstructing the wetland interface between the lake and tributaries lost through stream channelization. The TLBP recently instituted monitoring to begin to quantify bar or delta building rates at several locations.

Increased nutrient supply plays some role in increasing macrophyte density in shallow areas, and light limitation may be decreasing macrophyte density or extent in deeper portions of the lake. Increased sediment accumulation has likely created more habitat favorable for macrophytes.

Macrophytes can alter internal processes in the lakes through increasing primary production at greater rates per unit than algae [cf., Chapra 1997]) and can extract nutrients from the sediments. When weeds die back in the fall, accumulated nutrients are made available through mineralization. Decaying macrophytes exert a biochemical oxygen demand. Increasing macrophyte biomass is likely having a negative effect on the lake water quality.

The failure to develop load allocations specifically for macrophytes is not intended to detract from the importance of macrophytes related to water quality and habitat conditions in the lake. It is thought that by implementing management measures to reduce sedimentation and control invasive weeds, progress will be made in the control of macrophytes. Additional assessment of the lake macrophytes are anticipated under future efforts including updating of the TLBP Aquatic Weed Management Plan (TLBP, 2000).

### *6.6.4.3 Fishery Management Nutrient Issues*

Lake productivity is affected not only by inputs from the watershed, but also by the biological activity within the lake. Altering the fisheries can promote major changes in the zooplankton community which in turn can alter the grazing rate of phytoplankton (Sarnelle 1992, 1993). The Tenmile Lakes historically were dominated by anadromous fisheries of coho, steelhead, and sea run cutthroat trout. The lake served as a slack water rearing area supporting smolts to sufficient sizes to guarantee successful returns. These conditions were especially favorable to Coho, a species who over summer in the lakes. Historically, juveniles rearing in the lakes did not suffer predation pressures from introduced species.

The current fishery conditions are vastly different than their historical condition. The dominant fish are now exotic species, endemic to the Midwest. Largemouth bass is the primary game fish and there are abundant populations of bluegill, yellow perch, and crappie (Abrams et al. 1991). These introduced species are highly planktivorous fish, which are highly effective consumers of larger zooplankton species. The reduction of large zooplankton via fishery preferential grazing reduces zooplankton grazing pressure on phytoplankton allowing phytoplankton (algae and cyanobacteria) biomass to increase. Phytoplankton biomass is further able to take advantage of the reduced grazing pressure because more nutrients are currently available from watershed inputs. Excessive zooplankton grazing following introduction of the exotic tui chub into Diamond Lake is proposed as the primary mechanism responsible for the deterioration of water quality in Diamond Lake (Eilers, 2004). In addition, increased populations of zooplanktivorous fish and benthivores can making more nutrients available in the water column by disturbing sediments when feeding and through increasing nutrients provided by fishery biomass. Water quality problems in the lakes are likely the product of changes in both the watershed and fisheries

An attempt to eliminate the perch and centrarchids with a rotenone treatment of the Tenmile Lakes in 1968 failed to destroy the target fish. The second attempt to reduce the target species by introducing largemouth bass (*Micropterus salmoides*) resulted in a decline of the salmonids as a result of predation rather than a reduction in the target species.

Because of the decline in salmonid populations there has likely been a loss of marine derived nutrients. Returning adult salmonids spawned and their carcasses provided for nutrient cycling back to the watershed and lake. In small tributary streams to North and South Tenmile Lakes, many of the carcasses were consumed by aquatic species including insects and foragers (birds, bears, raccoons) rather than by decomposing and leaching minerals back to the water. Certainly a portion of these marine derived nutrients were released into the watershed. Schmidt et al. (1998), Kline et al. (1993), and Bilby et al. (1996) have shown that marine-derived nutrients from anadromous fish can be important components of nutrient cycling in Alaska and Washington.

The effect of anadromous fisheries on nutrient cycling can be determined to some degree by measuring changes in marine-derived nitrogen as reflected in the ratio of 15N/14N found in the historical sediment record at the lake bottom through sediment coring. A decrease in the 15N/14N ratio often reflects a decrease in returning salmon (cf., Bilby et al. 1996). However, despite the dramatic reduction in the salmon population, the 15N/14N ratio in the sediments of the Tenmile Lakes has increased. This indicates that increased nutrient loading from the watershed has overwhelmed whatever loss in marine derived nutrients occurred. The consideration of the effect on nutrient sources resulting from historical anadromous runs would not alter the estimates for sediment production from the watershed.

The alteration of fish populations in the Tenmile Lakes, although not originally caused by nutrient inputs from the watershed, may play a role in the recovery of the lake. A successful water quality improvement program for the Tenmile Lakes will likely need to incorporate both watershed restoration and some modification of the fish community composition. The re-examination of fishery management plans and goals will be an important part of diverse ongoing nutrient management programs discussed in the Tenmile Lakes Watershed Water Quality Management Plan.

## 6.6.5 Watershed Source Categories CWA §303(D)(1)

Watershed wide excess loading of both sediment and phosphorus has been identified in this TMDL. Loading capacity and allocations were identified specific to tributaries with mixed land use (forestry, agriculture, and rural residential). Loading allocations for urban sources were discretely defined. Lakefront sources were discussed. The level of uncertainty regarding this assessment is small and restoration efforts to reduce watershed wide sources of sediment and nutrients are technically warranted. There is ample opportunity to refine pollutant reduction targets as watershed conditions improve through time. Pollutant controls will be needed from all watershed sources and basin wide sediment abatement activities are crucial.

## ***6.7 MARGIN OF SAFETY – CWA §303(D)(1)***

The Clean Water Act requires that each TMDL be established with a margin of safety (MOS). The statutory requirement that TMDLs incorporate a MOS is intended to account for uncertainty in available data or in the actual effect controls will have on loading reductions and receiving water quality. A MOS may be expressed as unallocated assimilative capacity or conservative analytical assumptions used in establishing the TMDL (e.g., derivation of numeric targets, modeling assumptions or effectiveness of proposed management actions). Although modeling assumptions were relatively conservative many factors influencing in lake nutrient processes discussed in the previous section were poorly defined. Because of the complexity and number of factors influencing weed and algae conditions discussed in this TMDL, a relatively narrow margin of safety is incorporated and subsequently an implicit margin of safety of 10% has been selected.

Because of this narrow margin of safety both near and long term monitoring needed to guide implementation of this TMDL. The adequacy of the loading capacity and load allocations identified in this TMDL to protect and restore water quality should be revisited at regular intervals. Water quality and landscape monitoring will guide adaptive management over time, and will be used to evaluate the effectiveness of this sedimentation and phosphorus TMDL. This information will be needed to better define the lake recovery trajectory and guide adjustments to load allocations.

Subject to available resources, ODEQ will review and, if necessary, modify TMDLs and WQMPs established for the Tenmile Lakes Watershed on a five-year basis or possibly sooner if ODEQ determines that new scientific information is available that indicates significant changes to the TMDL are needed. In conducting this review, ODEQ will evaluate the progress towards achieving the TMDL (and water quality standards) and the success of implementing the WQMP.

### 6.7.1 Nutrient Enrichment

This assessment has some level of uncertainty associated with it, but the evidence for increased nutrient enrichment is strong.

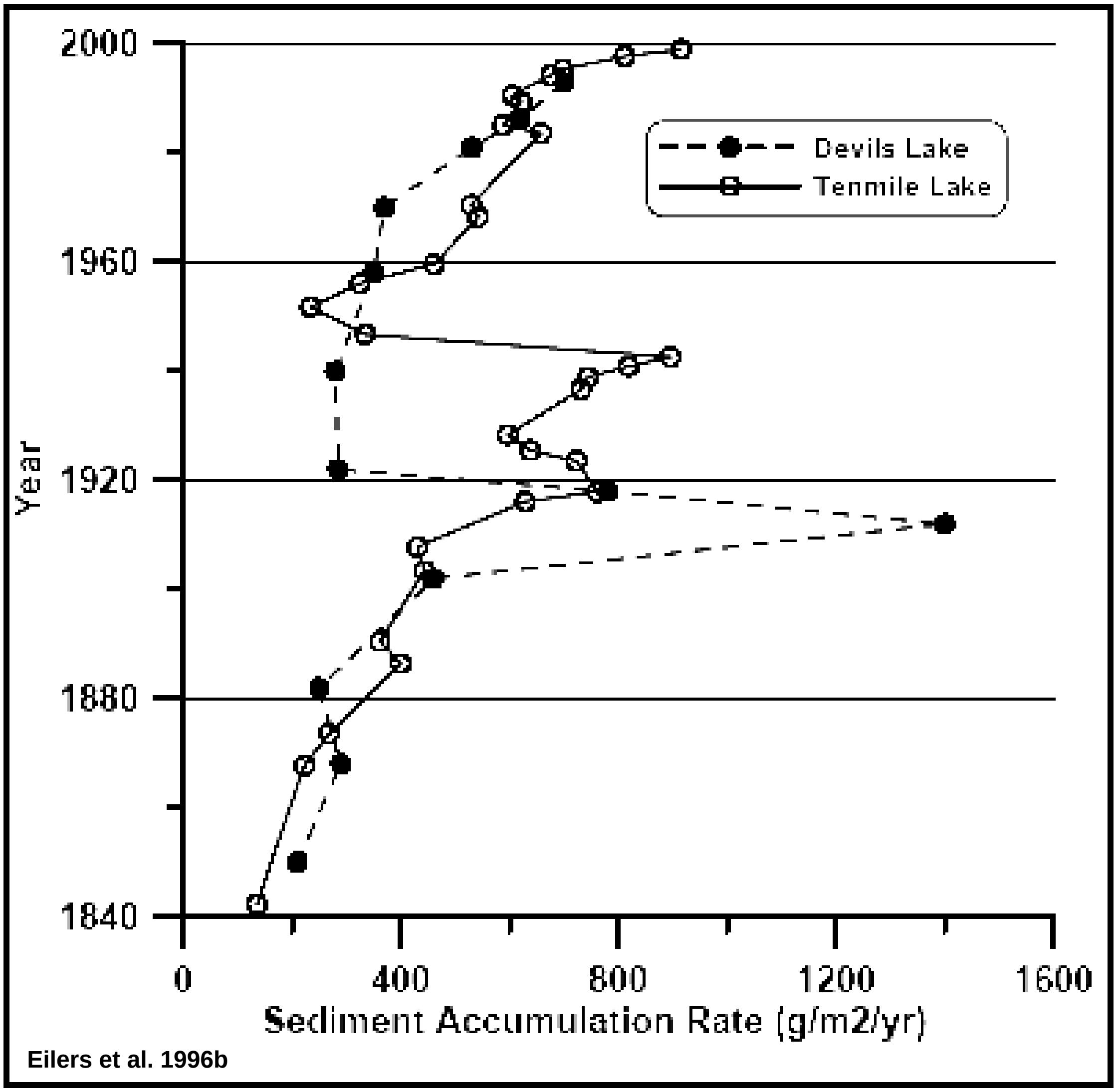
The direct monitoring of stream water quality from a watershed with functional wetland conditions at the lake interface allowed a comparison with water quality measurements collected from other major stream systems with active grazing and channelization. Discharge water from the watersheds with functional wetlands is two orders of magnitude lower in total suspended solids and at least 50% lower in concentrations of nitrogen and phosphorus.

The modeling of these tributaries under the historical landscape condition scenario provides evidence that the present nutrient loading from the watershed has been elevated by nearly 90% for phosphorus. Although stream monitoring and paleolimnological data were used to refine some of the model output, use of default coefficients for the different land use cover types would still yield dramatic increases in sediment and nutrient loading to the lake under current conditions. The watershed input of phosphorus was directly linked to sediment input because of the strong binding affinity between P and soil particles. Other activities such as livestock grazing and septic inputs only serve to further increase the P load above that associated with sediment input.

Sediment core sampling indicated that four sites show increases in sediment accumulation rates (SAR) of 100 to 400% above historical levels. The rates are greatest adjacent to tributaries with high disturbance and channelization. Analysis of the sediment record at site STA (South Lake – open water) included sediment nutrients, diatoms, and cyanobacterial akinetes, show results consistent with a major enrichment of the lake. Sediment data suggests that nutrient loading has increased two to four-fold for total phosphorus and comparable increases in nitrogen.

Examination of nearby lakes in a similar geomorphic setting provides some indication of how South Tenmile Lake has changed. Eel Lake has experienced les timber harvest and no stream channelization or grazing. Eel Lake has one-third the level of total phosphorus, twice the lake transparency, and one-sixth the concentration of chlorophyll a when compared to South Tenmile Lake. The sediment accumulation comparison with Devils Lake, located further north, exhibits a watershed history similar to South Tenmile Lake.

**Figure 48 - Sediment Accumulation Rate Comparison – South Tenmile Lake (STA) and Devils Lake**




The phytoplankton community composition in North and South Tenmile Lakes is indicative of a lake with high nutrient loading. Chlorophyll *a* levels are elevated and cyanobacteria are dominant in the summer and fall. Toxic blue-green algae create conditions unfavorable for human health. This represents a condition that would be unlikely in an undisturbed lake in this geomorphic setting.

The fisheries community has been radically altered with the introduction of numerous non-native fish, including centrarchids, yellow perch, and bullhead. The centrarchids and yellow perch, in particular, have been documented to degrade water quality in numerous lakes by consuming the larger zooplankton taxa, leaving a smaller zooplankton assemblage with lower phytoplankton grazing efficiency. The non-native fisheries community thus directly affects the water quality by altering the zooplankton/phytoplankton community structure, but may also increase internal cycling of nutrients within the lake.

## 6.7.2 Changing Landscape Conditions through Stewardship Activities

This TMDL is based on the analysis of the watershed in terms of the landscape condition in 1994. It was these landscape conditions that were utilized to populate the SWAT model project from whence load allocations were derived. Significant efforts have been underway since 1997 to improve landscape conditions, water quality, and fishery habitat conditions in the watershed as part of the Oregon Plan for Watersheds. Many individuals have and continue to implement stewardship efforts. For example, the Tenmile Lakes Basin Partnership implemented high priority sediment abatement projects between 2002 and 2005. These projects focused on reducing sediment delivery from areas at high risk of failure. A total of nearly 21,000 cubic yards of sediment at risk of delivery to the lakes was stabilized through sediment abatement projects. It is hoped that this TMDL will provide an improved focus on water quality drivers and surrogate measures and will help promote and guide this improving management trend.

## 6.7.3 Pollutant Loading Allocations and Reduction Targets

Currently sediment loads have been allocated based on Tenmile Lakes Watershed Reference Streams rather than exclusively to natural, pre anthropogenic sources. This loading capacity approach provides a relatively narrow margin of safety at this time. That said, sediment load reduction targets are aggressive and seek to reduce sediment loads by 50% within the next 25 years. Sediment accrual rate (SAR) reductions are identified as a target rather that a loading capacity or allocations.

A target of attaining a 50% reduction within the next 25 years has been incorporated. The target of 25 years was selected by the local advisory group as a timeframe wherein significant sediment abatement activities could occur and allow for a positive response of in lake processes (e.g. stored sediment), and improvements in lake water quality might be realized. The advisory group felt that the 50% reduction target represent significantly less lake sedimentation and sets a clear attainable goal for land managers. It is not intended to limit sediment reductions should the opportunity to reduce loading beyond 50% occur.

This approach will allow lake weed and algae conditions to be assessed through time in the context of significant nutrient load reductions. In addition, elements of uncertainty in nutrient enrichment discussed below will be better characterized through continued monitoring and water quality implementation plans. As this TMDL is implemented and load reductions are realized, the load allocations of this TMDL will be re-examined, and, if appropriate, the margin of safety will be adjusted.

# *6.8 TMDL LOADING CAPACITY AND LOAD ALLOCATIONS*

## 6.8.1 Target Identification and Loading Capacity - 40 CFR 130.2(f)

The Environmental Protection Agency (USEPA) and the State of Oregon do not currently have numeric water quality standards for nutrients. Sedimentation and nutrient loading were utilized in this TMDL to serve as water quality parameters which contribute to nuisance weed growth and algae presence adversely impacting multiple beneficial uses.

### *6.8.1.1 ORSs and OARs Applicable to Load and Waste Load Allocations*

Accelerated sediment accrual rates are addressed through Oregon Revised Statute (ORS) 468B.025 which describes prohibited activities states; No person shall cause pollution of any waters of the state or place or cause to be placed any wastes in a location where such wastes are likely to escape or be carried into the waters of the state by any means.

ORS 468B.025 describes prohibited activities and states; No person shall cause pollution of any waters of the state and ORS 468B.050 (1) (a) states; No person shall discharge any wastes into the waters of the state from any activity.

Wastes are defined as any substances which will or may cause pollution or tend to cause pollution of any waters of the state. Should this violation(s) occur it would be considered a Class I violation of Oregon environmental law.

Oregon Administrative Rule (OAR) 340-041-0007(13) statewide narrative criteria state; The formation of appreciable bottom or sludge deposits or the formation of any organic or inorganic deposits deleterious to fish or other aquatic life or injurious to public health, recreation, or industry shall not be allowed.

OAR 340-041-0036 addresses the parameter turbidity and states; No more than a ten percent cumulative increase in natural stream turbidities may be allowed, as measured relative to a control point immediately upstream of the turbidity causing activity. However, limited duration activities necessary to address an emergency or to accommodate essential dredging, construction or other legitimate activities and which cause the standard to be exceeded may be authorized provided all practicable turbidity control techniques have been applied and one of the following has been granted:

> (a) Emergency activities: Approval coordinated by ODEQ with the Oregon Department of Fish and Wildlife under conditions they may prescribe to accommodate response to emergencies or to protect public health and welfare;
>
> (b) Dredging, Construction or other Legitimate Activities: Permit or certification authorized under terms of section 401 or 404 (Permits and Licenses, Federal Water Pollution Control Act) or OAR 14l-085-0100 et seq. (Removal and Fill Permits, Division of State Lands), with limitations and conditions governing the activity set forth in the permit or certificate.

Should this violation(s) occur it would be considered a Class I violation of Oregon environmental law.

The loading capacities developed through this TMDL provide a reference for calculating the amount of pollutant reduction needed to bring water into compliance with Oregon water quality standards. USEPA's current regulation defines loading capacity as "*the greatest amount of loading that a water body can receive without violating water quality standards*." (40 CFR § 130.2(f)) The sediment loading capacities and nutrient target for the Tenmile Lakes Watershed identify these as indicators of water quality conditions which contribute to impairments caused by weeds and algae.

### 6.8.1.2 Loading Capacity Summary

For purposes of this TMDL loading capacities have been identified to address sediment delivery and subsequently lake sedimentation. Sediment loading capacities represent catchment delivery of sediment loads to the lakes.

| Table 44 – Sediment Loading Capacities | | | |
|---|---|---|---|
| **Application Point** | **Water Quality Parameter** | **Time of Measurement** | **Loading Capacity** |
| Average annual tributary sediment loads | tones per hectare (t/ha) sediment | 2-5 year storm return interval | 0.07 t/ha (18 t/mi$^2$) |
| Average annual "urban lands" sediment loads (3 catchments) | tones per hectare (t/ha) sediment | | Lakeside - 0.23 t/ha (60 t/mi$^2$) |
| | tones per hectare (t/ha) sediment | | W North - 0.22 t/ha (57 t/mi$^2$) |
| | tones per hectare (t/ha) sediment | | Central South - 0.18 t/ha (47 t/mi$^2$) |

Sediment load capacities are stated as an annual input and are applied year around. Seasonal variation was discussed at length earlier in the document. Sediment inputs are highly dependent on the quantity and intensity of precipitation. Winter and spring are the periods of maximum watershed sediment input and movement. Other sources of nutrients, like those from lakefront activities may be at their maximum in the summer months.

## 6.8.2 Load Allocations 40 CFR 130.2(g)

Load allocations are expressed as "mass per unit" loads, tones per hectare and grams per square meter, as defined in the TMDL regulations. Sediment load allocations are also stated as an annual input and are applied year around.

| Table 45 - Load Assessment Summary for the Tenmile Lakes Watershed | | |
|---|---|---|
| Scenario | Total Tones Per 18,222 Hectares Annually | Per Catchment Information Provided |
| Historical Modeled Loads | 608 | Table 25 |
| Current Modeled Loads | 8494 | Table 24 |
| Reference Derived Loads | 1352 | Table 33 |

An implicit margin of safety (MOS) of 10% has been selected. Please see a detailed discussion in the Margin of Safety section of this document.

| Table 46 – Load Allocations Summary for Tenmile Lakes Watershed | | | |
|---|---|---|---|
| | Total Tones Annually | 10% MOS | Load Allocation Total Tones Annually |
| Reference Derived Loads | 1352 | 135 | 1217 |

**The load allocations for the Tenmile Lakes Watershed are based upon a three pronged approach:**

- **Reduce sediment delivery from lake tributaries to the lakes**
- **Reduce lake sediment accrual rates for the lake bottom**
- **Target reduction in lake water column phosphorus**

A target of attaining a 50% reduction within the next 25 years has been incorporated. The target of 25 years was selected by the local advisory group as a timeframe wherein significant sediment abatement activities could occur and allow for a positive response of in lake processes (e.g. stored sediment), and improvements in lake water quality might be realized. The advisory group felt that the 50% reduction target represent significantly less lake sedimentation and sets a clear attainable goal for land managers that does not serve as a disincentive for positive actions It is not intended to limit sediment reductions should the opportunity to reduce loading beyond 50% occur.

Because the rate of internal processing of nutrients in lakes is not well understood the actual time to recovery, defined as the attainment of water quality standards and the attainment of fully supported beneficial uses unimpaired by nuisance weeds and algae, is not known. The lake recovery trajectory is discussed in more depth in the Standards Attainment section of this document. As a result of stored nutrients, lake recovery is predicted to span several generations.

| Table 47 - Sediment Reductions Needed | | |
|---|---|---|
| | Total Tones Annually | Percent (%) Reduction |
| Current Loads | 8494 | To Reference – 86% |
| Interim Target | 4247 | 50% Reduction in 25 Years |

Because other sources of phosphorus, not directly associated with sediments or other watershed and landscape condition driven processes, exist in the watershed a water column target has been identified. All watershed sources will need to be minimized, because at this time, lake internal processes likely provide 100% of this target total phosphorus.

### *6.8.2.1 Catchment Sediment Loading*

Full attainment of pollutant reductions to those of historical conditions is not feasible due to physical, legal or other regulatory constraints. Implementation Plans should identify potential constraints, but should also provide the ability to mitigate those constraints should the opportunity arise. For instance, at this time, the existing location of managed wetlands may preclude attainment of system potential nutrient reductions. In the future, however, should the opportunity to implement mutually acceptable wetland enhancement activities arise, consideration should be given to designs that support TMDL load allocations and pollutant surrogates, such as re-establishing the buffering functions of historic wetlands.

Because the landscape is significantly modified and the watershed is unlikely to achieve a return to historical sediment loads, selected Tenmile Lakes Watershed reference streams were utilized to set load allocations rather than historical conditions. Reference stream loads represent significant reductions when compared to current annual sediment loads. An interim target which seeks to reduce sediment loads by 50% within the next 25 years has been emphasized. And provisions have been made in the TMDL process whereby, as abatement measures are implemented, a re-evaluation of loading allocations and targets can occur.

The load allocation is given 100% to annual sediment loads derived from streams selected as reference. This load allocation applies to eleven of the twenty watershed catchments in the watershed. The use of selected drainages within watershed as reference at this stage in the process does set clear and attainable load reduction targets. For three other catchments, sediment loading allocations are given 100% to background sources determined as annual sediment loads present under modeled historical conditions. The historical condition scenario did not remove the City of Lakeside (urbanized area) but did incorporate historical drainage features (wetlands, disturbance regimes, etc.) to derive sediment load reductions.

ODEQ intends to regularly review progress of the WQMP and the associated Implementation Plans developed to achieve this TMDL. If and when ODEQ, in consultation with the management agencies, determines that either water quality standards have been met, or that the WQMP has been fully implemented and all feasible management practices have reached maximum expected effectiveness and the TMDL, its associated surrogates, or its interim targets have not been achieved, ODEQ shall reopen the TMDL and adjust it or its interim targets and its associated water quality standard(s) as necessary.

The determination that all feasible steps have been taken will be based on, but not limited to, a site-specific balance of the following criteria: naturally occurring pollutant concentrations prevent the attainment of the use; or human caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place; or hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use; or physical conditions related to the natural features of the water body preclude attainment of uses; or the cost of compliance would result in substantial and widespread economic and social impact. This process for making this determination is defined in 40 CFR 131 and further clarified in ODEQ's Draft Internal Management Directive (IMD) for Use Attainability Analysis (ODEQ, 2005).

## 6.8.3 Waste Load Allocations 40 CFR 130.2(h)

A *Waste Load Allocation (WLA*) applies to point sources. WLA is that portion of the loading capacity that a particular source may provide without causing the water quality criteria to be violated. No waste load allocations are made at this time.

The City of Lakeside storm water drainage is delivered directly to both North and South Tenmile Lakes. The City is not currently required to operate this drainage system under an NPDES permit because the population is below the current thresholds which require permitting. The City of Lakeside will address storm water management within their required water quality implementation plan. This planning process is discussed in more detail in the WQMP, companion to this TMDL. Upon future review of this TMDL, the City of Lakeside storm water collection system may be required to secure and NPDES permit which could identify discharge permit limits.

The City of Lakeside waste water treatment facility seasonally discharges to Tenmile Creek and utilizes a biosolids land application site in the upper watershed as part of that NPDES permit. The City of Lakeside has entered into a Mutual Order and Agreement with ODEQ to upgrade the waste water treatment plant facility, discharge only in the winter months when stream flow is sufficient, and to identify a new location for land application of treated effluent in the summer, low flow months. As there is no discharge from this facility into water quality limited waterbodies (North and South Tenmile Lakes) this facility has been determined to have no impact on lake weed and algae conditions. Biosolids application in the upper watershed should continue to be managed to provide no nutrient leaching or nutrient movement from the permitted site. Bio solids application is allocated a zero WLA. Additional detail regarding bio solids management is provided in the WQMP, companion to this TMDL.

General permits holders are required to comply with permit conditions and related water quality standards. These activities are not specifically provided a waste load allocation. Should ODEQ find these general permit conditions and compliance targets are not rigorous enough to prevent adverse impacts to the Tenmile Lakes these sources will be re-evaluated. The most common permitted activity in this category would be construction and/or land development sites where one acre or more of soil disturbance is expected to occur. Land development activities that impact less than one acre are exempt from NPDES permitting but are required to meet applicable water quality standards.

**Table 48 - Waste Load Allocations for Point Sources**

| ***Source*** | ***Waste Load Allocation*** |
|---|---|
| Current NPDES Permit Holders | 0% |

## *6.9 LOAD ALLOCATION SURROGATE MEASURES- 40 CFR 130.2(I)*

The Tenmile Lakes Watershed TMDL incorporates measures other than “daily loads” to fulfill requirements of 303(d). A loading capacity for the weeds and algae 303(d) listings can be derived [e.g. reduce invasive, non-native macrophytes that currently dominate the lake assemblage of plants; reduce algae that are impairing beneficial uses]. In addition to weed and algae reductions, this TMDL allocates “other appropriate measures” (or surrogates) as provided under USEPA regulations [40 CFR 130.2(i)]. Multiple surrogates can be used to measure actions that are tightly linked to the goals of reducing sediment and nutrient loading to North and South Tenmile Lakes to address weed and algae water quality limitations that are adversely impacting beneficial uses.

1. The implementation of watershed wide sediment abatement measures as a mechanism to achieve reductions in sediment and phosphorus loading to the Tenmile Lakes and their tributaries.

2. The implementation of projects to enhance or restore wetlands and floodplain connectivity and function as a mechanism to achieve reductions in sediment and phosphorus loading to the Tenmile Lakes.

3. The implementation of weed management control measures to control invasive weed species in the Tenmile Lakes.

Because water quality factors that affect weed and algal growth are interrelated, the surrogate measures referenced above rely on reducing sediment as well as other forms of phosphorus delivery to the Tenmile Lakes. Surrogates measures directly link to water quality parameters and load reduction targets set within this TMDL and can be quantified through time.

Achieving these reductions will require a landscape based approach beginning with reductions in upland sediment delivery, and stream bank and lakefront erosion. Restoring the hydrological connection of wetlands to filter and store sediment prior to entering the lake has also proven to be an effective buffering mechanism. Healthy riparian vegetation is an important component to provide nutrient filtering and uptake, provide channel stability and shade, and reduce heat loads.

Please see the Management Measures section of the companion WQMP document for more discussion about potential implementation actions which link to achievement of surrogate measures.

### 6.9.1 Reserve Capacity

Reserve capacity is an allocation for increases in pollutant loads from future growth and new or expanded sources. This assessment clearly indicates that landscape wide reductions in phosphorus and sediment loading are needed to attain water quality standards. Future growth will need to be conducted in a manner so as meet water quality.

This TMDL does not allocate a specific reserve capacity at this time but does acknowledge that water quality standards applicable to continuing land development activities do not require zero water quality pollutant contributions. Land development activities must be conducted in a manner consistent with management practices identified in water quality implementation plans as they become available or in required NPDES permits. NPDES permits and emerging implementation plans are required to be sufficiently rigorous so as to achieve water quality standards and criteria.

Nutrient limits will be incorporated into any future individual NPDES permits. These limits will also be sufficiently rigorous so as to achieve water quality standards for chlorophyll a and algae and should be derived in the context of the water column phosphorus target defined within this TMDL.

## *6.10 WATER QUALITY STANDARD ATTAINMENT ANALYSIS - CWA 303(D)(1)*

### 6.10.1 Lake Recovery Trajectory

The lake response to a given phosphorus concentration during the eutrophication process may differ from the same lake response during the recovery process. The accumulation of P in the sediments required an extended period to re-equilibrate with the overlying water column (cf., Chapra 1997). Even in the absence of ongoing nutrient enrichment of the sediments, lake response may be altered because of the permanent loss of lake volume from sediment input, expansion of macrophyte beds, and other long term changes to the watershed.

The uncertainty in lake response is illustrated in Figure 48 and is caused primarily by: (1) hysteresis, and (2) biological mediation. Hysteresis is a phenomenon in which the reverse path in a process differs from the forward path as shown in the figure below. Note curve A v B in response to nutrient loading and multiple scenarios for lake response to decreased nutrient loading (B v A; B v C; and B v D) depending on other actors within the lake. Water quality in a lake is the product of both watershed loading and internal cycling of nutrients. In scenario C and D the reduction of watershed loads to pre-settlement rates does not return the lake to its former condition.

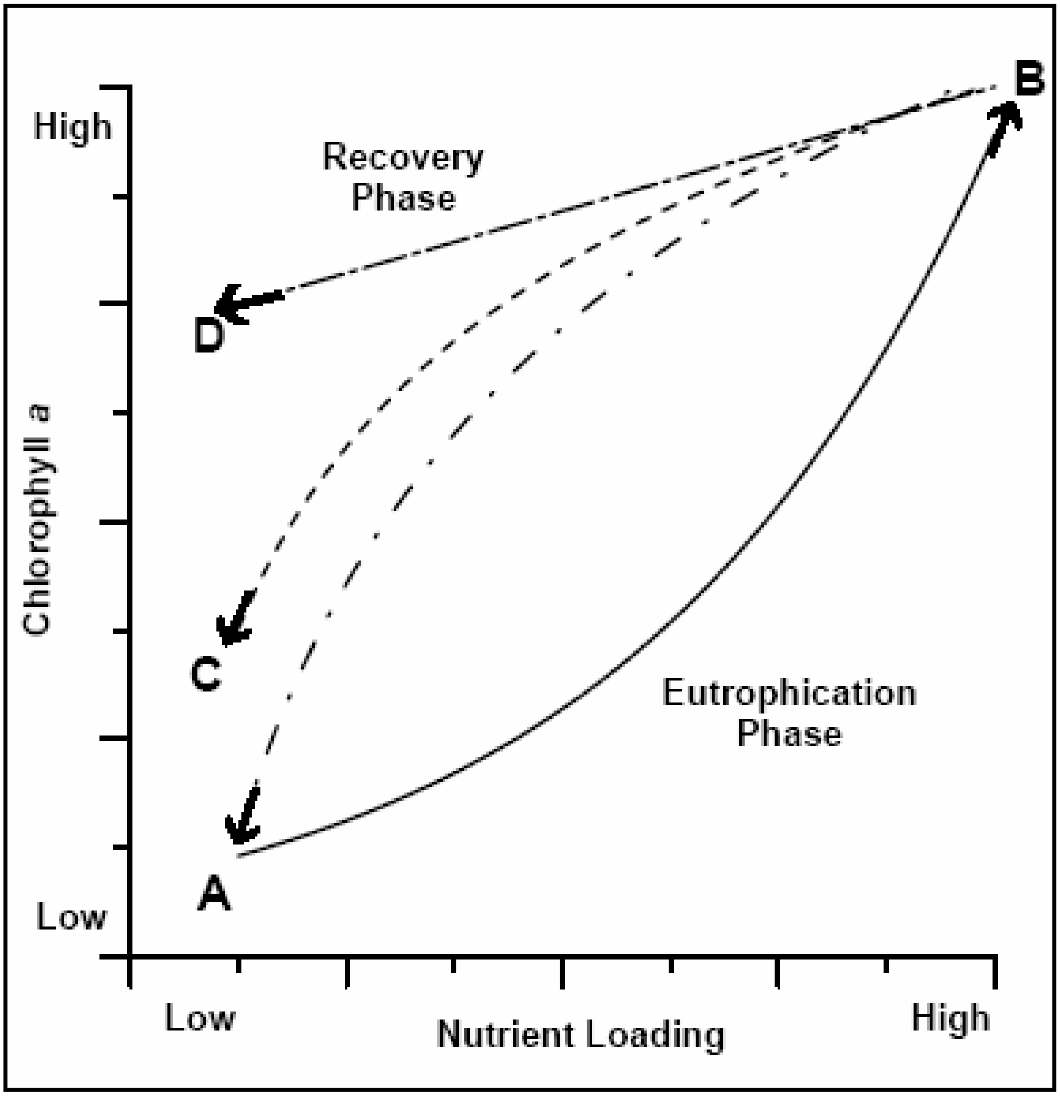



**Figure 49 - A Schematic Representation of Lake Response to Nutrient Loading**

Nutrient cycling within a lake can be profoundly altered by changing fisheries. The current fisheries community affects the lake very differently than the original fisheries. Historical predation on zooplankton was likely quite modest under a salmonid-dominated regime. Consequently, grazing pressure by zooplankton on the phytoplankton was probably quite high. Under the current fisheries, pressure on the zooplankton community is high because of the highly effective predation by centrarchids and yellow perch. Consequently, grazing pressure on the phytoplankton is reduced, thus allowing higher rates of algal biomass and a different relationship between TP and chlorophyll a (curve B v D).

Because the rate of internal processing of nutrients in lakes is not well understood the actual time to recovery, defined as the attainment of water quality standards and the attainment of fully supported beneficial uses unimpaired by nuisance weeds and algae, is not known. As a result of stored nutrients, lake recovery is predicted to span several generations.

## 6.11 WATER QUALITY MONITORING NEEDS

### 6.11.1 Baseline and Trend Water Quality Monitoring Information Needs for the Tenmile Lakes Watershed

- **Lake water column nutrients** – establish long term trend network to determine progress toward meeting the target of 7.1ug/l total phosphorus all season average. Sample analyses should be inclusive of standard nitrogen and phosphorus nutrient suite parameters.

- **Algae composition in conjunction with chlorophyll a** – continue long term trend network to determine progress towards reducing nuisance algal blooms. Continued algae characterization and biomass quantification.

- **Tributary sediment delivery** – establish long term trend network for tributary total suspended solids (TSS) and flow measurement during storm events

  - to better quantify sediment loading thresholds for streams monitored during development of the nutrient budget (Big, Benson, Murphy primarily)
  - to better quantify sediment loading thresholds for streams where load allocation s were based solely on modeling (Shutters Creek has been suggested as a high priority)
  - to better quantify sediment loading within streams at land management interfaces (Elliott State Forest boundary and at the private forestry and agriculture land interfaces, etc.)
  - to better quantify sediment and nutrient loading from the City of Lakeside (urban areas)

Sampling should target 2-5 year return interval storm events to address sediment threshold issues and larger storm events to begin to assess mass loading inputs.

**Table 49 - Return Intervals for Precipitation North Bend, Oregon**

| | 24 Hours | 2 days | 3 days | 4 days | 5 days |
|---|---|---|---|---|---|
| 2 year | 2.68 | 4.1 | 5.15 | 5.95 | 6.73 |
| 5 year | 3.81 | 5.51 | 6.60 | 7.57 | 8.41 |
| 10 year | 4.87 | 6.49 | 7.51 | 8.57 | 9.45 |
| 25 year | 6.43 | 7.74 | 8.59 | 9.74 | 10.66 |

- **Lake sediment cores** – establish additional representative sites; implement a long term trend monitoring program.

- **Physical monitoring** – physically monitoring (survey) delta or bar building at mouths of selected tributaries and determine linkages with tributary loading information.

- **Lake weed mapping** – set baseline of species composition (type), distribution, and density, and biomass of weeds (macrophytes) in the lake; conduct long term trend mapping to better define changes in weed biomass.

  TLBP has begun an annual aquatic weed survey using photo documentation and species identification in an attempt to monitor the advance of various troublesome species such as Egeria densa, and Eurasian milfoil.

- **Supporting water quality parameters** - When water quality monitoring is being conducted the collection of supporting parameters is highly recommended (dissolved oxygen, pH, turbidity, etc.).

- **<u>Lake bacteria monitoring</u>** - Very little data is available on lake bacterial water quality. Data in this area would provide valuable information related to water contact recreation.

- **<u>Introduced fish species</u>** - Initiate a monitoring program to study to determine non-native fish population levels. This information will be utilized to assess the biomass and subsequent nutrient loading from the non-native introduced fishery. It will also be utilized to assess to what extent the preferential grazing of zooplankton impacts the algal community in the Tenmile Lakes.

Long term monitoring and the adaptive management nature of this TMDL will be used to evaluate target goals over time and to allow the application of adaptive management to assure progress towards meeting LA targets.

## 6.11.2 Adaptive Management

*Adaptive management* is an important part of the TMDL and WQMP process in part because of the following reasons:

- TMDLs are numerical loadings that are set to limit pollutant levels such that numeric and/or narrative in-stream water quality standards are met. ODEQ recognizes that TMDLs are values calculated from mathematical models and other analytical techniques designed to simulate and/or predict very complex physical, chemical and biological processes. Models and techniques are simplifications of these complex processes and, as such, are unlikely to produce an exact prediction of how streams and other water bodies will respond to the application of various management measures. It is for this reason that the TMDL has been established with a margin of safety. Long term monitoring programs can provide critical information needed to refine modeling assumptions.

- It is possible, after application of all reasonable best management practices, that some TMDLs or their associated surrogates cannot be achieved as originally established. Technology for controlling nonpoint source pollution continues to develop. Water Quality Management Plans (WQMPs) are designed to reduce pollutant loads to meet TMDLs. ODEQ recognizes that it may take some period of time - from several years to several decades - after full implementation before management practices identified in a WQMP become fully effective in reducing and controlling pollution. In addition, ODEQ recognizes that technology for controlling nonpoint source pollution is, in many cases, in the development stages and it may take one or more iterations to develop effective techniques.

- Natural events (e.g. floods, fire, insect infestations, and drought) may interfere with or delay attainment of the TMDL and/or its associated surrogates. Despite the best and most sincere efforts, natural events beyond the control of humans may interfere with or delay attainment of the TMDL and/or its associated surrogates. Such events could be, but are not limited to: floods, fire, insect infestations, and drought.

- Full attainment of pollutant loading modeled for historic landscape conditions is not feasible at all locations due to physical, legal or other regulatory constraints. To the extent possible, water quality implementation plans developed by Designated Management Agencies and others should identify potential constraints, but should also provide the ability to mitigate those constraints should the opportunity arise. For instance, at this time, the existing location of managed wetlands may preclude attainment of system potential nutrient reductions. In the future, however, should the opportunity to implement wetland enhancement activities arise, consideration should be given to designs that support TMDL load allocations and pollutant surrogates, such as re-establishing the buffering functions of historic wetlands.

In employing an adaptive management approach to this TMDL and WQMP, ODEQ has the following expectations and intentions:

- Subject to available resources, ODEQ will review and, if necessary, modify TMDLs and WQMPs established for the Tenmile Lakes Watershed on a five-year basis or possibly sooner if ODEQ determines that new scientific information is available that indicates significant changes to the TMDL are needed. In conducting this review, ODEQ will evaluate the progress towards achieving the TMDL (and water quality standards) and the success of implementing the WQMP.

- ODEQ expects that each management agency will also monitor and document its progress in implementing the provisions of its component of the WQMP. This information will be provided to ODEQ for its use in reviewing the TMDL.

- As implementation of the WQMP proceeds, ODEQ expects that management agencies will develop benchmarks for attainment of TMDL surrogates, which can then be used to measure progress.

- Where implementation of the WQMP or effectiveness of management techniques is found to be inadequate, ODEQ expects management agencies to revise the components of the WQMP to address these deficiencies. The adequacy of management techniques will be assessed through long term water quality monitoring programs. ODEQ intends to regularly review progress of the WQMP and the associated Implementation Plans developed to achieve this TMDL.

- If and when ODEQ, in consultation with the management agencies, determines that either water quality standards have been met, or that the WQMP has been fully implemented and all feasible management practices have reached maximum expected effectiveness and the TMDL, its associated surrogates, or its interim targets have not been achieved, ODEQ shall reopen the TMDL and adjust it or its interim targets and its associated water quality standard(s) as necessary.

  The determination that all feasible steps have been taken will be based on, but not limited to, a site-specific balance of the following criteria: naturally occurring pollutant concentrations prevent the attainment of the use; or human caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place; or hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use; or physical conditions related to the natural features of the water body preclude attainment of uses; or the cost of compliance would result in substantial and widespread economic and social impact. This process for making this determination is defined in 40 CFR 131 and further clarified in ODEQ's Draft Internal Management Directive (IMD) for Use Attainability Analysis (ODEQ, 2005).

### 6.11.3 WQMP Overview

A Water Quality Management Plan (WQMP) is included as a companion document to this TMDL. The Water Quality Management Plan explains the roles of various land management agencies (federal, state, and local governments) as well as private landowners in implementing the actions necessary to meet the allocations set forth in this TMDL. It also includes, directly or by reference, the statutes, rules, ordinances, local plans, and all other known mechanisms for implementation. The WQMP for the Tenmile Lakes Watershed focuses specifically on the following Water Quality Implementation Plan (WQIP) and the Designated Management Agencies (DMAs) to which they apply. The following tables identify DMA's and the WQIP mechanism and status for various land uses and authorities. Plans that are currently in place may need to undergo review to determine their adequacy in addressing sediment delivery as a pollutant surrogate identified for weeds and algae as part of this TMDL. These management plans should be evaluated for their adequacy to address sediment abatement resulting from current and legacy management activities, effectiveness monitoring for this parameters, and outreach and education needs and opportunities specific to this parameter.

Voluntary efforts to improved water quality through individual or corporate stewardship actions are ongoing. Active volunteer programs offered by the Tenmile Lakes Basin Partnership and other entities facilitate the implementation of mutually acceptable management actions to improve water quality on both public and private lands. The TLBP is currently in the process of developing a voluntary WQIP to guide voluntary implementation efforts and identify tracking mechanisms for actions designed to improve water quality conditions.

**Table 50 - Land Use or Resource Type and DMA**

| Land Use - Resource | Ownership | Designated Management Agency |
|---|---|---|
| Timber | Private | Oregon Department of Forestry |
| Multiple Uses | Elliott State Forest | Oregon Department of Forestry |
| Agriculture | Private | Oregon Department of Agriculture |
| Urban | City and Private | City of Lakeside |
| Rural Residential | Private and public | Coos and Douglas Counties |
| Transportation | Public | Oregon Department of Transportation (ODOT), County, and City Jurisdictions |
| Lakeside Water District | City | City of Lakeside |
| Fishery | Public | Oregon Department of Fish and Wildlife |

| Table 51 – DMAs and Water Quality Implementation Plans | | |
|---|---|---|
| **Designated Management Agency** | **Implementation Plan** | **Status of Implementation Plan** |
| Oregon Department Of Environmental Quality | Oregon Administrative Rules | In place |
| Oregon Department of Forestry | Oregon Forest Practices Act | In place |
| Oregon Department of Forestry | Elliott State Forest Management Plan | Under development |
| Oregon Department of Agriculture | Coos Coquille SB 1010 AgWQMP and Rules | In place |
| Oregon Department of Fish and Wildlife | Tenmile Basin Fish Management Plan | In place |
| Division of State Lands | Bed and Banks - States Waters | In place |
| Oregon State Marine Board | Marine Law Enforcement | In place |
| State Highways | ODOT WQIP | In place (ODOT, 2004) |
| City of Lakeside | City of Lakeside WQIP (Ordinance, variance, enforcement programs) | Under development |
| Douglas County | County WQIP (Ordinance, variance, enforcement programs) | Development needed |
| Coos County | County WQIP (Ordinance, variance, enforcement programs) | Development needed |

The implementation of this TMDL and the associated plans is generally enforceable by ODEQ, other state agencies, and local government. However, it is envisioned that sufficient initiative exists to achieve water quality goals with minimal enforcement. It is expected that the Designated Management Agencies (DMAs) will work with land managers to overcome impediments to progress primarily through education and technical support. Enforcement programs may be necessary in instances where insufficient action towards progress is being made. This could occur first through direct intervention from land management agencies (e.g. ODF, ODA, counties and cities), and secondarily through ODEQ. The latter may be based on departmental orders to implement management goals leading to water quality standards attainment.

No individual permitted point sources are currently discharging to the Tenmile Lakes. A new point source may be issued a permit for discharge of the pollutant causing impairment, without modification of the TMDL, if it is demonstrated that the discharge will not cause or contribute to a violation of the water quality standard (See 40 CFR 122.44(d) in the NPDES permitting regulations). New discharges that achieve water quality standards at end-of-pipe would be candidates for permitting without a TMDL modification. For instance, in nutrient impaired waters, it may be allowable for a new facility to discharge wastewater that does not cause an increase in nutrient concentrations without modification of the TMDL.

ODEQ will work with DMAs in developing Implementation Plans that are consistent in meeting the assumptions and requirements of the load allocations. These plans will be developed/modified within 1 - 2 years following the development/modification of a TMDL and will include, but not be limited to, the following:

- Management measures tied to attainment of the TMDL,
- Timeline for implementation (including appropriate incremental measurable water quality targets and milestones for implementing control actions),
- Timeline for attainment of water quality standards including an explanation of how implementation is expected to result in the attainment of water quality standards,
- Monitoring and evaluation

If a source that is covered by this TMDL complies with its Implementation Plan (for example SB1010 plan) or applicable forest practice rules, it will be considered in compliance with the TMDL (OAR 340-41-0061).

ODEQ intends to regularly review progress of the WQMP and the associated Implementation Plans developed to achieve this TMDL. If and when ODEQ, in consultation with the management agencies, determines that either water quality standards have been met, or that the WQMP has been fully implemented and all feasible management practices have reached maximum expected effectiveness and the TMDL, its associated surrogates, or its interim targets have not been achieved, ODEQ shall reopen the TMDL and adjust it or its interim targets and its associated water quality standard(s) as necessary.

The determination that all feasible steps have been taken will be based on, but not limited to, a site-specific balance of the following criteria: naturally occurring pollutant concentrations prevent the attainment of the use; or human caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place; or hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use; or physical conditions related to the natural features of the water body preclude attainment of uses; or the cost of compliance would result in substantial and widespread economic and social impact. This process for making this determination is defined in 40 CFR 131 and further clarified in ODEQ's Draft Internal Management Directive (IMD) for Use Attainability Analysis (ODEQ, 2005).

Please see the Water Quality Management Plan for in depth discussions about actions that can be taken to improve water quality in North and South Tenmile Lakes and about Designated Management Agency (DMA) planning status and responsibilities.

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# APPENDIX A TENMILE LAKES NUTRIENT STUDY

# APPENDIX B DEPARTMENT OF HEALTH SERVICES ALGAL BLOOM FACT SHEET

Department Of Health Services Fact Sheet
Hazards from Microcystis Aeruginosa in Fresh Water

Microcystis aeruginosa is blue - green alga that grows naturally in many surface waters. In most bodies of fresh water and most weather conditions it does not pose a hazard to wildlife or human beings.

However, under certain conditions (such as when the water is warm with abundant nutrients) Microcystis aeruginosa can grow more rapidly than normal. The result can be large colonies that form floating masses on the water. These occurrences are called "algal blooms". Under these conditions, Microcystis aeruginosa can produce natural toxins (called microcystins) that are very potent. The microcystin toxins are produced and contained inside the Microcystis cells, and are released to the water when the cells die and disintegrate. Also, since the cells are very small, they can be ingested along with the water.

Toxin levels in a water body tend to be higher near shorelines and at the surface of the water where animal and human contact is most likely.

The primary toxic effect of microcystins is on the liver. At very high doses, death of liver cells and destruction of blood vessels in the liver can result in serious injury and possibly death. Though less is known about the long-term effects of microcystin toxins, animal studies have shown these toxins can cause chronic liver damage and may promote the formation of liver tumors. These effects are more likely to occur if exposure is frequent over a long period of time.

The levels of toxin necessary to produce immediate or acute illness in humans and animals are much higher than levels that may cause chronic liver injury. Drinking water standards are usually based on chronic effects. Currently, there is no drinking water standard in the U.S. for microcystins. Canada, Australia, and Great Britain have developed a guideline level of 1 microgram toxin per liter of water, or 1 part per billion (1 ppb). During algal blooms, toxin levels can greatly exceed 1 ppb.

Changes in weather or in other conditions in a water body influence the growth of blue-green algae. Generally, cooler weather, rainfall, and reduced sunshine will lead to reductions in algal growth and toxin levels. Algal blooms generally peak and die off rapidly and toxin levels in the water decline over days or weeks. Only blue-green algae experts can distinguish visually between different kinds of algal growth, and are able to determine when blooms have disappeared. Testing of the water is the only way to be certain that toxin levels are no longer dangerous.

Contact Us:

Kenneth Kauffman
kenneth.w.kauffman@state.or.us
Environmental Health Specialist
503-731-4012

Dave Stone
dave.stone@state.or.us
Toxicologist
503-731-4012

# APPENDIX C TENMILE WATERSHED DAILY LOAD CALCULATIONS

## Daily Sediment Load Targets

Traditionally ODEQ has assigned loads and load reductions for sediment on an annual basis, but recent guidance from the EPA has focused on assigning loads on a daily basis. This appendix adjusts annual TMDL targets stated in section 6 to reflect daily loads. However, for implementation of TMDLs, ODEQ believes it is still more practical to assess the impact of load reductions on an annual basis.

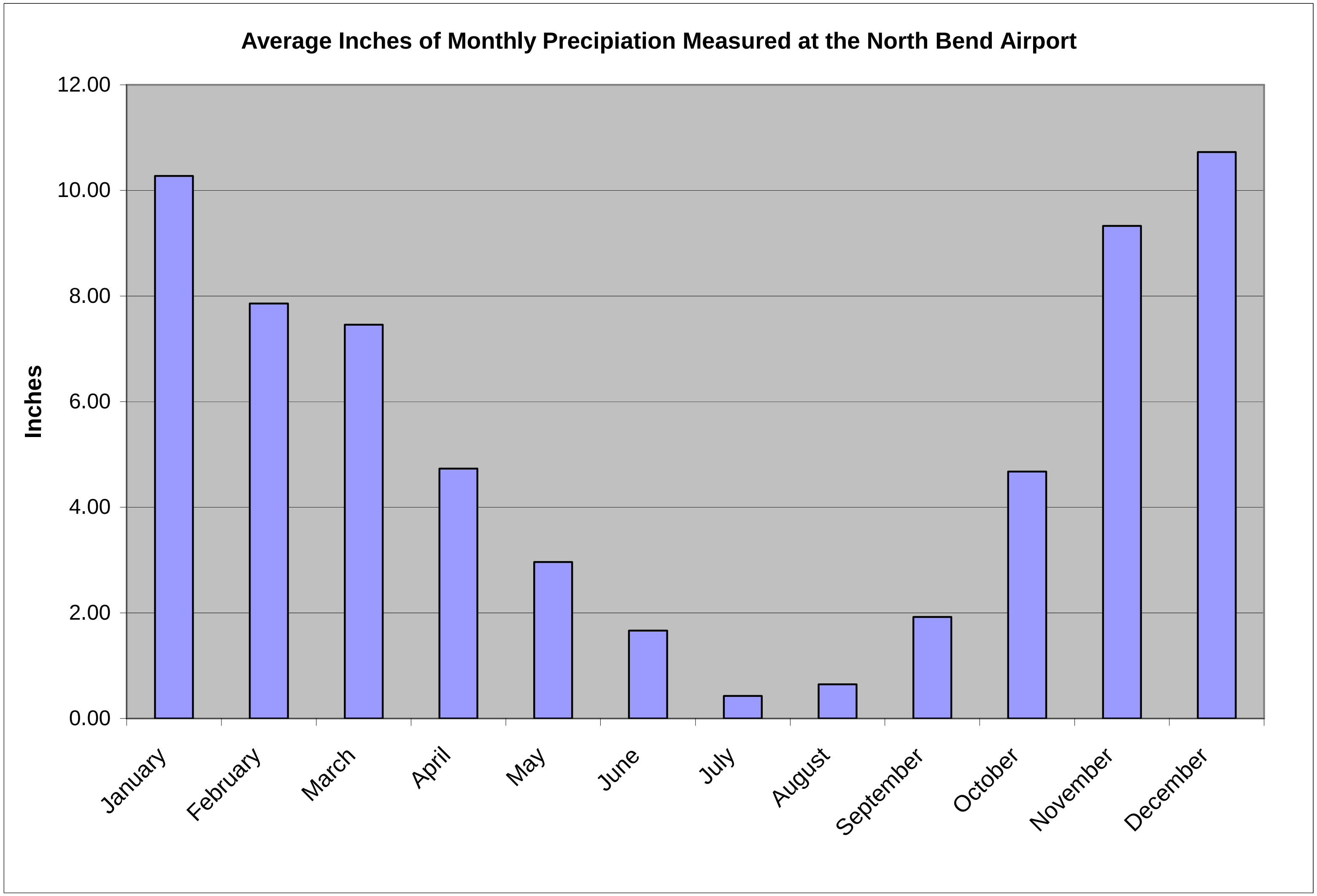
It is well understood that pulses of pollutants, in this case sediment, occur during high discharge events. To better relate target sediment loads to this phenomenon, daily sediment loads were developed using precipitation data obtained from the National Oceanic and Atmospheric Administration and the National Weather Service Cooperative Observer Network station number 6073 located at the North Bend FAA Airport. Precipitation data have been recorded at this station beginning in 1910 to present. Three years in this period of record were identified as incomplete years (1910, 1927, and 1928) and data from these years were excluded. The North Bend Airport precipitation record, supported by field flow measurements, was utilized to support the development of the hydrological modeling component for this project. This precipitation information will be used to represent the driving factor for stream flows for Tenmile Watershed tributaries and/or catchments. Sediment TMDL loading capacity (LC) and load allocations (LA) were developed for fourteen Tenmile Watershed catchments.

After determining monthly precipitation averages, the percentage of precipitation occurring during each month was calculated. The precipitation percentage for each month was then multiplied by the sediment load target and divided by the number of days in the month. The end result was a precipitation based daily sediment load target for the fourteen Tenmile Watershed catchments.

Monthly precipitations in inches are shown in figure C1. Precipitation occurring between the period November through March account for 73% of the annual total precipitation and targeted sediment loading is highest for this period. Less precipitation occurs between the period April through October and lower target sediment loads are identified for this period.

Table C1 outlines the daily sediment load targets by month and by day. Catchment calculated monthly and daily loading are graphically depicted in figures C2 and C3. By reducing the existing sediment load to the amounts listed below, sediment will be reduced in sufficient quantities to support beneficial uses.

Figure C1 – North Bend Airport Monthly Precipitation Averages



| Table C1 - Tenmile Watershed Monthly and Daily Load Calculations | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Catchment Sediment Loads** | January | February | March | April | May | June | July | August | September | October | November | December |
| 11 mixed use @ 18 tons/mi$^2$/year | | | | | | | | | | | | |
| tons/mi$^2$/month | 2.95 | 2.26 | 2.14 | 1.36 | 0.85 | 0.48 | 0.12 | 0.19 | 0.55 | 1.34 | 2.68 | 3.08 |
| tons/mi$^2$/day | **0.10** | **0.08** | **0.07** | **0.05** | **0.03** | **0.02** | **0.00** | **0.01** | **0.02** | **0.04** | **0.09** | **0.10** |
| Lakeside urban use @ 60/ mi$^2$/year | | | | | | | | | | | | |
| tons/mi$^2$/month | 9.84 | 7.52 | 7.14 | 4.53 | 2.84 | 1.59 | 0.41 | 0.62 | 1.84 | 4.48 | 8.93 | 10.27 |
| tons/mi$^2$/day | **0.32** | **0.27** | **0.23** | **0.15** | **0.09** | **0.05** | **0.01** | **0.02** | **0.06** | **0.14** | **0.30** | **0.33** |
| West North urban use @ 57tons/ mi$^2$/year | | | | | | | | | | | | |
| tons/mi$^2$/month | 9.34 | 7.14 | 6.78 | 4.30 | 2.69 | 1.51 | 0.39 | 0.59 | 1.75 | 4.25 | 8.49 | 9.76 |
| tons/mi$^2$/day | **0.30** | **0.26** | **0.22** | **0.14** | **0.09** | **0.05** | **0.01** | **0.02** | **0.06** | **0.14** | **0.28** | **0.31** |
| Central South urban use @ 47/ mi$^2$/year | | | | | | | | | | | | |
| tons/mi$^2$/month | 7.71 | 5.89 | 5.59 | 3.55 | 2.22 | 1.25 | 0.32 | 0.48 | 1.44 | 3.51 | 7.00 | 8.05 |
| tons/mi$^2$/day | **0.25** | **0.21** | **0.18** | **0.12** | **0.07** | **0.04** | **0.01** | **0.02** | **0.05** | **0.11** | **0.23** | **0.26** |

Figure C2 Calculated Catchment Daily Sediment Loads

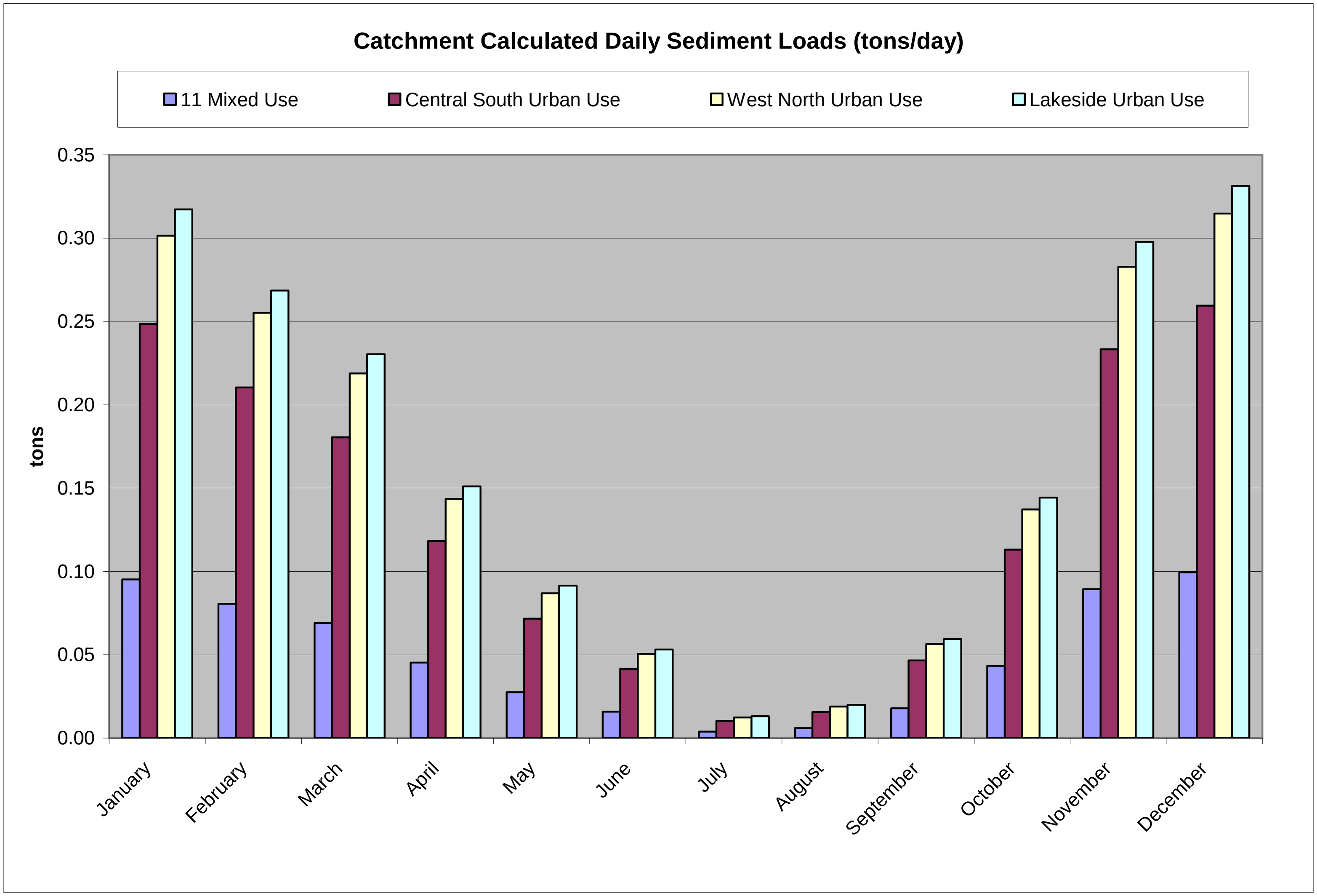


Figure C2 Calculated Catchment Monthly Sediment Loads