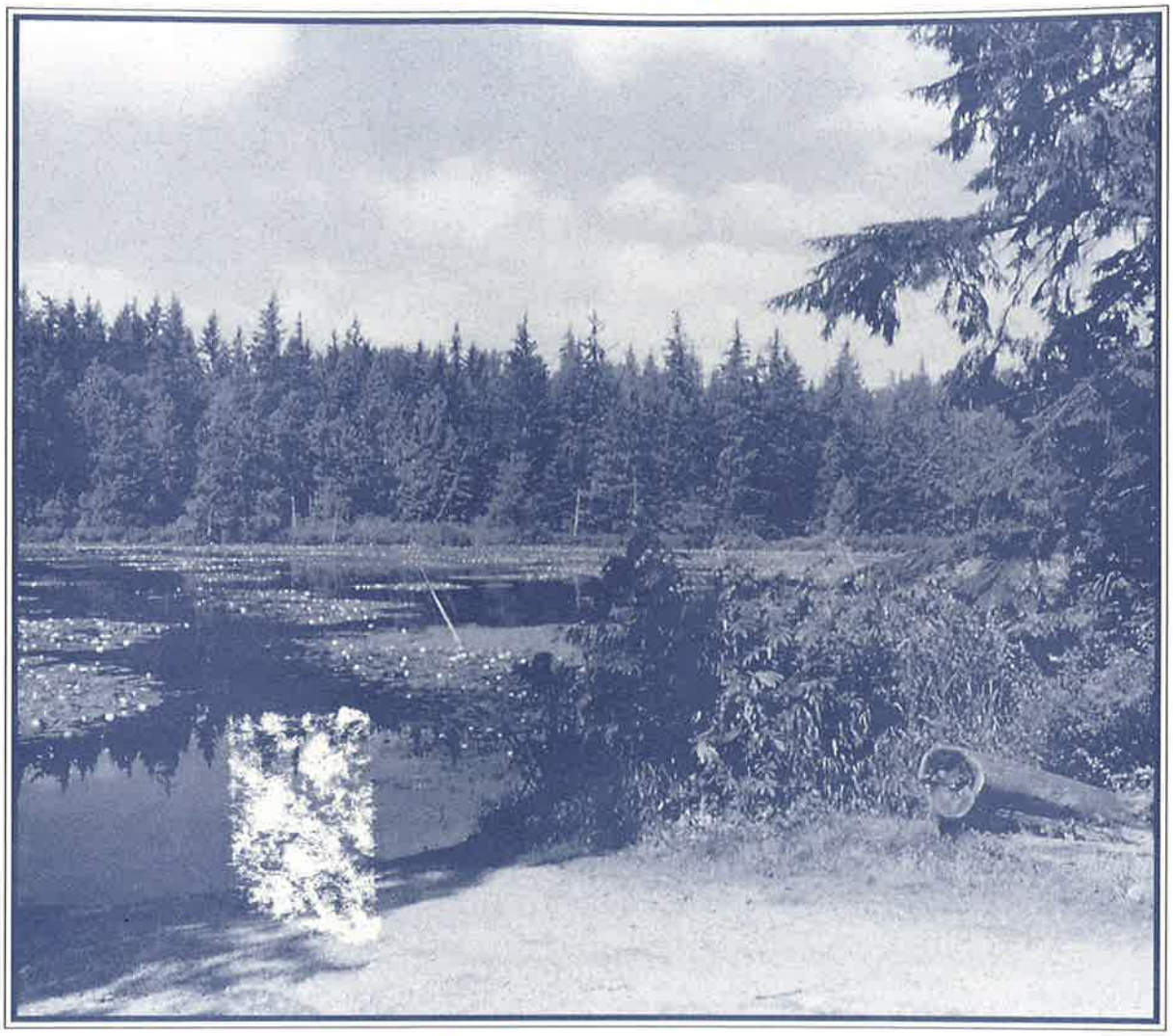
KCR 1260

Lake Twelve Management Plan



Final Report

King County Surface Water Management

ENVIROVISION

Washington State Department of Ecology

May 1994

King County
Surface Water Management Division
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May 16, 1994

RE: Lake Twelve Management Plan Final Report

Dear Recipient:

The enclosed Plan final report covers Lake Twelve and its watershed located in southeast King County. Lake Twelve is a small, shallow lake located in the Cedar River basin, approximately one mile northeast of the City of Black Diamond. The Plan recommends restoration and watershed management measures to improve and prevent further degradation of the lake ecosystem and the beneficial uses it supports.

The plan for protection and restoration of Lake Twelve must address existing and future problems experienced by the lake and meet the following three goals set forth by area residents: 1) maintain long term water quality; 2) maintain the aesthetic character of the lake; and 3) provide long term control of aquatic plants.

The limnological data collected during the study does not support an intensive in-lake effort to control internal nutrient loading to Lake Twelve. The aquatic plant population appears to be the major limitation to continued support of the beneficial uses of the lake. The recommended in-lake restoration measure is to develop and implement an Integrated Aquatic Plant Management Plan (IAPMP) for control of macrophytes. The second alternative which may be instituted if monitoring indicates that water quality has deteriorated, or if implementation of the IAPMP does not provide adequate control of the plants, is a lake dredge project.

Recommended watershed management measures include those to control pollution from developed residential areas. Basinwide controls include those for controlling runoff from forest and mining activities, and street and construction site runoff. Developed area measures include septic system maintenance programs, proper landscaping techniques and other private site runoff control techniques, and alternative housekeeping practices.

In order to evaluate whether the Plan is meeting stated objectives, a plan for continued lake monitoring is necessary. Water quality monitoring will occur through continuation in Metro's volunteer monitoring program, as well as more comprehensive monitoring that will occur every five years. Aquatic macrophyte populations will also need to be monitored.

Public involvement and education programs focusing on identification and mapping of aquatic plants, disseminating information on how residents impact lake water quality, and how they can implement best management practices is

recommended. Lake residents should be involved in review of mine closure plans, forest management plans, water supply pipeline plans, and other development and land use zoning changes that will affect the Lake Twelve watershed.

The total cost for implementation of the Lake Twelve Management Plan is estimated at $111,000. These costs are based on a five-year period, though some of the implementation steps, such as septic tank system inspections would be performed only once in the five-year period. It is important to note that this cost includes $20,000 for development of the IAPMP which began during May 1994, and a $25,000 public access element. Some improvements to the public access area would be needed to meet existing Phase II grant requirements. These include the addition of a park identification sign, installation and maintenance of garbage receptacles, a picnic area, and installation and maintenance of toilet facilities. This public access improvement element would only be required if a Phase II implementation grant project (such as a lake dredge program) was applied for. It is recommended that the Lake Twelve Association consider forming a lake management district or develop other appropriate measures to raise revenues required for local match grant funding requirements.

If you have any questions concerning the Plan, please call Bob Storer, Lake Twelve Management Plan Project Manager, at 296-8383.

Sincerely,

Jim Kramer
Manager

JK:BS:vs

Enclosure

April 1994

Lake Twelve Management Plan

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ACKNOWLEDGEMENTS

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Bob Storer, the Project Manager with King County Surface Water Management, directed the project and maintained communication between the many project team members. Allen Moore, the Grant Officer with the Washington State Department of Ecology, provided agency perspective and grant assistance. Esko Cate, with the Lake Twelve Association, helped coordinate resident activities and played a key role in informing residents of study progress and providing feedback on residents' concerns. These people were instrumental to the successful completion of the project.

We would also like to thank the members of the Technical Advisory Committee for Lake Twelve. These were:

Mark Abernathy - Pacific Coast Coal Company
Jim Beiler - University of Washington
Esko Cate - Lake Twelve Association, President
Pat Dunn - Hong West & Associates
John Ellis - Weyerhaeuser Company
Harry Gibbons - KCM, Inc.
Bill Kombol - Palmer Coking Coal Company
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The chapter on lake water quality is a summary of a report prepared by Eugene B. Welch, Jim Beiler, and Dimitri Spyridakis of the University of Washington.

Appreciation for their professional work is extended to Hong West & Associates for aiding development of the groundwater data.

EXECUTIVE SUMMARY

Lake Twelve is a small, shallow lake located in the Cedar River basin of southeastern King County, approximately one mile northeast of the City of Black Diamond. Residential homes are located along the lakes perimeter, however, most of the watershed is undeveloped and is comprised of forestland and a large bog-type wetland. Increases in aquatic macrophytes, reoccurring algal blooms, and concerns about water quality impacts from sedimentation ponds associated with local mining operations, prompted King County Surface Water Management (KCSWM) to apply for a grant to study the lake. KCSWM received a Centennial grant from the Washington State Department of Ecology to perform a Phase I study of the lake. Study objectives were to; 1) Perform a limnological survey of Lake Twelve, 2) Provide information, education, and involvement opportunities to watershed residents, and 3) Provide a restoration and management plan to improve and prevent further lake water quality degradation.

MONITORING RESULTS

Temperature and Oxygen

Thermal stratification did develop in Lake Twelve; the lake was stratified from the middle of April through the end of September. Dissolved oxygen concentrations in the hypolimnion were very low during this period, and anoxic conditions developed for about a one month period. The short duration of the anoxia indicated that thermal stratification was not very stable and there was some mixing between the layers; a not uncommon character of shallow lakes.

Nutrients

Nutrient concentrations were relatively low throughout the study period. TP concentrations ranged from 4.9 to 12.3 ug/L with the highest values occurring during winter months when stormwater runoff and other "external" sources were highest. Whole-lake average TP concentrations were relatively constant throughout the year, and although TP concentrations in the hypolimnion were usually higher than the epilimnion, it was not to the degree seen in lakes for which internal loading sources are determined to be important. TN concentrations were also low, ranging from 306 to 1,185 ug/L, and followed the same seasonal pattern as TP. Concentrations of available nutrients (SRP and nitrate+nitrite and ammonia) varied more throughout the year than total nutrient concentrations, but were similarly low. The TN:TP ratio for Lake Twelve was estimated at 60:1, indicating that the lake is phosphorus limited.

Water Clarity and Algae Growth

Secchi disk readings ranged from 1.4 to 6.0 meters, with a summertime average of 3.6 m. Whole-lake volume-weighted chlorophyll a ranged from 1.4 to 20.7 ug/L. Other than a small epilimnetic peak in concentrations that occurred in April with a larger hypolimnetic peak that occurred in August, there was little difference between epilimnetic and hypolimnetic chlorophyll a

concentrations. During the study period, there was no evidence of the algal blooms that have been noted as a problem in the past.

Comparatively few blue-green algae were found in Lake Twelve during the study year. Overall, the phytoplankton population was dominated by yellow-green and green algae and desmids. These are indicative of relatively unproductive (oligotrophic) conditions. Although there were the typical spring, summer, and fall peaks in algal abundance, concentrations were not high enough to cause nuisance bloom conditions.

Aquatic Plants

Aquatic plants are the main issue of concern for Lake Twelve residents, who believe plants have invaded a greater portion of the lake and increasingly impede their use of the lake. It has been estimated that light intensity will allow plants to thrive at depths of 4 meters or less in the lake. Since the average depth of the lake is 3 meters, this indicates that at least 50% of the surface area is habitable by plants. The white water lily, (*Nymphaea odorata*), Eurasian water milfoil (*Myriophyllum spicatum*), and the watershield (*Brasenia*) were the most common species collected. The areal-weighted mean for all species was 63 g/m^2. This density and coverage is high enough to significantly impact recreational use of the lake, and past experience with milfoil suggests it will continue to form denser more extensive beds as time progresses.

Water and Phosphorus Budgets

Precipitation (12%), sedimentation pond inflow (2%) and groundwater (.2%), together account for less than 15% of the incoming water to the lake. Drainages from along the northshore of the lake, account for another 34% of the incoming water. The majority of the inflow (52%) originates from ungauged sources. The source of this water is likely from surface inflows along the southern shore and may also reflect error in the groundwater estimates.

Phosphorus budget results were similar to water budget estimates. Precipitation (9%), sedimentation pond inflow (2%), and groundwater (1%) again accounted for less than 15% of the incoming phosphorus. The northshore runoff (41%) and ungaged inflows (48%) accounted for the vast majority of the phosphorus. Not all of the incoming phosphorus could be accounted for by measured or estimated outflows; there was a residual phosphorus loss of 18%. This represents the phosphorus lost through settling into the lake sediments. These results signify two important facts; 1) The largest source of phosphorus appears to be from surface water inflows or runoff water, and 2) There is no evidence of net internal loading of phosphorus at this time.

RECOMMENDED IN-LAKE RESTORATION MEASURES

The limnological data collected during the study does not support an intensive in-lake effort to control internal nutrient loading to Lake Twelve. The aquatic plant population appears to be the major limitation to continued support of the beneficial uses of the lake. The recommended in-lake restoration measure is to develop an *Integrated Aquatic Plant Management Plan (IAPMP)* for

control of the macrophytes. The second alternative selected which may be instituted if monitoring indicates that water quality has deteriorated, or if implementation of the IAPMP does not provide adequate control of the plants, is a lake dredge project.

RECOMMENDED WATERSHED MANAGEMENT MEASURES

Recommended watershed management measures include those to control pollution from the basin as well as those focused at controlling pollution from developed residential areas. Basin-wide controls include those for controlling runoff from forest and mining activities, and street and construction site runoff. Developed area measures include septic system maintenance programs, proper landscaping techniques and other private site runoff control techniques, and alternative housekeeping practices.

MONITORING AND DOCUMENTATION

In order to evaluate whether the plan is meeting stated objectives, a continual plan for monitoring the lake is necessary. Water quality monitoring will occur through continuation in Metro's volunteer monitoring program, as well as more comprehensive monitoring that will occur every five years. Aquatic macrophyte populations will also need to be monitored. The specifics of this program will be developed during production of the IAPMP.

PUBLIC INVOLVEMENT AND EDUCATION

Public involvement and education will occur through a number of mechanisms. A Master Milfoiler program, funded with development of the IAPMP would provide interested citizens with an opportunity to learn to identify and map plant beds. Citizens will also be needed to continue the volunteer monitoring efforts. Public education includes disseminating information on septic system maintenance, alternative landscaping and housekeeping practices, and other information on how residents impact lake water quality and how they can implement BMP's. Lake residents should be involved in review of mine closure plans, forest management plans, and land use zoning changes that affect the Lake Twelve watershed.

COST

Total cost for implementation of the Lake Twelve Management Plan is estimated at $111,000. This includes cost for development of the IAPMP, but does not include a cost estimate for implementation of that plan.

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INTRODUCTION

PROJECT BACKGROUND

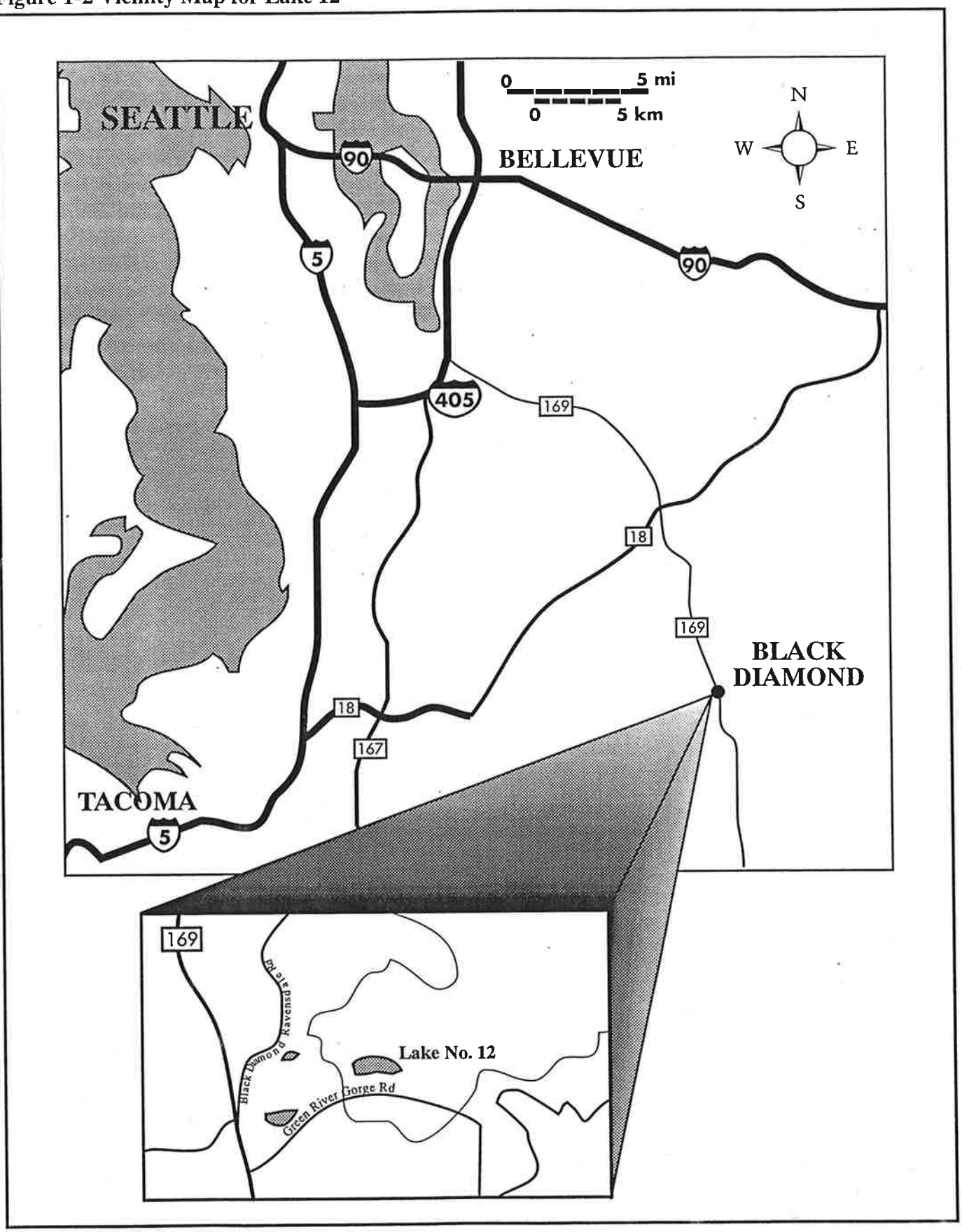
Lake Twelve is a small (43 acres), shallow (average depth of 10 feet (3 meters) and maximum depth of 28 feet (8.5 meters)), lake located in the Cedar River basin of southeastern King County, approximately one mile northeast of the City of Black Diamond (Figure 1-1). Although much of the lake's shoreline is developed as residential property, the majority of the 398 acre watershed is undeveloped. Forestland and a large bog-type wetland comprise the majority of the watershed.

In 1983, land adjacent to the western boundary of the Lake Twelve watershed was cleared to make way for an open cut surface mining operation. In 1985, mining operations began. In 1986, Pacific Coast Coal Company (PCCC) built a large noise berm between the lake and the mining site to limit the impact of noise from the mining site on nearby properties.

Surface runoff from the berm was diverted to two detention ponds which in turn discharge to the lake. Before the berm was seeded and stabilized, a large rain event caused the berm to fail and slide into the sedimentation ponds. Not only did this cause an immediate, observable impact on lake water quality (according to local residents a turbidity plume was evident for 3-4 months), it also resulted in loss of much of the storage capacity in the ponds. This and other concerns about changes in lake quality prompted local residents to initiate a preliminary limnological study to examine lake water quality and the affect of the berm failure and sedimentation pond discharge waters on the lake.

In addition to the event related increases in turbidity, the primary concerns identified by lake residents was the increase in algae blooms and an increase in aquatic plant density especially as it pertained to increases in Eurasian Watermilfoil. Results of the study are reported in "Water Chemistry and Algal Blooms in Lake Number 12: Impacts of Coal Strip Mining", T. Smayda. December 1988. Some of the findings of the study were; 1) Phytoplankton bloom development was more frequent and severe, 2) Aquatic plants were very abundant and their decay promoted low dissolved oxygen levels in the bottom waters, release of phosphorus and therefore increased algal blooms, 3) A large sediment load was delivered to the lake as a result of the PCCC sedimentation ponds and associated runoff, and 4) Septic leachfield drainage and the PCCC ponds were each estimated to account for about 6 Kg of P per year during the study year which compared to a natural background load of 9.3 Kg.

Figure 1-2 Vicinity Map for Lake 12



These study results and citizens' continued concerns about deteriorating water quality prompted the King County Surface Water Management (SWM) Division to apply for a grant to study the lake in more detail. In 1990, SWM received a Centennial grant from the Washington State Department of Ecology (WSDOE) to perform a Phase I Restoration/Feasibility study of the lake. Study objectives were to; 1) Perform a limnological survey of Lake Twelve, 2) Provide information and education, and opportunities for public involvement to the technical advisory committee, watershed residents, users of the watershed, and affected agencies, 3) Develop a restoration and management plan to improve and prevent further lake water quality degradation. There were three primary participants involved in completion of the grant requirements. King County Surface Water Management was responsible for project administration functions, public involvement, and the wetland assessment. The University of Washington performed the limnological study, and the consultant team of Envirovision and KCM Inc., performed the restoration analysis and developed the lake management plan. Additionally, a Technical Advisory Committee (TAC) was established for the purpose of hearing reports on the progress of the study, discussing key findings, and reviewing and commenting on the draft and final reports. Membership on the TAC included representatives from the Lake Twelve Association (LTA), Pacific Coast Coal Company (PCCC), Palmer Coking Coal Company, Weyerhauser Company, the City of Black Diamond, and the previously mentioned team members.

The University began the limnological assessment during the spring of 1991 and continued monitoring the lake for the following year. Results from the limnological study are presented in "Lake Twelve Quality, Nutrient Loading and Management" (Welch, et al. 1993); a summary of those results is provided in Chapter 2 . These results, in conjunction with lake management goals set by the watershed residents, form the basis for recommendations made in this report.

LAKE AND WATERSHED CHARACTERISTICS

Lake Twelve and its watershed has unique characteristics that are important in assessment of restoration or management alternatives, and that must be considered in efforts to maintain the aesthetic character of the lake. The unique character of Lake Twelve is defined by a number of key factors. The lake is small and shallow. These two features alone have many implications. Because the lake is small it does not have a large volume of water, so that even small increases of nutrients, sediments, or other pollutants can have a significant impact. The shallow nature of the lake means that a large portion of the lake is available for aquatic plants to inhabit, the sediments may be easily

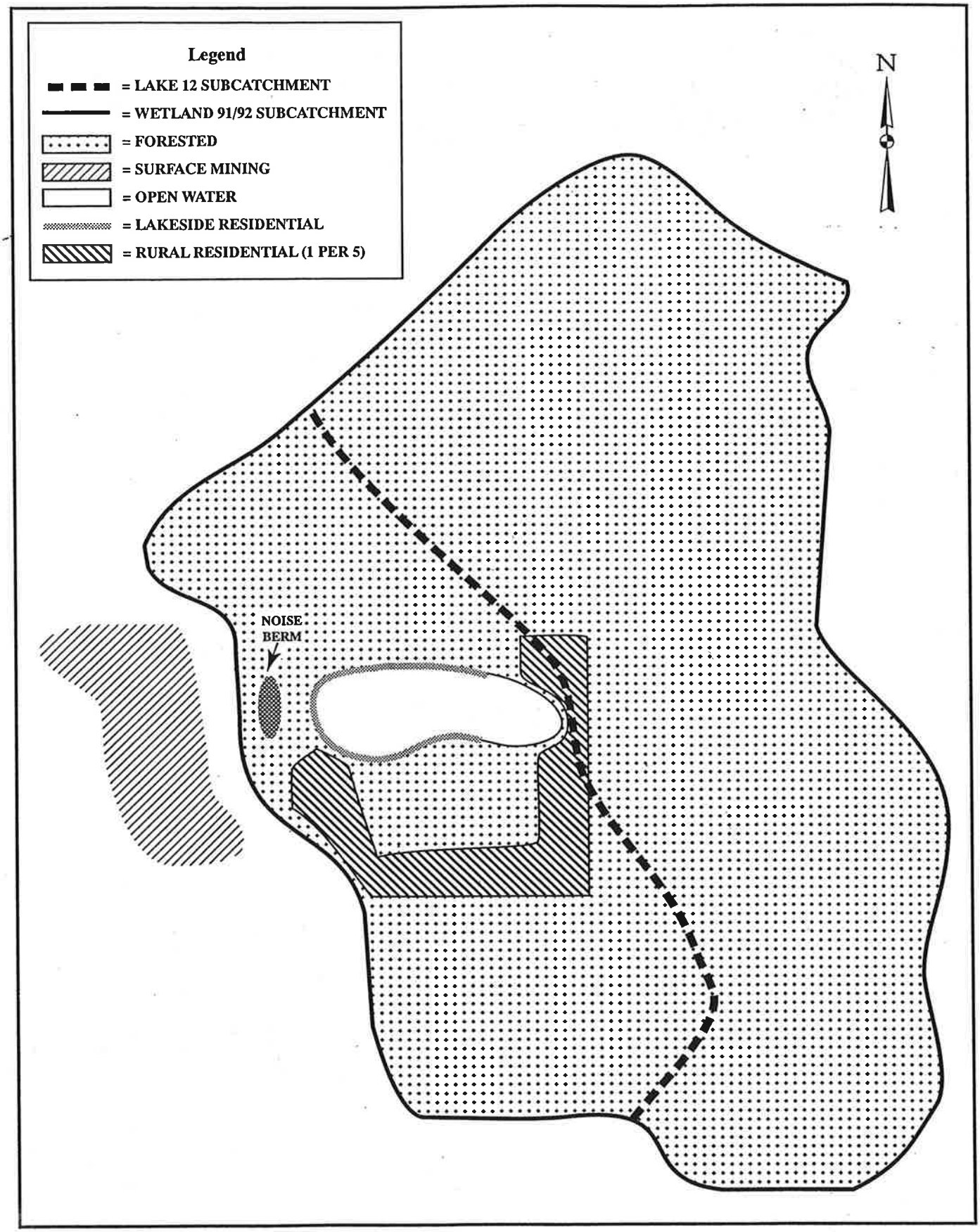
disturbed by wind activity, and nutrients that accumulate in the sediments can be easily mixed into the water column.

Another important feature is the lake's hydrology; the way water moves into and out of the lake. There is no one major inflowing stream, but instead there are three small streams and many intermittent surface water runoff features that together represent the incoming water. Water leaves the lake through a large wetland located along the eastern shoreline and a small stream that flows through the wetland area. Consequently, neither the inflow nor outflow can be represented by one significant, monitorable, or controllable source. The volume of outflowing water in combination with the total volume of water in the lake is used to determine the flushing rate, or how long it takes for the lake water to be replaced by incoming water. In the case of Lake Twelve, the flushing rate has been estimated to be 2.5 times/year, a moderately low rate. This rate can also be important in terms of effectiveness of in-lake restoration activities. A low flushing rate results in greater sedimentation of pollutants and therefore less loss of these pollutants through the lake outflow.

Last, the wetland located along the eastern shoreline is over twice the size of the lake itself. In hydrologic terms, the wetland is the much more important feature. This wetland is also the cause of the naturally dark color of the water; another identifying feature of Lake Twelve. (Although the wetland is "downgradient" of the lake, the difference in elevation is minimal and may even favor the lake during dry months. Consequently, the lake mixes freely with water beneath the "floating bog", which affects the color and chemistry of the lake water.

Rooted plants (called aquatic macrophytes) occupy much of the shoreline of Lake Twelve, essentially growing around the entire perimeter to a depth of approximately 4 meters (13 feet). White water lilies (Nymphaea odorata), watershield (Brasenia), and Eurasian water milfoil (Myriophyllum spicatum), are the most common species. The former two species grow in the shallower, nearshore waters, while the milfoil colonizes nearshore and deeper waters. Milfoil is an invasive species that can quickly colonize a shallow lake. Because of its dense growth habit, it is a nuisance species that impacts swimming, boating, and fishing activities. Although the lilies and watershield have been considered to be problems in the past, it is the recent rapid growth of milfoil that is currently of most concern to area residents.

Figure 1-2 Landuse in the Lake 12 & Wetland LCR–91/92 Subcatchments



The 161 ha (398 acres) of moderately steep to rolling hills that form the watershed for Lake Twelve are primarily comprised of forested land (86%) (Figure 1-2). The land was originally logged in the 1920's or 30's (Ellis, J., personal communication). Consequently, about ten years ago when the stand reached an age of about 60 years, cutting of the second growth began. At this time, roughly half of the forested portion of the Lake Twelve watershed has been through a second harvest (Ellis, J., personal communication).

The remaining portion of the watershed consists of the lake itself and surrounding shoreline (11%) and the mining operations noise berm (3%). Recently, 23 ha of the lake's watershed (14% of the watershed) has been rezoned from forestry use to the residential 5 acre designation (one dwelling per five acres). Development of land within the watershed represents the most important long-term threat to the quality of Lake Twelve. Development will result in increased impervious surfaces, which can lead to increased runoff and erosion, and increased quantities of pollutants available to be washed into the lake.

As previously described, the most notable feature of the Lake Twelve watershed is the existence of a large bog type wetland along the lake's eastern border. Not only is this wetland the likely driving force behind the lake's hydrology, it is considered a very high quality wetland that provides important plant and wildlife habitat. As part of this study a wetland assessment was performed. Previously, the lake and wetland were classified separately as two Class 2 wetland systems; Lower Cedar River (LCR)-91 and LCR-92. Field observations indicated that the two wetlands were part of the same system, and the system is being considered for reclassification as a Class 1(c) wetland. The wetland (now labelled LCR-91/92) is a 136 acre wetland (44 acres of open water) composed of five different vegetative classes. The wetlands size and vegetative complexity provide evidence of the importance of the system for local plant and wildlife habitat as well as recreational opportunities.

Due to the importance of this wetland, all restoration activities that affect the lake will be closely scrutinized to ensure there is no negative impact to this system. The wetland lends another advantage directly to the lake residents. Thanks to its existence, no residential development has or can occur along this portion of the shoreline. Fewer homes along the shore not only translates into fewer pollutants entering the lake, it also means that this shoreline will always retain its wild, natural, and aesthetically pleasing character.

The lake's natural shallowness and the presence of the wetland have aided development of dense, nuisance growths of lilies, pondweeds, and others. Although these plants undoubtedly seem like more of a nuisance than an advantage, they may be playing an important role in limiting the area colonizable by milfoil. This allows for a more diverse plant community that is better for all aquatic life, is more aesthetically pleasing, and probably has less of an impact on recreational uses than monotypic stands of milfoil.

Last, the Lake Twelve watershed is small and relatively undeveloped. This is a great advantage when it comes to initiating watershed control measures. It is much easier to control nonpoint source pollutants by implementing control measures before development occurs and while there is still undeveloped land available for things such as detention basins or biofiltration swales. This portion of King County will be increasingly impacted by development pressure. Concerned residents, agency staff, and other users must take action now if the lake is to be protected and preserved.

BENEFICIAL USES

Lake Twelve provides many beneficial uses including; boating, fishing, swimming, domestic water supply, and aesthetic value to area residents and other users of the lake and watershed, in addition to providing important fish and wildlife habitat.

A public boat launch is located near the eastern end of the lake, adjacent to the wetland. This is where the lake is shallowest and therefore aquatic plants are very dense. Boating access via the public launch has become increasingly difficult due to the dense plant growth. During mid-summer there is only a narrow lane of access from the launch to the open water portion of the lake. For many private docks the lake can be completely inaccessible during mid to late summer when the plants are tallest and at their greatest density.

During a 1983 fishery survey of the lake, Rainbow and Cutthroat trout, Yellow Perch, Brown Bullhead, and Pumpkinseed were collected through gill and trap nets and beach seining activities. Largemouth Bass and other sunfish are also known to inhabit the lake. The Bullheads and Pumpkinseed appeared to comprise the majority of the fish population. According to Washington Department of Wildlife (WDW) personnel, the lake contains an overpopulation of smaller, stunted fish, that is probably a result of disruptions to the natural predator-prey relationships caused by the dense aquatic plant beds. The department rates the lake as a moderately important fishery lake (T. Cropp, Washington Department of Wildlife, as reported in the

Aquatic Weed Management Fund Grant Application for Lake Twelve). The number of fishing days per year coincides with the seasonally operated public boat launch. Although no data exists to estimate annual use, WDF has estimated that approximately 10 percent of the total annual fishing occurs on opening day (T. Cropp, op cite.)
Waterfowl also use the lake, especially during the winter months. These include; Western Grebes, Mergansers, Cormorants, Coots, and Canada Geese. Lake fish and plants provide food for these birds during the November to March period. No wildlife surveys have been done to estimate the total number and type of wildlife inhabiting this lake/wetland system. Given the system's size and diversity it can be assumed that it is a very important aquatic ecosystem within the Cedar River Basin.

There are 74 residential lots on Lake Twelve. About 30 of these lots contain full-time residences and there are several seasonal residences. Prior to 1980, many of these residences used the lake for drinking water. The occurrence of several algal blooms, and general odor and turbidity problems that developed in the mid-1980's have caused residences to change and use the lake water for non-consumptive purposes only.

PROJECT GOALS

On October 29, 1992 a public workshop was held in the City of Black Diamond to discuss the results of the limnological survey, inform residents of potential restoration options, and list and prioritize residents' management goals for Lake Twelve. After listening to the results from the survey and learning about potential lake restoration techniques and their drawbacks, the thirty people present were asked to list all or any goals they might have for the project. The resultant list is included in Table 1 below. Next, each person was asked to list their three priority goals; these results were used to rank each of the goals, as also shown in the Table.

As shown, the three top ranked goals selected were to; 1) Maintain the long-term water quality of the lake 2) Maintain its aesthetic character, 3) Control weeds and provide long-term aquatic plant protection. These goals, along with the information gathered during the restoration analysis, were used to select the long term management goal for Lake Twelve.

The long-term management plan selected for Lake Twelve was to develop an Integrated Aquatic Plant Management Plan for the lake. A grant to develop such a plan has since been applied for through

WSDOE's Aquatic Weed Management Fund (AWMF) and approved. This alternative was selected because it would result in somewhat immediate solutions to the plant problem and because the cost for developing and implementing such a plan was reasonable. A lake dredging effort was selected as the preferred alternative lake management technique to be reconsidered if future water quality monitoring indicates that the lake water quality as measured by trophic indicators has degraded.

Table 1-1. Results from Goal Setting Session for Lake Twelve.

GOAL	Number of Votes	Priority
Maintain long-term water quality	18	1
Maintain aesthetic character	12	2
Control weeds and provide long-term aquatic plant protection	10	3
Eradicate weeds	9	4
Sustain Wildlife	5	5
Good fishing	3	6
Provide water supply	2	7
Recreation	1	8

LIMNOLOGICAL SUMMARY OF LAKE TWELVE

The following is a summary of a limnological study of Lake Twelve completed by the University of Washington (Welch et al., 1992). These study results along with lake management goals selected by residents, were used to develop the restoration recommendations described in Chapters 3 and 4.

PHYSICAL AND CHEMICAL CHARACTERISTICS

Temperature and Oxygen

Water temperature is an important measurement in lakes. Temperature is used to determine whether a lake "thermally stratifies". Thermal stratification occurs when near surface waters are warmed by the sun while deeper water remains cold. If this difference is great enough and lasts long enough, three distinct layers will form in a lake. These are; the "epilimnion" which is the warm surface water, the "metalimnion" which is the transition zone between layers, and the "hypolimnion" the deep, cold waters. Once formed, these layers can be quite stable with little mixing between them. And as a consequence, they can develop different physical, chemical and biological characteristics.

Thermal stratification did develop in Lake Twelve during the study period; the lake was stratified from the middle of April through the end of September. As is common in thermally stratified lakes, dissolved oxygen (DO) levels in the hypolimnion were very low during this period. Hypolimnetic DO concentrations were below 2 mg/L from the middle of July until the beginning of October. This compares to DO concentrations of 6.3 to 9.2 in the near surface water during this same period. There were also times when no oxygen was present in the bottom waters; that is, anoxic or anaerobic conditions existed. These anoxic conditions did not persist for more than a month indicating that stratification was not very stable and there was some mixing between layers. This is not uncommon in shallow lakes such as Lake Twelve in which the bottom waters may be more easily influenced by wind causing mixing to occur.

In addition to being important to aquatic life, the presence of oxygen affects other physical and chemical measurements. Possibly one of the most important effects is that during anoxic conditions, phosphorus can be released from the sediments. Then, when the lake destratifies, there is a ready supply of phosphorus that mixes into the upper, more productive surface waters and causes increases in algae growth.

Nutrients

Nutrients are important because they are the building block upon which the food web is formed. Phytoplankton, or algae, assimilate nutrients directly from the water and need a continued supply to grow and reproduce. Algae are the food source for zooplankton (small, floating organisms), which are in turn the food source for fish. The primary nutrients of interest in a lake ecosystem are phosphorus and nitrogen.

Lake nutrient concentrations are used to answer three key questions about a lake's ecology. The first is; What nutrient limits growth or productivity? If we know what the limiting nutrient is, then by controlling this nutrient we can begin to control productivity. Phosphorus and nitrogen are the primary nutrients of interest in a lake ecosystem; it is almost always the concentration of phosphorus that limits growth. That is, the lack of a constant phosphorus supply causes a "bottleneck" in continued growth and reproduction. These processes are stalled until further phosphorus is supplied. The second question is; what is the trophic status of the lake? Trophic status refers to the relative age, or productivity level, of a lake. An oligotrophic lake is young, has low nutrient concentrations, and low productivity. An eutrophic lake has high nutrient concentrations and productivity, while a mesotrophic lake lies between these extremes.

Probably the most important question in terms of lake restoration measures is; Where are the nutrients coming from? There are two categories of sources; internal sources and external sources. Internal sources are generated from inside the lake. Important internal sources can include the lake sediments which can release phosphorus as described previously, and lake plants that are composed of phosphorus (and other nutrients) which is released when the plants die and decompose. External sources include inflowing streams, stormwater runoff, septic system discharges and others that originate outside of the lake itself. If a lake is to be restored or maintained, the major sources must be identified and controlled.

Seasonal variations in nutrient concentrations and variations between parts of the lake or between lake depths are also important to assessing how a lake functions. These same comparisons are made with other parameters measured, such as dissolved oxygen, temperature, and pH.

In Lake Twelve, phosphorus and nitrogen were both measured in at least two ways: the total amount of the nutrient present and the portion of the total amount that is believed to be useable or available to phytoplankton. These forms are termed Total Phosphorus (TP) or

Total Nitrogen (TN) and Soluble Reactive Phosphorus (SRP), Nitrate+Nitrite nitrogen and Ammonia nitrogen. The later two nitrogen forms are often summed to provide an estimate of the amount of inorganic nitrogen (IN) present.

TP concentrations were relatively low in the lake throughout the study period (Figure 2-1). Concentrations ranged from 4.9 to 12.3 ug/L with the highest values occurring during the winter months when stormwater runoff and other "external" sources were highest. These values are well below thresholds of 14 and 25 ug/L that have been used for determining mesotrophic and eutrophic conditions (Porcella et al., 1980). In lakes where internal loading of phosphorus is important and where productivity is high, phosphorus concentrations will be highest during summer months and the hypolimnion will have much greater concentrations than the epilimnion during the period. This was not entirely the case in Lake Twelve. Average TP concentrations were relatively constant throughout the year, and although TP concentrations in the hypolimnion were usually higher than in the epilimnion, it was not to the degree seen in lakes for which internal loading sources are determined to be important (Figure 2-2).

Figure 2-1 Whole-lake volume-weighted TP concentrations.

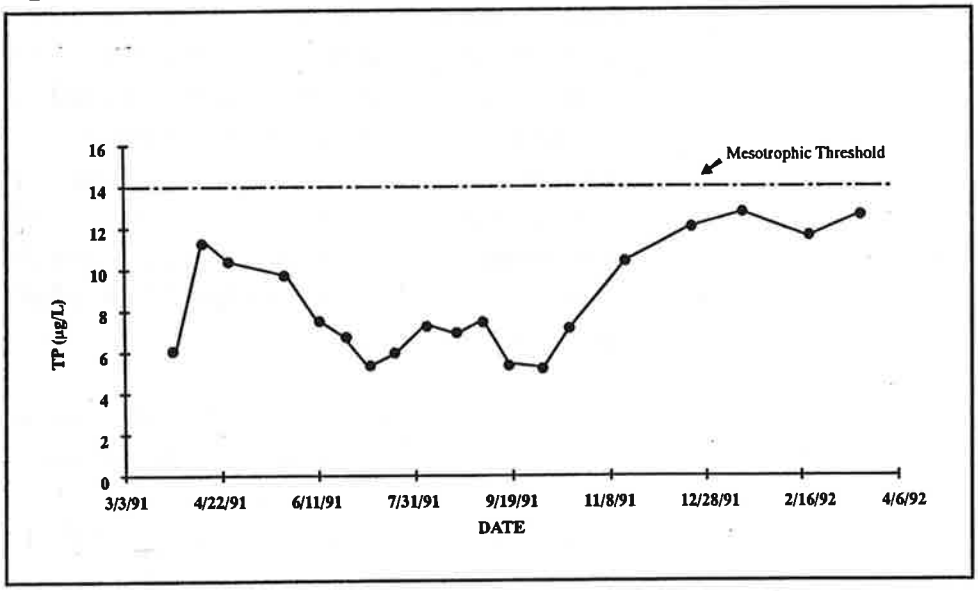
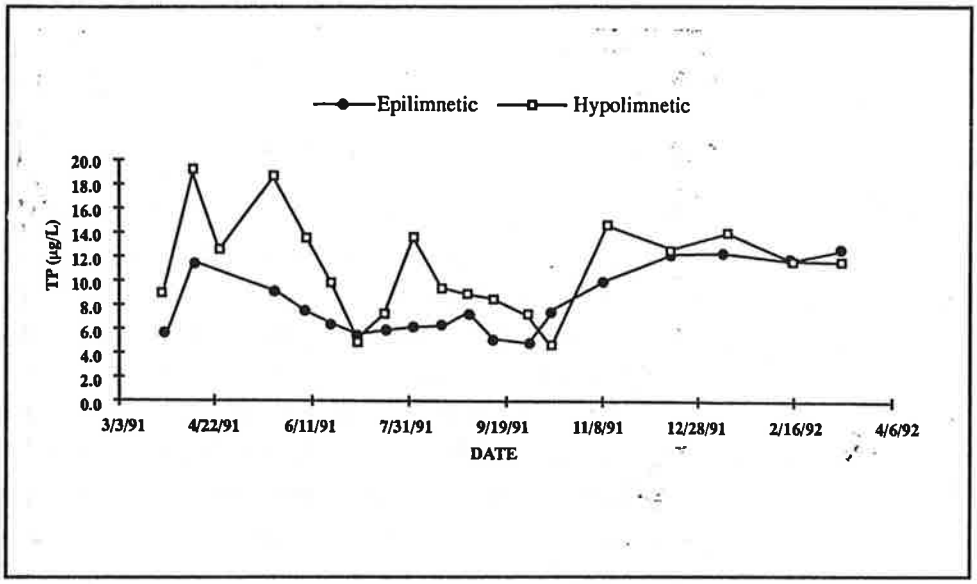


Figure 2-2 Epilimnetic and Hypolimnetic TP Concentrations.



SRP concentrations were also low. Mean whole-lake SRP concentrations ranged from approximately 2 to 4 ug/L. The hypolimnetic and epilimnetic concentrations were similar throughout the study. This suggests one of two things; there was no significant internal P loading from the lake sediments and/or there is enough light available in the hypolimnion to allow algal growth and therefore nutrient uptake. The latter is supported by comparison of the ratio of total P to available P (TP:SRP) between the epilimnion and hypolimnion. Typically, this ratio would be lower in the hypolimnion because there are fewer algae to utilize the SRP. In the case of Lake Twelve the opposite was true. The latter is also supported by chlorophyll a (chl a) results in which epilimnion and hypolimnion concentrations were basically equal throughout the year. (As will be described in more detail below, chlorophyll is used as an indicator of algal growth.)

TN concentrations during the study ranged from 306 - 1,185 ug/L. Similar to TP, the concentrations were higher during winter months when external loading sources were highest. These represent high TN values especially when compared to TP concentrations. Comparison of the ratio of TN to TP is used to determine which of the nutrients is limiting. Generally, if the ratio is below 10:1 a lake is thought to be nitrogen limited, above a ratio of 15:1 a lake is phosphorus limited. For Lake Twelve the ratio is about 60:1. Thus phosphorus appears to be the limiting nutrient in the lake, and the nutrient that will be emphasized in study results and restoration efforts.

Another way of assessing nutrient limitation is to examine the ratio of available forms of the nutrients; that is, the sum of the nitrate+nitrite and ammonia as compared to SRP. During summer months nitrate+nitrite concentrations decreased to very low levels, which is typical of lakes of low productivity. The low concentrations extended beyond the period of anoxia which reflects uptake by algae. These low concentrations of nitrate+nitrite coupled with low ammonia concentrations result in a low IN concentration and therefore low IN:SRP ratio. The mean summer IN:SRP ratio in Lake Twelve was 10:1, which indicates that in terms of available nutrients the lake is somewhat equally limited by both nutrients. Thus, if one nutrient were increased the other would quickly become the limiting factor and growth would continue to be nutrient limited. Nevertheless, due to the very large ratio of TN:TP described above, phosphorus is still considered the key nutrient for control in this lake.

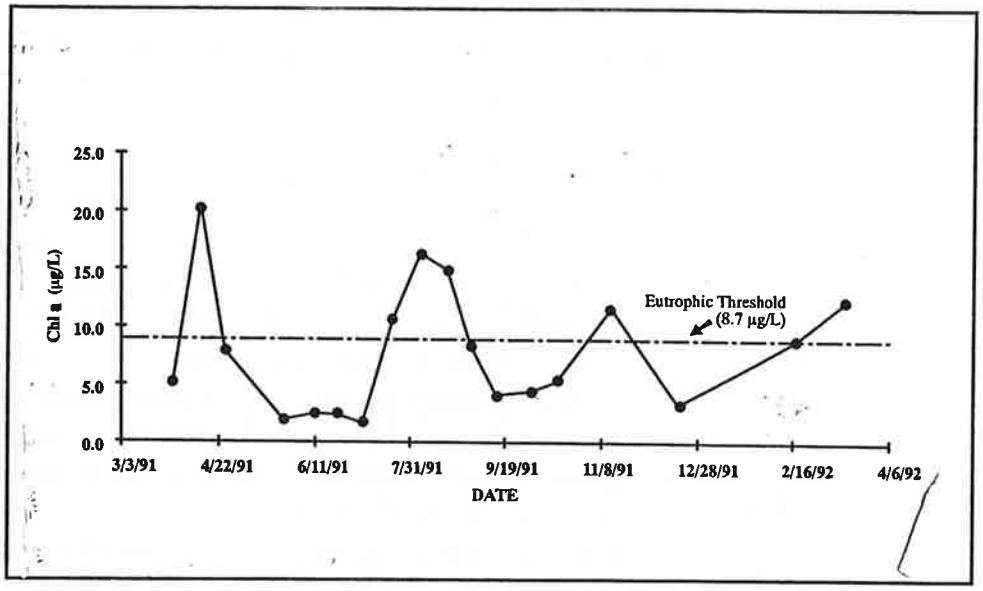
Water Clarity and Algae Growth

Secchi disk transparency is measured by slowly lowering a white and black disk into the water column and recording the depth at which the disk can no longer be seen. It is a measure of how clear a lake is. Secchi disk readings are used as an indirect measure of a lakes' productivity and trophic state. In lakes where algal productivity is high, the lake becomes "clouded" by organisms and secchi disk readings will be low. According to the trophic state index (TSI) developed by Carlson (1977) summertime secchi disk readings of greater than 4 meters indicate oligotrophic conditions, while readings of less than 2 meters indicate eutrophic conditions. Unfortunately, secchi disk transparency is also affected by lake color, which is not necessarily accounted for in the trophic state index. In Lake Twelve where the water is naturally a dark color due to influence from the adjacent wetland, secchi disk readings will be comparatively low given other measures of the lakes' productivity.

In Lake Twelve the secchi disk readings ranged from 1.4 meter to 6.0 meters, with a summertime average of 3.6 m. According to the trophic state index this would indicate the lake was borderline between oligotrophic and mesotrophic conditions.

Since chlorophyll is used by phytoplankton to convert light into biomass, the concentration of chlorophyll in a lake is a measure of algae growth. Chlorophyll a (chl a) is a measure of that portion of the chlorophyll that is still active. In Lake Twelve, whole-lake volume-weighted mean chl a ranged from 1.4 to 20.7 ug/L, with a summertime average of 7.3 ug/L (Figure 2-3). This summer average is slightly below the eutrophic threshold of 8.7 ug/L suggested by Chapra and Tarapchak (1976). Thus, according to this parameter, the

Figure 2-3 Whole-lake volume weighted chlorophyll a concentrations.



lake would be considered to be mesotrophic. Other than a small epilimnetic peak in concentrations that occurred in April and a larger hypolimnetic peak that occurred in August, there was little difference between hypolimnetic and epilimnetic concentrations of chl a in the lake.

BIOLOGICAL CHARACTERISTICS
Algae or Phytoplankton

In addition to being concerned with the overall concentration of algae in a lake, as measured by chlorophyll, it is also important to know the type of algae present. Different species are more or less likely to cause nuisance bloom conditions than others. The group of algae known as the "blue-greens" are the known problem causers.

Comparatively few blue-greens were found in Lake Twelve during the study year. Overall, the phytoplankton population was dominated by yellow-green and green algae, and desmids. These are indicative of relatively unproductive (oligotrophic) conditions. Although there were the typical spring, summer, and fall peaks in algal abundance, concentrations were not high enough to cause nuisance bloom conditions during the study period.

These low concentrations have not always been the case in Lake Twelve. During a 1987 study, chl a concentrations of over 100 ug/L were measured at a 6 to 7 meter depth in the lake and high concentrations persisted for a two month period (Smayda, T., 1988). The concentrations were caused by a dense bloom of a blue-green algae known as *Oscillatoria,* and a green flagellate, *Gonyostomum.*

Furthermore, residents have been concerned in the past about severe algae blooms. It is possible that past blooms were caused by the changed lake water quality conditions brought on by the failed noise berm and discharge of turbid waters to the lake. However, it is also possible that the 1991-1992 study year was atypical or that the lake is within a transition period of changing water quality.

Aquatic Plants

Aquatic plants are the main concern for Lake Twelve residents, who describe the plants as increasingly invading a greater portion of the lake and further impeding their already restricted use of the lake. A number of limited plant surveys have been done on the lake since 1976. These have indicated that milfoil, lilies, and pondweed are the primary species present and that plants inhabit the lake to depths of about five meters. Except for a few years when milfoil density was thought to have decreased, the studies do not note any significant changes in plant populations. However, no quantitative biomass estimates were made during these surveys. A large portion of Lake Twelve is shallow (average depth of 3 meters) and it has been estimated that light intensity will allow plants to thrive at depths of at least 4 meters in the lake. Consequently, at least 50% of the lake area is habitable by aquatic plants. Visual assessments (Plate 1) indicate that plants have already colonized most of this habitable area and confirm that plants have reached a density that would impede recreational use of the lake.

During this study it was confirmed that aquatic plants have colonized most of the lake where the depth is less than 4 meters (Plate 1). White water lily, (*Nymphaea odorata*), Eurasian water milfoil (*Myriophyllum spicatum*), and watershield (*Brasenia*) were the most common species collected. The highest biomass levels measured were 197, 73, and 148 g/m^2, respectively. The areal-weighted mean for all species was 63 g/m^2. Although this areal-weighted mean is low compared to some other lowland lakes (levels exceeding 200 g/m^2 are common in heavily infested lakes) it is high enough to constitute a problem for lakeside residents and other lake users. (The middle, deeper portion of the lake is almost inaccessible from some parts of the shoreline during the peak growing season.)

Milfoil is probably the greatest concern for the lake and its users. Although it is a recent invader it already is the largest contributor to lake biomass. And, experience on other lakes has shown that many aquatic plants, especially milfoil, will continue to form denser, more extensive beds as time progresses. This emphasizes the existing and future concerns for plant growth in the lake. The only limitation aid this growth will be water depth.

An additional study to assess the potential for plant growth in Lake Twelve sediments was performed by the University of Washington. The bioassay experiments in which milfoil growth in sediments from Lake Twelve, Green Lake, and Union Bay of Lake Washington were compared, indicated that the growth was similar between the sediments. Thus, concerns about increased density and surface coverage by the milfoil are justified.

Another concern associated with milfoil growth is the potential impact on internal loading of phosphorus. The plants obtain the phosphorus required for growth from the lake sediments. Then, when the plants die and decay, this phosphorus is released to the water column and can contribute to summertime algal blooms. Furthermore, this process may accelerate the invasion of milfoil. As plant production increases the rate of sediment accumulation increases, which in turn increases the area shallow enough for milfoil growth (Welch et al., 1992).

BUDGETS AND OTHER ESTIMATES

The Water Budget

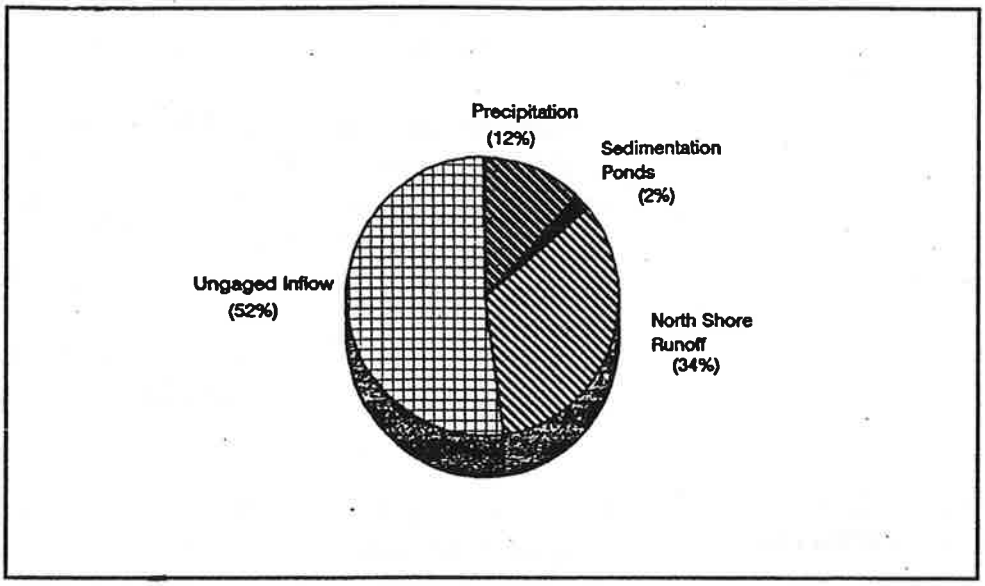
An important part of understanding how a specific lake functions is knowing how water enters and leaves the lake. Water budgets are constructed from surface flow, precipitation measurements, and estimates of evaporation and groundwater influence. Lake Twelve represented a particularly difficult case for constructing a water budget because the outflow is indistinct (outflow through the wetland can be through a small channel or as subsurface flow through the bog itself) and therefore difficult to measure. Even the surface water inflows are not ideal, since there are many small drainages rather than a few substantial inflows. Although all lake water budgets should be considered gross estimates, the hydrology of Lake Twelve has resulted in some increased uncertainty in the budget estimates.

Figure 2-4 depicts the water budget for Lake Twelve. Precipitation and discharge from the PCCC sedimentation ponds were measured on a daily basis, so these measurements are quite accurate. Precipitation was estimated to account for 12% of the inflow of water to the lake. The sedimentation ponds together contributed 2.1% of the incoming water volume. Drainages from along the north shore of the lake were estimated to account for 34% of the inflow, and groundwater was estimated (through well level measurements and slug tests) to account for only 0.2% of the inflowing water.

Estimates of loss of water from the lake indicated that the majority (85%) was lost as discharge through the wetland, 6.7% was lost as evaporation from the lake surface, and 0.4% change in lake storage.

When the monthly measurements or estimates for each of these inflow and outflow features were totaled there was always a "residual" volume of water that could not be accounted for.

Figure 2-4 Lake Twelve Water Budget.



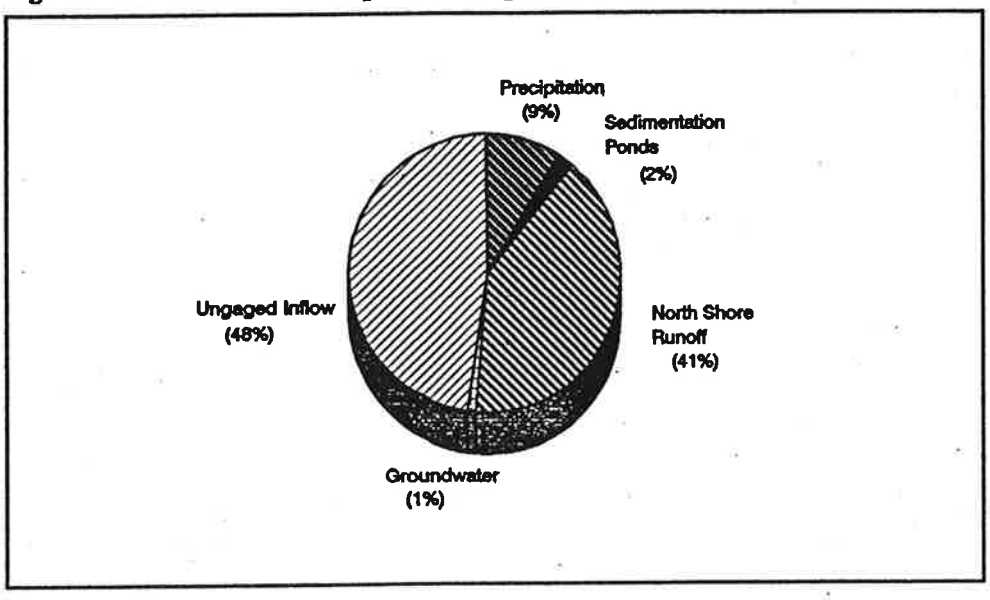
Most often this residual was in the form of inflowing water; this "ungaged inflow" represented an average of 52% of the water budget. The source of this water is likely from surface inflows along the southern shore and also may reflect some error in the groundwater inflow estimates. "Ungaged outflow" averaged 8.9% of the water budget. Since there were only three months when the residual was due to outflow waters and these months were fairly wet (April, October and November) the outflow probably occurred as either discharge to the wetland or groundwater recharge.

The largest concern in terms of confidence in the water budget is the 52% estimate of ungaged inflow. This represents the majority of the incoming water. It might be reasonable to assume that during the winter months when precipitation was heavy that most of this inflow was a result of surface water draining from the south shore. During the dry summer months its source is more likely to be recharge from groundwater or the wetland. As will be discussed in the following section, the exact source of the water is important because different sources have different nutrient concentrations and therefore their contribution may be more or less important.

The Phosphorus Budget

Using the water budget information and results from measurements of phosphorus concentrations in the different sources, a phosphorus budget was developed. According to these budget results, precipitation accounted for 8.8 % of the incoming phosphorus, the PCCC sedimentation ponds contributed 2.1%, north shore runoff 41%, groundwater 0.5% and ungaged inflow 48% (Figure 2-5).

Figure 2-5 Lake Twelve Phosphorus Budget.



Phosphorus loss from the lake was estimated to be 64% through discharge to the wetland, 0.1% from change in lake storage, and 34% from ungaged outflows. Using mass balance estimates, this still resulted in a residual phosphorus loss of 8%. The residual, in this case, represents the phosphorus lost through settling into the lake sediments.

These results signify two important facts; 1) the largest source of phosphorus appears to be from surface water inflows or runoff water and, 2) there is no evidence of net internal loading of phosphorus (from the sediments) at this time.

ANALYSIS OF RESTORATION ALTERNATIVES

CRITICAL ISSUES FOR LAKE TWELVE

An analysis of the restoration alternatives for Lake Twelve requires a critical consideration of lake characteristics, nutrient sources, and trophic interactions that determine productivity of the system. As described in Chapter Two, water quality during the April 1991 to March 1992 period of study was relatively good. It is not clear whether the results reported were anomalous, (i.e., the result of an unusually windy summer that destabilized thermal stratification and prevented significant phosphorus release from the sediments); represented permanent changes in the watershed that have reduced external loading, (i.e., establishment of vegetation on the noise berm); or are a valid representation of the normal, long-term productivity of the Lake Twelve ecosystem.

There was no evidence that internal loading of phosphorus was a significant element in the phosphorus budget of Lake Twelve during the study period. Similarly, nutrient enrichment of groundwater by septic systems did not contribute substantially to phosphorus loading. Sedimentation ponds A and A^1 were minor sources of phosphorus. In contrast, nonpoint sources in the watershed contributed about 89 percent of the total phosphorus loading to the lake. Most of the external phosphorus loading originated from the north shore portion of the watershed (40.5 percent of total loading) and from storm-generated overland flow in the forested portion of the watershed, which was reported as ungaged flow (48.1 percent of total loading).

Aquatic macrophyte densities were relatively low when compared to other Puget Sound lowland lakes, though apparently high enough to affect recreational use of the lake. The nuisance character of aquatic macrophytes is primarily a function of biomass allocation patterns, not standing crop biomass or productivity. For example, plants that form a mat at the surface of a lake are a greater nuisance than those that remain close to the sediment surface. Because of their role in productivity of Lake Twelve and their nuisance character, aquatic macrophyte management is the key component of the Lake Twelve management plan.

Competitive interactions between macrophytes and phytoplankton adds an element of uncertainty to macrophyte control options. Reduction in macrophyte biomass may lead to a loss of existing competitive control over phytoplankton by macrophytes, and result in increased growth of phytoplankton. Consequently, additional steps, such as reducing

phosphorus loads, must be taken to simultaneously control the phytoplankton and phosphorus reduction efforts must be included in the management plan. Since the majority of the phosphorus load to Lake Twelve is from nonpoint sources, control of these sources is also a component of the restoration plan.

Restoration measures that reduce phosphorus loading to the lake and/or address nuisance macrophyte growth can be grouped into two categories. *In-lake* techniques address internal sources of phosphorus and control of macrophytic vegetation within the lake. *Watershed management* measures reduce the quantity of pollutants (primarily phosphorus) entering the lake from point and nonpoint sources in the watershed. In this chapter, both categories of restoration alternatives are discussed and evaluated. A summary of the advantages, disadvantages, and estimated costs of various restoration alternatives is presented in Table 3-1. The estimated costs are based upon the cost of each specific activity and, unless otherwise specified, do not include associated costs, such as taxes, engineering, administration, permitting, SEPA review, environmental monitoring, or construction management. In the following sections, the in-lake and watershed management options are evaluated in detail.

IN-LAKE RESTORATION MEASURES

Dredging

The purposes of dredging are to deepen shallow lakes, remove nutrient rich or toxic sediments, and reduce the area colonizable by macrophytic vegetation. Since there was no evidence of toxicity or nutrient release from sediments, the primary benefit of dredging in Lake Twelve would be a reduction in area impacted by macrophyte growth. An ancillary benefit would be an increase in lake volume and mean depth, which would enhance water quality by increasing water residence time and lessening entrainment of sediment-released phosphate and particulate matter. Furthermore, since the aging process in lakes is a simple matter of slowly filling in over time, dredging essentially increases the life span of a lake. In Lake Twelve, using the estimated sedimentation rate of 1.83 cm/yr (UW,1992), in about 55 years the lake will have gained another meter of sediments and become that much shallower allowing plants to colonize an even greater portion of the lake. Conversely, if one meter of sediments was removed, the lifespan of the lake would increase by approximately 55 years, and the portion of the lake colonizable by plants would be reduced accordingly.

Lake dredging is a long-term water quality and macrophyte control solution. The initial cost of dredging, however, is high. Dredging costs could be reduced and benefit maximized by focusing dredging

Table 3-1 Summary of Lake Restoration and Watershed Management Alternatives.

IN-LAKE MEASURES

	Advantages	Disadvantages	Estimated Costs
Dredging	■ Controls aquatic vegetation, deepens lake, increases lake volume ■ Improves water quality	■ Temporary resuspension of sediments ■ Temporary destruction of habitat ■ Disposal concerns ■ High cost	$345,000 to 1,100,000 Based on removal of an average of 2 m of sediment from 25% of lake area at $3 to $10/m^3 $17,250 to $57,500/yr. (20 yr. amort.)
Aluminum Sulfate Treatment	■ Lowers lake phosphorus content ■ Inhibits release of phosphorus from sediment ■ Increases water column transparency	■ Temporary measure ■ Potential toxic impacts ■ Increased macrophyte growth	Not assessed (internal loading was not a major contributor to phosphorus loading)
Hypolimnetic Aeration	■ Maintains oxygen in hypolimnion ■ Limits release of phosphorus from sediments ■ Increases habitat and food supply	■ Difficult to supply adequate oxygen ■ Potential for destratification and subsequent algal blooms ■ No effect on macrophytes	Not assessed (internal loading was not a major contributor to phosphorus loading)
Artificial Circulation	■ Disrupts or prevents stratification ■ Provides aeration and oxygenation ■ Increases aerobic habitat	■ Does not decrease algal biomass ■ May decrease water clarity ■ Adverse impact on cold-water fish ■ No effect on macrophytes	Not assessed (Lake 12 is too shallow)
Riplox	■ Oxidizes sediments, inhibits phosphorus release	■ High cost ■ Low confidence in effectiveness (too few reported case studies)	Not assessed (internal loading was not a major contributor to phosphorus loading)
Sediment Covers	■ Inhibits or prevents macrophyte growth ■ Nontoxic ■ Low environmental impact in small applications ■ Unobtrusive nature ■ Ability to target problem areas ■ Can be installed in areas that are inaccessible to harvesters	■ High capital cost ■ Prone to damage, displacement, and plant regrowth	$0.34 to $8.60/m^2 (Depends on material)

Table 3-1 Continued

IN-LAKE MEASURES			
	Advantages	**Disadvantages**	**Estimated Costs**
Harvesting of Macrophyte Biomass	■ Removes plant biomass and nutrients ■ Requires no toxic substances ■ Vegetation may be composted	■ Labor intensive, seasonally dependent ■ Access constraints ■ May facilitate colonization of new areas due to fragmentation ■ High capital and O&M costs ■ Removes fish ■ Ongoing effort ■ Depth restriction (<1.5 m, 5 ft.)	$15,000 to $103,000/year (Depending on cutting intensity and contractor or County operation)
Sterile Grass Carp	■ Controls aquatic vegetation ■ Requires no toxic substances	■ Potential impacts on other organisms ■ May increase nutrient cycling and stimulate algal blooms due to grazing and digestive activities ■ Possible escape and infestation of nontarget areas ■ Introduction of parasites	$250,000 + annual restocking ($300 to $500)
Herbicides	■ Inexpensive ■ Easy to apply ■ Controls macrophyte and phytoplankton growth	■ Potential toxic effects ■ Decomposing plant material releases nutrients to water column ■ Short-term benefit ■ Requires temporary restriction on recreational activities ■ Dissolved oxygen depletion due to decomposing plants ■ Repeat applications needed	$13000/treatment ($300/acre x 43 acres)
Water Level Drawdown	■ Controls macrophytes ■ Consolidates sediments ■ Facilitates dredging or excavation	■ Poor effectiveness in mild, wet climates ■ Short-term benefit ■ Intensifies algal blooms ■ Temporary adverse impacts on fish and invertebrates	Not assessed

Table 3-1 Continued

WATERSHED MEASURES			
	Advantages	**Disadvantages**	**Estimated Costs**
Improved On-Site Septic Systems	■ Reduced nutrient loading	Requires inspection and regulatory personnel	$5,000 per year
Pond Effluent Polishing	■ Reduced nutrient loading	Potential toxic effects	Not assessed (Pond effluent was a minor contributor to phosphorus loading
Improved Roadside Ditch Maintenance	■ Reduced sediment transport to lake ■ Provides biofiltration (nutrient removal) ■ Removes some toxins	■ Requires annual mowing and vegetation removal ■ May reduce ditch flow capacity	$2600 per mile (Does not include removal of clippings.)
Stream and Wetland Buffer Zones	■ Reduces streambank erosion and downstream sedimentation ■ Provides shade/lowers stream temperature ■ Improves fish and wildlife habitat ■ Vegetation sequesters nutrients	■ May require land conversion ■ May require fencing ■ May require seeding or plant stock	Capital: ($0 to $1000) per acre O&M: Minimal
Improved Forestry and Development Practices	■ Reduces quantity and velocity of surface runoff ■ Reduces erosion and sedimentation in receiving waters ■ Reduces nutrient and organic matter loading	■ Requires regulatory and inspection personnel	Borne by industry and developers
Alternative Landscaping Methods	■ Reduces nutrient loading ■ Reduces erosion and sedimentation in receiving waters ■ Provides wildlife habitat ■ Reduces amount of toxins entering the lake ■ Reduces amount and velocity of runoff	■ Requires resident participation, substitution of products, and acceptance of aesthetics	Minimal, may provide long-term savings
Alternative Household Practices	■ Reduces nutrient loading ■ Reduces toxics loading ■ Reduces runoff volume	■ Requires resident participation, substitution of products, and acceptance	Minimal, may provide long-term savings
Roof Drain Modifications	■ Reduces nutrient loading ■ Reduces toxics loading ■ Reduces runoff volume	■ Requires conversion of existing roof drain systems	Varies
Public Awareness Program Implementation	■ Provides education and increased watershed awareness	■ Requires committed organization	$5,000 per year

operations on areas where the nuisance character of macrophyte vegetation in Lake Twelve is manifested, e.g., near-shore areas in the western end of the lake where recreational activities are concentrated. Cooke et al. (1986) reported that dredging costs ranged from $0.24 to $14.00 /$m^3$ in 64 lake dredging projects. Transport of spoils is a major cost factor, and identification of an appropriate disposal site that has the capacity to handle the large volume of nutrient-rich water associated with dredged sediments is often a large obstacle in dredging projects. If the adjacent PCCC mine property could be utilized for dredge disposal and dewatering, and to reduce spoil transport costs, many of the problems associated with dredging would be eliminated. If the mine could be used, dredging costs could be as low as $3/$m^3$. Deepening near-shore areas of the lake to four meters by removing an average of two meters of sediment over 25 percent of the lake area would require removal and disposal of 87,500 m^3 (115,000 yd^3) of sediment. At estimated costs of $2.28 to $7.60/$m^3$ ($3 to $10/$yd^3$), total dredging costs would be $345,000 to $1.1 million dollars. Amortized over an effective lifespan of 20 years, annual costs of dredging would be $17,250 to $57,500.

Environmental concerns associated with dredging include:

- Resuspension of sediments accompanied by liberation of nutrients or toxic substances during dredging (can be mitigated with alum)
- Temporary destruction of benthic invertebrate communities and habitat
- Disposal of dredged material.

Many of the above problems are short-lived and can be minimized with proper planning. For example, benthic invertebrates quickly recolonize dredged areas, and sediment assays can be used to determine whether toxic contaminants are a concern.

As noted above, the primary purpose of dredging Lake Twelve would be to reduce macrophyte growth, however, benefits are difficult to quantify. Water depth, through its effect on light and disturbance regimes, is an important determinant of aquatic macrophyte community structure and zonation. Milfoil life history (*phenology*) and physiology allows it to exploit disturbed environments, such as the environment produced by dredging. These biological traits are common to most "weedy" species. Lilies are adapted to more stable environments, free of disturbance. Dredging near-shore areas would likely reduce coverage of water lilies, but it may expand the zone colonizable by Eurasian watermilfoil. Furthermore, if increased mean depth and

water residence time resulted in increased water clarity, the maximum depth colonizable by submersed macrophytes would increase.

Uncertainty in the importance of hypolimnetic sediments as a source of phosphorus necessitates caution in the application of dredging in Lake Twelve. Given the uncertainty over the importance of internal loading of phosphorus to Lake Twelve it may not be prudent to embark on an expensive dredging program at this time. A dredging program that includes hypolimnetic as well as near-shore sediments should be considered if, in the future, internal loading proves to be a major contributor of phosphorus to Lake Twelve and a primary cause of water quality degradation.

Macrophyte Harvesting

The purpose of macrophyte harvesting in Lake Twelve would be to reduce the nuisance character of near-shore vegetation to enhance beneficial uses of the lake. Removal of macrophyte tissues from the lake by harvesting would also reduce internal nutrient loading to the lake by preventing release of tissue nutrients to the water column during plant senescence. Since rooted macrophytes obtain most of their nutrients from the sediment, continued, long-term harvesting of macrophytes may result in decreased sediment nutrient availability and reduced macrophyte growth.

There is evidence that multiple harvests within a growing season can have carry-over affects in the following season. Perkins and Sytsma (1981) reported that three harvests of Eurasian watermilfoil in Union Bay of Lake Washington resulted in increased species diversity (more desirable species in harvested plots) and decreased milfoil density, at least temporarily, the following spring. Relative susceptibility of aquatic macrophyte species to harvesting has not been studied in detail. Generally, milfoil has been found to be resilient and regrows rapidly after harvest, while water lilies are relatively susceptible to harvesting.

The advantages of harvesting aquatic macrophytes relative to other macrophyte control techniques include:

- Plant biomass and incorporated nutrients are removed immediately preventing subsequent oxygen depletion and nutrient release
- Open areas in the macrophyte bed can be created immediately
- Habitat (i.e., the lower parts of the plant) remains for fish, wildlife, and other aquatic organisms
- Toxic substances are not added to the aquatic system

- Specific locations can be targeted while preserving designated conservancy areas
- Recreational uses may continue during harvesting with little interference
- Harvested vegetation may be used as composting material.

Harvesting can be accomplished through mechanical (mowers, tillers) or manual (hand-pulling, rakes) methods. Harvesting can be part of an integrated management strategy for plant control when used in conjunction with other methods, e.g., herbicides, biological control, drawdown, and bottom screens.

Mechanical harvesting can be a slow, labor-intensive process because of seasonal factors and physical constraints. In temperate areas, harvesting is restricted to periods of favorable weather conditions and peak plant biomass. Access to sites may be limited by obstacles (e.g., docks, submersed stumps and rocks) or by water depth. Shallow beach areas often cannot be harvested effectively by commercial equipment. Furthermore, only relatively small areas can be harvested by individual harvesters, which may cause disputes over prioritizing target areas. Harvesting may also facilitate colonization of new areas (by some species) through production of plant fragments. (This may be especially true for milfoil.)

Mechanical harvesting requires a large capital investment and has high operation and maintenance costs. Costs vary depending on area harvested, accessibility (i.e., proximity to boat ramps and off-loading areas) and location of and fees associated with disposal sites. Although costs as low as $300/acre have been reported by organizations that own their own equipment, harvesting by private contractors costs between $500 and $800/acre. Purchase costs of harvesters range from $11,000 to $160,000. Harvesting in Thurston County in recent years has cost $300 to $350/acre.

Mechanical harvesting of the entire lake three times per growing season would cost between $45,000 and $103,000/year (Table 3-1), depending on the transport and disposal cost assumptions and whether the County or a contractor performed the operation. Although costs of a less intensive harvesting schedule would be lower($15,000 for a single cut of the whole lake by a contractor at $350/acre), multiple cuts are required to obtain a reduction in the nuisance level of biomass. Assuming a cutting rate of 0.5 ha/day, the entire lake could be cut in one month; three cuts could be accomplished by one machine during a growing season. Focusing cutting operations on areas that receive the

most recreational use would maximize the impact of harvesting on areas in which macrophytes create the greatest nuisance. More intensive cutting (more cuttings per year) would also be more likely to produce a long-term impact on Eurasian watermilfoil growth. Total area harvested could be adjusted to funding levels. Lake users would have to prioritize cutting areas and reach a consensus on the cutting rotation to prevent disputes.

Manual harvesting methods can be used to clear plants from shorelines and are often employed by homeowners to remove plants from around docks and swimming areas. Manual harvest methods have the additional advantage of being inexpensive and easily applied by homeowners. It is the only harvesting method effective for controlling plants around docks and in nearshore areas, and it can have long lasting impacts on plants such as water lilies if the entire root mass is removed. However, manual methods are labor-intensive and can disturb benthic invertebrate populations.

Costs of manual methods depend on whether commercial products and services are used. For example, hand-pulling costs a homeowner nothing more than time; the use of a paid "puller" can cost up to $130 for an average waterfront lot (Ecology 1990). A homemade asphalt rake costs about $85, while a commercial weed cutter costs approximately $250 (with accessories).

Sediment Covers

Numerous attempts have been made to control aquatic plant growth through the use of bottom screening materials. The screens when placed properly on the lake sediments provide a barrier that plant shoots can not penetrate. The screens are expensive and difficult to apply over large areas. In some cases, screens have failed to control macrophyte growth because they became displaced, degraded by sunlight, or covered with silt.

A number of materials may be used for bottom screening, ranging from burlap to silica-coated screens. The new silica-coated screen is not subject to plant regrowth, is easy to maintain, and does not become displaced; however, the capital-cost of the material is high ($13.89/$m^2$ or $1.25/$ft^2$ installed). Bottom screening for aquatic macrophyte control is not cost-effective on a large scale; private application of sediment covers on swimming areas, around boat docks, and in areas inaccessible to harvesters should be considered by lake-shore residents. It should be recognized that sediment covers must be cleaned and maintained annually. With proper installation and maintenance, sediment covers can be very effective in controlling macrophyte growth with few negative environmental impacts.

Sterile Grass Carp

Grass carp (*Ctenopharyngodon idella* Val.), are used to control aquatic plants because they have a broad vegetarian diet and can consume large quantities of plant biomass. Their high consumption capacity combined with a high growth rate can result in very efficient plant biomass removal. At warmer temperatures, Grass carp can consume 50-60% of their body weight; at an average weight of around 10 Kg (22 lb) each fish may be consuming 5 Kg (11 lb) of plant material each day. Production of triploid fish, which are sterile, has alleviated much of the concern about uncontrolled reproduction of these fish and infestation of nontarget waterbodies. Grass carp have been introduced into many lakes in Europe and the United States to control aquatic macrophytes. At low stocking densities, grass carp selectively graze on preferred plant species (e.g., elodea and pondweeds) and can allow less preferred species (e.g., Eurasian watermilfoil) to proliferate.

Species preferences and impacts associated with the introduction of grass carp are not well defined. Although fish condition factor (weight/length ratio) and growth rates were low when fed a milfoil diet in laboratory feeding studies (Anderson et al. 1992); they appear to prefer milfoil over Brazilian pondweed and grow quite well in Devil's Lake, Oregon (Wagner 1992). A recent, detailed study of the limnological impact of grass carp introduction into a lake in Texas found that water quality declined after introduction (Maceina et al. 1992). The decline in water quality was attributed to changes in fish populations that had a cascading effect on lower trophic levels. An increase in zooplanktivorous fish populations led to a decline in phytoplankton grazing pressure, an increase in phytoplankton abundance, and decreased water quality.

The initial cost of introducing grass carp to Lake Twelve is estimated at about $250,000. Annual restocking costs are relatively low ($300 to $500/yr.). Concern over emigration of grass carp to nontarget waterbodies requires construction of effective containment structures in lake inlets and outlets. Due to the broad wetland outlet for Lake Twelve, any containment structure would need to be located downstream at the culvert crossing for 290th Ave. This would leave the immediate wetland vulnerable to disruption by the carp. Concerns about affect to the adjacent wetland, loss of fish and wildlife habitat, and the potential impact to phytoplankton populations, would need to be addressed before recommending Grass carp as a restoration alternative.

Herbicides

A wide variety of herbicides have been used to control nuisance aquatic plants. Herbicides are easy to apply relative to other plant control techniques, e.g., harvesting and dredging. The cost to apply herbicides for control of aquatic plant growth is approximately $300 to $1,200 per acre. Some selective removal of milfoil can be accomplished with careful application of the correct chemical compounds, and herbicide use as a short-term control strategy is becoming a more accepted practice. The herbicide Sonar (fluridone) was recently applied to Long Lake in Thurston County, preliminary results indicate it was effective at removing milfoil and appeared to cause only minor damage to non-target plants. Use of herbicides, however, leaves the macrophyte community open to reinvasion by nuisance macrophyte species and poses special environmental problems including:

- Potential toxicity to nontarget organisms (plants and animals)
- Release of nutrients from decomposing plant material
- Short-term control of nuisance biomass
- Temporary restriction of recreational activities within treated areas.

Of particular concern in Lake Twelve is the potential impact of herbicide application on the high quality wetlands at the outlet of the lake. Another concern is that lake water is piped directly into many lakeside homes. Although it is primarily used for non-consumptive purposes, it has the potential to be used as drinking water, especially as no other potable water source is available to lake residents (other than bottled water). Obtaining permits for herbicide application is always difficult; the presence of the wetland and water supply issues would exacerbate the difficulties. These issues that are specific to Lake Twelve, as well as those that apply to any lake herbicide treatment must be considered and weighed against other control measures for the lake.

Integrated Aquatic Plant Management Plan

This alternative is described last amongst the macrophyte control alternatives because it may be a combination of any number of the previously described methods. This is a relatively new concept that when implemented may involve a number of different aquatic macrophyte control methods. It is based on the premise that different lake activities or beneficial uses require differing types of control. For example, boat lanes only need to be clear of plants in the upper few feet of water and may be best managed through a harvesting program. Conversely, areas near swimming beaches should be relatively free of aquatic macrophytes and bottom screening may be the selected method for control.

To develop an integrated plan, first a lakes beneficial uses must be agreed upon, then a map of activity zones developed, and then decisions on control techniques can be made. The plans rely on the development of an informed citizenry who can weigh the benefits and weaknesses of each approach to reach consensus on the optimum short- and long term strategy for control. Since the planning is essentially done at the community level, these plans should have the advantage of public participation and understanding, and therefore the support of the community.

Other advantages and disadvantages associated with an integrated plan would be dependent upon which control methods were finally selected. This method would not be expected to cause any significant change to the water quality of Lake Twelve; although the reductions in aquatic plant biomass should result in decreased loading of phosphorus to the lake and possibly a decrease in lake sedimentation rates if a major portion of the biomass is removed.

OTHER IN-LAKE TECHNIQUES ASSESSED

A preliminary assessment of the following techniques was also performed. Since these techniques focus on controlling internal loading and in many cases can be expected to cause an increase in aquatic plant populations, they were not analyzed in detail.

Aluminum Sulfate Treatment

The purpose of aluminum sulfate (alum) addition is to lower water column phosphorus content and retard sediment phosphorus release. Alum increases water clarity, which may increase productivity and the area colonizable by aquatic macrophytes. Alum addition to the water column results in the formation of a polymer that binds phosphorus and organic matter. This aluminum-phosphate-hydroxide compound (commonly called alum floc) is insoluble and settles to the bottom. Once on the sediment surface, alum floc retards phosphorus diffusion from the sediment to the water. Alum has been used extensively in the United States and has generally been successful in controlling phosphorus release from lake sediments (Cooke et al. 1986). Given the uncertainty of the importance of sediment phosphorus release in Lake Twelve, and the potential for increases in aquatic macrophyte populations, alum application should not be considered at this time.

Hypolimnetic Aeration

Hypolimnetic aeration uses an air-lift device to bring cold, hypolimnetic water to the surface of lakes where it is aerated and then returned to the hypolimnion. Dissolved oxygen concentrations in the hypolimnion are maintained at levels that prevent dissolution of ferric-hydroxides that bind phosphorus in the sediments, preventing sediment release of phosphorus to the hypolimnion. This results in a decrease

in lake phosphorus loading and concentrations which causes direct decreases in phytoplankton productivity. Further control of phytoplankton can be gained through the impacts on zooplankton populations. The darker, oxygenated hypolimnetic waters can provide zooplankton a refuge from predators that depend on vision to locate their prey. This allows zooplankton populations to increase and further reduce phytoplankton populations through higher grazing pressure. For these same reasons hypolimnetic aeration can have a positive influence on macrophyte growth; decreased phytoplankton populations equate to increased light levels and better growing conditions for macrophytes.

Control of internal phosphorus loading is the primary purpose of hypolimnetic aeration. Since internal loading is not considered to be a problem in Lake Twelve at this time, and since this method would not exert any control over aquatic macrophytes, and has the potential to cause an increase in the macrophytes, hypolimnetic aeration is not recommended.

Artificial Circulation

The objective of artificial circulation is to completely mix the lake using pumps, jets, or bubbled air to prevent or disrupt stratification. An increase in the mixing depth limits phytoplankton production by transporting phytoplankton deep in the water column, where low light levels limit productivity. The primary improvements in water quality with artificial circulation are aeration and chemical oxidation of substances in the water column, an increase in habitat for aerobic animals, and reduced phytoplankton productivity. The depth of Lake Twelve is inadequate to provide the exposure to low light levels necessary for artificial circulation to be successful and the technique is not applicable in Lake Twelve.

Riplox

The Riplox technique is used to oxidize surface sediments to prevent release of nutrients to the water column and reduce internal nutrient loading. A solution of calcium nitrate is injected into the sediment, which stimulates denitrification and oxidizes sediment organic matter. The technique is cost effective when compared to alum applications, however, there are few case studies reported in the literature. As with the previous methods described, since there is no evidence that internal loading of phosphorus is a problem in Lake Twelve the Riplox technique is not recommended.

Water-Level Drawdown

Water-level drawdown has been used to control nuisance aquatic plants through freezing or desiccation. Drawdown has also been used to consolidate sediments and to facilitate dredging and excavation to deepen lakes. Drawdown to control macrophyte growth is most

effective in areas with cold winters (Cooke et al. 1986, Olem and Flock 1990). Effectiveness of this technique can be short-term. Aquatic plants returned to pre-drawdown densities one year after drawdown in a western Washington lake (Jacoby et al. 1983). In addition, a lake drawdown may cause; algae blooms after the lake is refilled, dissolved oxygen depletion leading to fish kills, temporary loss of invertebrates, and loss of the use of the lake during the drawdown period. Drawdown is not recommended for Lake Twelve because of the negative impacts listed and ineffectiveness in moist, mild climates.

WATERSHED CONTROL TECHNIQUES

Lake restoration traditionally has focused on in-lake methods for reducing or eliminating an existing problem such as internal loading of phosphorus or nuisance plant growth. The fact is, unless measures are in place to protect a lake from pollutant generating watershed activities, improvements caused by lake restoration efforts may be short-lived.

In most cases, control of watershed pollutants seems an insurmountable task. The amount of land involved can be large, land use activities are numerous and varied, and many people are involved. In urban area lakes, the situation is even more difficult; in developed areas much of the damage that might have been prevented, such as limiting the amount of impervious surface, has already occurred. Lake Twelve is rather unique in this respect. The watershed is small, has few land use activities, and is located in a relatively rural area. These characteristics equate to a greater potential for successful long term protection of the lake if protective plans and enforceable regulations are put in place before the inevitable land-use changes. Unfortunately, the lack of existing problems can make it more difficult to generate interest in lake protection.

Control of nutrient and sediment loading to Lake Twelve is critical for maintenance and improvement of lake water quality, especially if macrophyte control results in increased phytoplankton productivity. Human activity and geophysical conditions in the Lake Twelve watershed are fundamental determinants of nutrient and sediment loading rates. Application, monitoring, and maintenance of Best Management Practices (BMPs) for preventing or reducing the amount of pollution generated by nonpoint and point sources in the watershed is essential. BMP's are defined as a practice or combination of practices that is determined to be the most effective, practicable means of preventing or reducing the amount of pollution generated by nonpoint sources to a level compatible with water quality goals (Novotny and Chesters, 1981).

The major existing concerns for Lake Twelve are related to existing watershed activities. These are controlling impacts from; residential, surface mining, and forestry activities. Long term concerns are related to conversion of forest land and natural areas to residential land. The following watershed management measures describe recommended practices for reducing or controlling pollutants originating from the watershed. The measures are divided into two categories; basin-wide controls and developed area controls.

BASIN-WIDE CONTROLS

Forest Management Practices

Approximately 86% of the Lake Twelve watershed is comprised of forest land that is primarily used for timber production. Some forestry management activities can cause negative impacts to area surface waters, these include; spraying with herbicides or fertilizers, creation and maintenance of logging roads which can cause increases in erosion and sedimentation, and logging activities themselves which disrupt the soil surface, remove protective vegetation and in other ways promote increases in erosion and sedimentation. Any measure that reduces the volume, sediment, and nutrient load of runoff will slow eutrophication and further degradation of lake water quality.

Existing State regulations and the Timber/Fish/Wildlife (TFW) Agreement provide the regulations and recommendations for controlling forestry impacts to area surface waters (and other natural resources). These impacts are controlled through a "forest management plan" created for each harvest area. Since these plans are written previous to planned harvest there are no existing plans on which to comment that directly affect the Lake Twelve watershed. The plans are developed after a site visit by a TFW team that is comprised of people from resource agencies as well as forest managers. The plans describe where roads will be placed, where streams are located and the width of vegetated buffer strips that must be left to protect them, specific harvesting techniques used, and future plans for revegetation, spraying, and road abandonment.

Eroded sediments and other debris associated with logging activities can either enter a lake through overland runoff or through inflowing streams. Since there are no forested/harvestable parcels located directly adjacent to the lake, direct overland flow is not a great concern. Therefore any pollutant inputs associated with logging activities will likely be associated with the small, intermittent drainages that discharge to Lake Twelve. These drainages should be protected through the use of vegetated buffers and enforcement of other forestry BMP's. Thus, the recommendations as listed by the TFW agreement and Forest Practices Act defined by State law, if properly implemented

and enforced should be sufficient to protect the Lake Twelve watershed.

Recommended Action — BW-1 —

King County Surface Water Management (KCSWM) staff and Lake Twelve citizens should be kept informed about planned forestry activities in the watershed. A copy of the forest management plan for affected areas should be sent to KCSWM and the president of the Lake Twelve Association for review and comment. The reviewers should concentrate specifically on where road building and forestry activities occur near surface waters that discharge to Lake Twelve and be sure adequate (50 feet) buffer strips are planned. The forester in charge should be a member of the Lake Twelve Association, and in this capacity describe forest management plans as they relate to the Lake Twelve watershed.

All Forest Management Plans for parcels within the Lake Twelve watershed should meet laws promulgated by the State Forest Practices regulations and the TFW Agreement. The plans should include assessment of cumulative impacts within the watershed and evaluation techniques.

Members of the Lake Twelve association should be notified whenever applications are made to convert forest land within the watershed to some other land use designation. The Lake Twelve Association should actively review and provide input and comments during the permitting process.

Surface Mining Activities

Surface mining activities constitute less than 3% of the watershed, although the potential for impact to the lake (as demonstrated by the failure of a large berm in 1986 and discharge of highly turbid water to the lake) can be great. However, there are no longer any mining activities occurring in the portion of the mine that is within the Lake Twelve watershed, and no plans to return to the area; thus mining impacts are not expected to increase.

Mining impacts to the lake and other natural resources are regulated through the WSDOE and through the U.S. Department of the Interior under the Office of Surface Mining (OSM). Direct impacts to Lake Twelve from discharge of sedimentation pond waters is regulated by WSDOE through a National Pollutant Discharge Elimination System (NPDES) permit. The permit lists monitoring and water quality requirements for the discharge.

Effluent from the PCCC settling ponds was relatively low in phosphorus and contributed only about 2 percent of the total phosphorus loading to the lake during the study period. Although some reduction in phosphorus loading could be obtained by provision

of flow-dependent alum injection (adjusting alum dose according to the volume of flow), the reduction in loading obtained would not justify the ongoing expense and risk of aluminum toxicity at this time. Vegetation development on the noise berm has apparently reduced nutrient loading from historical levels, illustrating the effectiveness of biofiltration in reducing the pollutant loads to surface waters.

In addition to controlling impacts during mining activities, OSM also requires that mined land is "reclaimed" after the mine is closed. Reclaiming includes returning the land to its original contours, revegetating, and selecting or designating a future use for the land. In this case, full reclamation as required by OSM would involve removing the existing berm and sedimentation ponds. Disruption of the berms, and filling of the ponds could again cause impacts to Lake Twelve through increased erosion and sedimentation from the affected area. It is strongly recommended that the reclamation plan excludes removal of the existing berm and sedimentation ponds.

Since a major portion of the external phosphorus load to Lake Twelve was from overland flow, future decline in lake water quality may justify diversion and alum treatment of overland flow from the south and north shores. If this step were taken, it may be possible to use the existing settling ponds as settling basins for the treated water prior to discharge to the lake. If internal phosphorus loading is an important source of phosphorus in the future, injection of alum-treated overland flow into the hypolimnion via a diffuser could serve a dual purpose in destratifying the lake and depositing an alum floc on the sediment surface to reduce sediment release of phosphorus. The effectiveness of such a treatment would depend upon the future magnitude of the external and internal phosphorus loading and would require further study.

Recommended Action
— BW-2 —

Continued monitoring of the discharge with yearly reports to the Lake Twelve Association summarizing TSS and TP concentrations and loadings and future plans.

Mine closure and reclamation plans should <u>not</u> require removal of the existing noise berms and sedimentation ponds and returning these areas to their original contours, since this disruption could again result in erosion and sedimentation problems for the lake. County staff should meet with personnel from PCCC to discuss the best approach for relating these concerns to OSM, to ensure they are reflected in the mine reclamation plans.

The Lake Twelve Association should be involved in reviewing the reclamation plan for the mine, especially plans for future use of the mining area. Reclamation plans should include water quality protection for the lake.

Stream and Wetland Buffer Zones

Streamside and wetland buffer or riparian zones are terms used to describe a vegetated strip of land left between stream channels, wetlands, or lakeshores, and the adjacent surrounding uplands. Riparian areas act as water and energy dissipation zones for sediment deposition, but also as active uptake sites for nutrients that can stimulate phytoplankton and macrophyte productivity in Lake Twelve. If vegetation has been removed from buffer areas, it should be replanted. Normally this zone is 25 to 50 feet wide on both sides of the stream and entirely around the perimeter of wetlands. (Required widths can be as great as 100-300 feet or more, depending on the sites' importance and sensitivity to disruption.) The King County Sensitive Areas Ordinance was instituted to protect streams, wetlands, and other critical or sensitive areas through supplemental development requirements and additional provisions for controls. Requirements of this ordinance should be followed to identify critical areas and their buffers. Healthy, maintained, native vegetation within the buffer zone provides several benefits:

- Provides filtration of pollutants from adjacent lands
- Stabilizes streambanks
- Reduces sedimentation downstream
- Shades the stream and reduces stream temperature
- Provides cover and food for fish and other wildlife
- Provides wildlife habitat and migration corridors
- Moderates microclimate of riparian system, and
- Provides an aesthetic natural amenity.

Recommended Action
— BW-3 —

All critical areas (streams, wetlands, and shorelines) in the Lake Twelve watershed should be identified and buffer zones delineated. Local volunteers should perform an annual inventory of all direct drainages to the lake and notify County personnel if there are signs of damage to the riparian corridor or the buffer. This should include checking for signs of sedimentation, erosion, blocked culverts, or loss of vegetation in these areas.

Improved Roadside Ditch Maintenance and Provision for Biofiltration

Pollutants that accumulate on road surfaces originate either as atmospheric deposition (such as settling of vehicle emissions) or are created by wearing of car parts and discharge of oil and grease. Rainfall erodes soil and transports these pollutants and others to overland ditches and streams in the watershed. Overland flow during storm events was a major source of phosphorus loading to Lake Twelve (48 percent of annual P loading). Reduction of this source is critical to protecting and enhancing water quality in the lake. As the area adjacent to the lake becomes more developed, the amount of impervious road surface will increase along with traffic intensity, consequently, there will be more pollutants available and more paths for their delivery to the lake.

There are many methods for controlling both the quality and quantity of runoff from roadways. Use of biofiltration ditches (grassy swales) along roadsides to slow down the runoff and filter out pollutants is probably the most simple and effective method. Grasses such as fescue and rye possess excellent biofiltration capabilities and they should be encouraged. It is recommended that shoulders and/or swales mowed more than once per year should have clippings removed each time, budget permitting, to prevent nutrient release to the lake from plant decomposition. With proper design and maintenance of the biofiltration swales, the phosphorus load in the overland flow could potentially be reduced by 50 percent.

Runoff waters can also be directed through an oil-water separator, sedimentation pond, retention/detention basin, or constructed wetland. However, these can be very expensive and land intensive control methods. The method selected should be dependent upon site characteristics, and degree of control needed.

Control of runoff water from roads is regulated through King County Ordinance #10636. This ordinance provides "minimum requirements for reducing and controlling the discharge of contaminants", "either directly from one discharge or through the collective impact of many small discharges". Pollutants entering the road drainage system should be removed through treatment systems installed outside the public right-of-way (R.O.W.) and be maintained by private property owners. Since 14% of the watershed has been recently rezoned from forestry use to residential use (one dwelling per five acres), and residential development represents the most important long-term threat to the lake, new development projects should be required through SEPA to provide enhanced biofiltration. This is particularly important with respect to the drainageway along S.E. Green River Gorge Road (S.E. 312th St.). The County encourages the formation of cooperative agreements with

private developers to reconfigure this drainageway into a biofiltration swale and agree to its long term maintenance.

Recommended Action
— BW-4 —

Since overland flow accounts for 48% of the phosphorus load to the lake, and this source is directed to the lake through the system of road drainageways and culverts, it is important that these drainageways and culverts are properly designed and maintained. The perimeter road around Lake Twelve within 200 feet of a drainage crossing should be evaluated by King County Roads and SWM staff, to assess the condition of the drainageway and its ability to function as a runoff filter. There are no improvement projects planned for this section of roadway for at least the next four years. This drainage course, however, will be an important element to consider for phosphorus control mitigation requirements during SEPA permitting processes associated with any future development or capital improvement project. The onsite evaluation should address the need for retaining significant vegetation in the wetted perimeter of the drainageway to act as biofiltration swales or other methods for reducing flow and/or pollutant loads to the lake. A complete evaluation should be performed every five years or more often if development increases. (Evaluations by volunteers in the intervening years should be available for early identification of problem areas.)

Public Works staff should actively seek community groups (Lake Twelve Association) to participate in the Adopt-A-Road program. Through this program volunteer groups "adopt" a two mile section of road and remove litter from the roadway at least twice each year over a two year period. A permanent sign is erected identifying the adopting group. This can enhance ownership of actions taken by residents in the watershed and promote the awareness and protection of the lake by others. Information on the Adopt-A-Road program is provided in Appendix I.

In addition residents can maintain their own ditches as biofiltration swales by entering into a formal agreement with King County Roads Maintenance. "Owner will Maintain" signs are issued by the County, once the agreement has been signed.

Livestock Management

During development of the Phase I study, a livestock management problem was noted on a parcel located on the south side of the lake. One horse is pastured on this property which is adjacent to a stormwater drainage ditch that directly discharges to Lake Twelve. Poor management practices associated with livestock keeping can contribute significant nonpoint pollutant loadings to downstream receiving waterbodies.

In December 1993, the King County council passed Ordinance No. 11168 which revises the standards for management of livestock in the county in a manner that minimizes the adverse impacts of livestock on the environment, particularly with regard to their impacts on water quality and salmonid fisheries habitat. The ordinance sets density and management standards. Farm management plans are encouraged to be developed in cooperation with the King County Conservation District. These plans will require site-specific management measures for minimizing non-point pollution from agricultural activities including, but not limited to: 1) livestock watering, wetland and stream corridor management; 2) grazing and pasture management; 3) confinement area management; and 4) manure management. Farm management plans generally seek to achieve a 25 foot buffer. Property owners with farms containing large livestock densities (greater than 1 animal unit/2 acres) would not be required to follow a farm management plant if the owners adhere to management standards contained within the ordinance.

Recommended Action
— BW-5 —

A farm management plan should be developed for this property.

DEVELOPED AREA MANAGEMENT

The majority of the pollution within the Lake Twelve watershed is the result of human activity. Nonpoint pollutants originate on each parcel in the watershed and are a threat to lake water quality due to their collective impacts. Failing septic systems, improper use of fertilizers, pesticides and other common household chemicals, erosion at construction sites, increased impervious area, and general housekeeping practices are just a few ways that humans impact lake systems.

On-Site Waste Disposal (Septic Systems)

Septic systems can be an important source of nutrients, pathogens, toxicants and other pollutants. The very nature of lake property and homes magnifies the potential for septic system influence. Homes are built close to the shore to take maximum advantage of the lake view; many lake homes were first built as summer residences and have septic systems that are undersized for existing use or systems that were retrofitted into existing structures; and often high groundwater tables and/or aquifers are located close to the surface along lake shores. These factors increase the probability of failure of a septic system.

Although groundwater contamination by septic systems was not found to be a major contributor to water quality problems in Lake Twelve, improvements to and maintenance of existing systems and proper siting

or retrofitting of any additional systems is easy and inexpensive to implement relative to large-scale basin or in-lake restoration measures.

In order to assess the potential for impacts from septic systems, small wells or piezometers were placed in series of three that ran perpendicular to the shoreline (Welch et al., 1992). The difference in water elevation as measured in the peizometers was used to estimate the rate of groundwater flow to the lake. Chloride (used as an indicator of septic influence) was measured in the wells and in the lake. The average chloride concentration in the lake was 2-3 mg/L, while in the wells the maximum concentrations ranged from 10 to 41 mg/L. These high groundwater chloride concentrations indicate that some septic systems are failing and influencing adjacent groundwater quality. However, the low lake concentrations and low measurements for groundwater inflow (groundwater was only estimated to represent 0.2% of the lake water budget), indicate that the septic systems are not currently having a large impact on lake water quality (Welch et al., 1992). These findings are somewhat contradictory to reports of wetted soils or ponded water commonly observed on lakeshore property.

Unfortunately, the 1991-1992 winter wet weather season was exceptionally dry which may have resulted in an underestimate of both the degree of contamination and the quantity of water involved. In any case, due to the proximity of the septic systems and the potential for failure, control of this watershed source of phosphorus and other contaminants will be important to the future water quality in Lake Twelve.

There are three main categories of action that each resident can take to help ensure the proper operation of their system: 1) reduce water use; 2) reduce the use of chemicals in the home and eliminate their discharge to the septic system; 3) have the system regularly inspected and maintained, and 4) include installation or upgrading of on-site sewage disposal systems whenever remodelling or expanding residences.

Reducing the volume of wastewater generated from a home may be the single most useful deterrent to septic system failures. Each system is designed to treat a specified amount of water. But water use and the system's effectiveness changes over time. For example, the addition of bathrooms, laundry facilities, or increased family size all equate to increases in the volume of water discharged to the septic system. Furthermore, the volume of water a system can effectively treat

becomes smaller over time as drainfields clog with solid particles. As alluded to earlier, lake-side homes are especially susceptible to volume increases as summer residences are converted to full-time homes. This is especially important because full-time residence means winter use of the home. Winter is the most critical time period for septic systems in the Puget Sound basin. Water enters the system both as waste from the house and as infiltration from precipitation and a system can easily become saturated and fail; discharging untreated sewage to the groundwater or to nearby surface waters (e.g. Lake Twelve).

There are many ways to reduce water use in the home. The use of low-flush toilets (or placing plastic bottles full of water in tanks), and water saver showerheads and faucets are examples of inexpensive physical changes that reduce water use. There are also many changes in personal habits that can decrease water use, such as not using washers or dishwashers unless there is a full load, limiting shower time, not letting the faucet run while cleaning, and others. Homeowners using septic systems should be especially stringent during the winter months. Spreading out wash loads over the week and eliminating extra washing during periods of heavy rainfall are simple measures that can be taken to avoid overloading the system during this critical period.

Reducing the use of household chemicals is a valuable practice whether waste is discharged to a wastewater treatment facility or to a private septic system. These toxicants are difficult to eliminate in any treatment system, but in an on-site system they may have the additional impact of killing beneficial bacteria that decompose the waste material. The loss of the bacteria and other factors leading to a less efficient system may cause direct discharge of these toxicants to the lake or groundwater.

King County recommends that septic systems be pumped and inspected every three years by a licensed firm and that the owner inspect the system and drainfield every year. Appendix I contains copies of pamphlets available through the Seattle-King County Department of Health that describe how to care for septic tank and other on-site systems including information on how to inspect your own septic tank. King County also has low interest, home repair loans for low and moderate income homeowners that can be used for septic system repairs. Information on these loans can be obtained by calling the King County Housing Hotline (296-7640). Information on these loans is also included in Appendix I.

Recommended Action
— DA-1 —

Water conservation practices should be promoted through public education efforts, the lake's newsletter and meetings. Water conservation practices should include the use of low flow faucet aerators, flow restrictors for shower heads, water conserving toilets or the use of plastic bottles filled with pebbles in toilet tanks, and water conserving lawn and garden practices.

Low flow plumbing fixtures are recommended for installation in each house that utilizes an on-site septic system.

The use of garbage disposals in houses with on-site systems should be discouraged.

A group septic pump-out event should be scheduled by the Lake Twelve Association to increase public awareness and participation and possibly also receive a price break. The pump-out event should be announced through LTA's newsletters, followed by pump-out reminders and be scheduled every three years at a minimum.

A workshop should be scheduled for the lake residents to help them with developing a personal "pollutant assessment" for their home and property. Through learning exercises residents would determine their septic system's susceptibility to failure, the amount of runoff generated from their sites, and rate themselves in terms of water conservation and other protective measures. The exercises would be for each homeowner's own information so they can determine for themselves the importance of water conservation efforts and other steps needed to minimize the potential for pollutant contribution from their home.

A local ordinance requiring the installation of low flow fixtures in new housing or a tax break incentive should be promoted.

Copies of the King County septic system maintenance brochures and information on the loan program should be sent to all lake residents.

In most cases, controlling nonpoint pollution problems from failing on-site systems does not require the creation of new programs. The need can be addressed through existing programs within Seattle-King County Department of Health, Washington State Department of Ecology, Washington State University-King County Cooperative Extension, local conservation districts, health departments, and other state and federal agencies.

Control of Developed Area Runoff

In addition to problems associated with septic systems, individual residences also contribute to lake quality problems through surface water runoff from their property. The total volume of runoff that enters the lake from a specific site is related to the size of the site, soils, slope of the land, distance from the lake, and most importantly the amount of impervious surface area on the site. (Impervious surfaces are those that rainwater can not filter through such as buildings, asphalt, concrete, and can even include heavily used trails.)

Since existing impervious surfaces are difficult to eliminate, the issue is one of trying to control runoff from these surfaces. Directing runoff to a grassy swale or the lawn instead of directly to the lake or a stream can be effective for decreasing both the amount of runoff and the concentration of pollutants entering the lake. (Runoff from driveways should be controlled before roof runoff since the former receives a continual supply of oils, grease, metals, and other pollutants associated with automobiles and equipment.)

Other activities such as washing the car on the lawn instead of on the driveway (the grass filters out the pollutants and gets watered at the same time), sweeping sidewalks and drives instead of hosing them with water, and reducing or eliminating the use of pesticides and fertilizers around the lawn and garden are simple, effective methods for controlling the input of toxicants and other pollutants from personal property.

Minimizing the extent of impervious surface areas should always be considered when taking on new construction projects. A smaller driveway or parking pad and the use of grasscrete are ways of reducing impervious surface area for your automobile needs. Smaller decks or the use of patios (i.e. flagstones interspersed with vegetation) may decrease runoff from outdoor living areas. Generally, things such as concrete steps or asphalt pathways down to the lake should also be avoided. Though these changes may appear to be insignificant, controlling nonpoint pollution and runoff demands controlling input from many small areas or sources such as these.

Lawn and other high maintenance landscaping should be limited as much as possible, especially in the nearshore area. These often require pollutant contributing upkeep measures such as mowing, fertilizing, and chemical weed control. A 25-50 foot "buffer" comprised of native vegetation along the lake shore will in itself keep these activities away from the lake shore and act as a natural filter strip for pollutants that runoff from other yard areas. Even smaller buffers of 10 to 25 feet of native vegetation can help reduce nutrient and other pollutants from

entering nearshore areas. This natural buffer will also be more attractive to most wildlife yet less attractive to geese which are becoming a problem in many urban area lakes. Natural vegetation along the shore and shallow water areas also allows hiding and feeding areas for small fish and can reduce impacts from boat wakes on shorelines.

Control of runoff from new developments should follow the regulations in Chapter 9 of the King County Code "Surface Water Management". Chapter 9 states that a drainage review will be required for all projects which would; 1) Add more than five thousand square feet of new impervious surface; or 2) collect and concentrate surface and storm water runoff from a drainage area of more than five thousand square feet; or 3) contain or abut a floodplain, stream, lake, wetland, closed depression, or other sensitive area (as defined by K.C.C. 21.54). The drainage plan would be required to meet all of the requirements that apply to the project as detailed in the Surface Water Design Manual for King County.

Recommended Action
— DA-2 —

The King County Lake Stewardship program should be utilized to promote local awareness and involvement in lake protection issues. A public education and involvement plan should be developed that includes dissemination of brochures, newsletter articles, speakers, and promotion of a "model home" or landscaping project. The public education effort should cover the following topics or practices:

- *Preserve native vegetation along streams and the lake shore. If vegetation must be removed, selectively replant native species of trees, shrubs, and groundcover.*
- *Establish and maintain vegetated filter strips, berms, swales, or buffer zones down-gradient of houses, gravel parking areas, driveways and other impervious areas to provide biofiltration and sediment control.*
- *Convert existing lakeside fire pits to provide containment and easy removal and disposal of ashes. Various toxins and nutrients within ash residue contribute to lake degradation.*
- *Avoid use of beauty bark near streams or where it can get into storm drains (bark fibers clog drains). Also, when beauty bark is used be sure it is not treated with salts, dyes, or pesticides.*
- *Eliminate disposal of grass clippings, tree cuttings, ashes, and miscellaneous debris in or near streams and the lake. Establish a community or backyard compost pile away from stream corridors and provide regular maintenance. Compost piles save money by reducing garbage disposal costs and produce rich humus (a material far superior to commercial fertilizers) to add to gardens or potted plants.*

- *Avoid spraying pesticides and herbicides on windy days. Read labels carefully and avoid using toxic products in excess or during poor weather conditions. Apply pesticides only when pests are actually observed. Home remedies, such as soap and water, may be used effectively to control common pests. If pesticides must be used, try organic products such as Pyrethrum of Thurigens. Always apply these products sparingly.*
- *Promote the use of simple construction techniques to help reduce the amount of runoff entering streams and protect water quality. The use of gravel and stepping stones in place of concrete for patios, walks, etc., can increase percolation and reduce runoff. Downspouts from roof drains or drains from driveways should not be routed toward a stream or the lake. Runoff water should be directed to properly designed storage systems, e.g., french drains or detention basins, and effluent from these structures should be directed into grass-lined swales before entering streams or the lake. Increased infiltration into the ground helps maintain a steady supply of clean water to the lake all year.*
- *Temporary seeding should be promoted to reduce erosion caused by prolonged rainfall on exposed soils. Grass seeds, such as annual rye grass, cereal rye, and gray oats can be applied with lime to achieve rapid growth and soil protection. Care must be taken, however, when applying fertilizers near a stream or the lake; they must be applied sparingly and accurately. Permanent seeding and planting are preferred over temporary measures. When seeding grasses, prime planting times to ensure success are April 20 to June 1, and September 1 to October 1.*
- *Promote the establishment of a "pollutant free zone" within 50 feet of the lake shoreline. No fertilizers, pesticides, oil and gas, or other pollutants should be allowed to be used within this zone.*

Alternative Household Practices

Establishing and maintaining good water quality depends on the willingness and cooperation of all people living, working, and playing in the lake's watershed. Users of the watershed can help by ensuring that all products that can cause water quality problems are used, stored, and disposed of properly. Even small adjustments in household practices can have an impact on improving stream, lake, and even groundwater quality.

Household liquid wastes contain a mixture of personal hygiene products, medications, gray water from washing machines and baths, and numerous products used for cleaning. Most of these products are disposed of in household drains and septic tanks. A septic tank holds one to two days worth of liquid waste, and from one to several years of solid wastes. The liquid effluent returns to the subsurface soils and

the groundwater via the drainfield. The effluent often contains potentially harmful viruses, bacteria, and chemical compounds. A failing septic system can supply nutrients to the lake which can result in acceleration of the eutrophication process and contribute to increased macrophyte growth and nuisance algal blooms.

Many of the chemicals found in household septic tanks are persistent and can travel through the soil and groundwater. Organic toxicants that are common in septic tank effluent include carbon tetrachloride, toluene, trichloroethylene, chloroform, benzenes, and m-xylene (Burnes et al. 1984). Because of their volatile nature, these compounds are less likely to remain in the wastewater or soil, and without a direct escape route to the air, are likely to migrate through soils to groundwater supplies. (Septic system additives are not recommended for on-site septic systems.)

Recommended Action — DA-3 —

As with controlling residential area runoff, changes in housekeeping practices must be made through the public education and involvement plan for Lake Twelve. The plan should include at least the following elements:

- *Provide information to all residents about household hazardous waste products and alternatives to the use of these products, in addition to providing information on the proper use and disposal of hazardous materials.*
- *Recycle solvents, e.g., paint thinner, by taking them to a household hazardous waste collection service.*
- *Give excess paint to a friend, neighbor, or theater group to use. To dispose of less than one quart, allow paint to evaporate in a well-ventilated area away from children and pets. Discard the dried paint in the trash.*
- *Give excess pesticides away or take to a household hazardous waste disposal service.*
- *Use household cleaners according to directions.*
- *Recycle waste motor oil at service stations. Dispose of antifreeze and brake fluid at hazardous waste disposal areas.*
- *Use biodegradable/low-phosphate cleaning products. Use of low or nonphosphate-containing detergents within the watershed should be encouraged by a public awareness campaign.*
- *Reuse and recycle as much as possible.*

Proposed Development Projects

The City of Tacoma, Department of Public Utilities, Water Division is proposing to construct the Second Supply Pipeline to provide municipal water to the City of Tacoma, South King County and Federal Way. The proposed pipeline will be approximately 33 miles long, extending westward from the headworks of the Green River, near Enumclaw and the Howard Hanson Dam, through Black Diamond, Auburn and Federal Way and terminating in Tacoma.

This pipeline will impact approximately 10 acres of Class I and II wetlands, cross several streams and waterways, and directly disturb vegetation and soils within the pipeline right-of-way (ROW). The route as proposed will be constructed in the south ROW edge to reduce impact aid the wetlands of the Lake Twelve wetland complex (LCR 92 and 93). Additionally, the pipeline ROW appears to cross the southern end of the Lake Twelve watershed and somewhat parallels the SE Green River Gorge Road (cutting through the public boat launch area and private driveways).

In 1989, the King County Council passed, and the executive subsequently approved, Ordinance No. 9193 conditionally approving the 1987 Tacoma Water System Plan. One of the conditions set forth in this ordinance was the development by the executive of a comprehensive mitigation plan for this pipeline to be approved by the council prior to the issuance of certain King County permits and approvals for the project. In March 1993 the King County Council passed ordinance No. 10776 approving the comprehensive mitigation plan (CMP) element of the City of Tacoma's 1987 plan.

Many of the impacts will be mitigated through compliance with the proposed CMP, applicable ordinances and legislation, and adherence to construction best management practices. The CMP includes over 130 construction related mitigations, including the requirement that disturbed portions of Class I, II, and III wetlands be restored according to a County approved restoration plan and, in addition, be replaced or enhanced at a 2:1 ration for Class I and II wetlands and a 1:1 ratio for Class III wetlands. Some project related impacts, particularly cumulative impacts cannot be mitigated. In these cases, the CMP proposes establishment of an Environmental Resource Fund, financed by Tacoma and administered by King County, to develop fish habitat protection projects in the Green River corridor and to fund off-site land acquisitions to protect nearby sensitive areas and replace recreational opportunities.

The CMP generally groups construction mitigation requirements into nine categories: 1) construction monitoring; 2) erosion and

sedimentation control; 3) historical/cultural resources; 4) materials handling and air quality; 5) public information; 6) roadways and parks; 7) soils; 8) waterway crossings and fisheries; and 9) wetlands, plants and animals.

There are three requirements for the public information mitigations:

1) Tacoma shall hold a public workshop(s) for the citizens of King County on the final project design and mitigation plans before King County approval of the master grading permit.

2) Information specific to the overall plan and the phases of construction impacting the various communities shall be readily accessible to the affected community.

3) Tacoma shall provide a Hot Line to be staffed 24 hours a day. This Hot Line shall have a direct link with the monitors at the site and King County inspectors, and response to trouble calls shall be immediate if conditions dictate. Records of trouble calls shall be kept, and be available to agencies with jurisdiction. The Hot Line phone number shall be conspicuously posted at each construction site and provided to King County Departments.

Due to the fact that approximately 48-52% of the incoming phosphorus and water to Lake Twelve is attributable to ungauged flows, it would appear that implementation of effective erosion and sedimentation controls are crucial in preventing additional pollutant loading to the lake as a result of this project.

Recommended Action
— DA-4 —

The Lake Twelve Association will need to participate at all levels in the public information portion of the project, to monitor the development of this construction project in their watershed. This will aid in generating a greater awareness of the issues of concern in the Lake Twelve watershed and thus help to ensure no significant impacts occur.

Construction of the pipeline and granting of a 100 foot easement along the roadway provides an opportunity to acquire some valuable assets for the lake.

Area residents, Palmer Coke and Coal Company representatives, County staff, and other interested parties should meet with the City of Tacoma to discuss installing stormwater treatment facilities and possibly a bike path in the easement, as mitigation measures for pipeline construction.

CONCLUSIONS AND RECOMMENDATIONS

The limnological data collected during the study does not support an intensive in-lake effort to control internal nutrient loading to Lake Twelve. Water quality should continue to be monitored to document any deterioration in water quality and to identify the source of the nutrient loading responsible for any decline.

The management plan for Lake Twelve should focus on watershed management measures and control of aquatic macrophytes. Removing macrophyte biomass would serve a dual purpose in reducing the nuisance character of the vegetation (and enhancing beneficial uses) and reducing internal nutrient loading when the plants senesce. An Integrated Aquatic Plant Management Plan would allow implementation of a number of different plant control methods and could be developed to optimize costs and beneficial uses.

Dredging is a more permanent solution to macrophyte problems, but lack of evidence of internal phosphorus loading and the possibility that milfoil could expand into the dredged areas necessitates caution in implementing a dredging program. If internal nutrient loading from the sediments is important in any future decline in lake water quality, a dredging program should be reconsidered.

External phosphorus loading accounted for about 89 percent of the phosphorus entering Lake Twelve. Watershed management measures that reduce nutrient loading should be implemented immediately. Use of BMPs for control of nonpoint sources in the watershed and adoption of the guidelines for developed property management are relatively inexpensive techniques for maintaining and enhancing water quality in Lake Twelve. For the most part, watershed management measures can be implemented through a public awareness program. Indeed, public awareness and participation are critical elements of any successful plan for restoration and maintenance of water quality in Lake Twelve. In the absence of an increase in internal nutrient loading, a program of macrophyte control coupled with control of nutrient loading from the watershed should protect and enhance water quality in Lake Twelve.

The appropriate controls for macrophytes and the specific areas to be managed will be spelled out in the proposed Integrated Aquatic Plant Management Plan (the preferred lake restoration alternative).

RECOMMENDED LAKE MANAGEMENT PLAN

GOALS AND OBJECTIVES

The existing water quality of Lake Twelve, as measured by trophic state indicators appears to be good. The primary concern for the lake in terms of beneficial uses stems from the aquatic plant community. Although the existing plant community has not reached the density measured in other Puget Sound lowland lakes, it has reached a level at which recreational use of the lake is affected. Macrophytes covered about 40-60% of the lake surface in the late 70's and early 80's before milfoil had begun to spread. Assay results and experience with other lakes signifies that the plant community will continue to gain in density and surface coverage, creating greater problems in the future. The majority of the watershed is contained within forested land (86%) in early to mid-age stands that will not be scheduled for cutting for another 20 years. Therefore most of the watershed is currently protected from activities that could be expected to negatively impact Lake Twelve. Fourteen percent of this land has recently been rezoned to a rural density of 1 per 5 acres. Although development at this density is not expected to cause a large impact to the lake, this represents what will probably be an accelerated demand to develop the land. There is no reason to believe that portions of the watershed will not eventually be rezoned to a higher density, and that property near the lake will be rezoned first since it will be the most valuable for residential development. A plan for protection and restoration of Lake Twelve must address these existing and potential future problems experienced by the lake and meet the goals set forth by the area residents to:

- Maintain long term water quality
- Maintain the aesthetic character of the lake
- Provide long-term control of aquatic plants

The objectives needed to meet these goals include:

1. Reduce or control existing loading of nutrients and other pollutants from the watershed to the maximum extent possible, and allow no increase in hydraulic or nutrient loading.

The watershed loading rate for TP has been estimated at 31 mg/m2/yr (Welch, et. al., 1993). Assuming TP loading from the rezoned portion of the watershed doubles, the yield from the watershed would increase

by 5 mg/m2/yr to 36 mg/m2/yr, and would cause an increase in lake TP concentrations of 1.3 ug/L (Welch et al., 1993). This increased loading is not likely to cause a perceptible change in lake phosphorus levels. By comparison, if this same amount of land were converted to typical urban densities, the external loading would increase by over three times and it was predicted that summer TP concentrations would increase to 25 ug/L, the threshold for eutrophic conditions. This example supports the importance of watershed control measures for protecting Lake Twelve.

2. Decrease the density, remove, or alter, plant communities to allow and enhance human use of the lake while protecting fish and wildlife habitat and maintaining good water quality.

The density and growth pattern of aquatic plants in Lake Twelve already affect the lake's beneficial uses. Furthermore, if milfoil continues to colonize new areas and invade areas currently inhabited by other plant types, recreational use will be further inhibited. In Green Lake in Seattle, milfoil was only present at a few sites in 1981. By 1986, its biomass had increased to 30-50 g/m2, and by 1991 it averaged 483 g/m2 (Welch et al., 1993). Sediment assay results indicate that Lake Twelve sediments have the same capacity for milfoil growth. Since milfoil has been present in Lake Twelve for 15 years and has not yet reached the densities measured in Green Lake, there may be some limiting factor such as inhibition by existing plants. Consequently, alteration of the plant communities should be approached with caution to ensure the existing balance is not exchanged for one that is more advantageous to the milfoil.

3. Maintain the existing trophic level of the lake; summer average TP concentrations at or below 8 ug/L and summer visibility (secchi disk depth) at 3 to 3.5 meters.

Currently, Lake Twelve can be classified as an oligotrophic to mesotrophic lake according to summertime TP, visibility, and chlorophyll measurements. Any increases in nutrients or other pollutants will eventually cause these trophic indicators to change, and as the lake becomes more eutrophic there will be an increase in algal blooms and increased sedimentation (or accelerated rates of depth loss). To maintain the existing trophic status, all sources of external loading to the lake should be controlled.

4. Involve lake residents and others in the community through public education and through providing leadership roles (e.g. through the King County Lake Stewardship Program) for their participation in lake protection and education efforts.

Many of the watershed protection techniques discussed in Chapter Three rely on participation of local citizens. These techniques will not be effective unless a large majority of the local residents understand their importance, accept a greater ownership in the watershed, and lead or at least participate in their implementation. The role of the County and other agencies should be to provide the initial information; e.g. why is water conservation important? what can you do to help?; the community is best suited to take on the role of continually reinforcing the ideas and providing opportunities (e.g. lake pump-out events) for their implementation. The County has begun this process through the lake stewardship program. One of the goals for the planning process during development of the IAVMP for Lake Twelve should be to locate a volunteer steward who would be willing to track watershed activity, keep residents informed about protection concerns and efforts, and generally promote protection of the lake and watershed.

THE MANAGEMENT PLAN FOR LAKE TWELVE

The recommended lake management plan includes development of an Integrated Aquatic Plant Management Plan (IAPMP) for control of the macrophytes, implementation of watershed control measures, monitoring to assess changing conditions, and a public education and involvement plan. The second alternative selected which may be instituted if monitoring indicates that water quality has deteriorated, or if implementation of the IAPMP does not provide adequate control of the plants, is a lake dredge project. Watershed control measures and monitoring would also be necessary under this alternative.

Integrated Aquatic Plant Management Plan

As previously described, the theory of this approach to aquatic plant control is to select plant control techniques that meet the requirements of the beneficial use that occurs in each portion of the lake. An IAPMP might include a variety of approaches to controlling the plants. Techniques such as harvesting, bottom screening, or even sediment removal might be selected to be used in combination in the lake. Production of the plan requires input from area residents in mapping the plant beds and defining the different beneficial uses and the areas in which they occur. The plant control technique will be selected based on the primary activity(s) that occurs in each mapped area.

King County Surface Water Management Division has already applied for and been approved for a grant from the WSDOE to develop an IAPMP for Lake Twelve that establishes a balance between water quality and beneficial uses. The proposed grant objectives are to: 1) Develop an updated bathymetric map, aquatic plant location and density map, and a zonal use map for aquatic plant management; 2) Document the process used and implement a regional public involvement and education program for other area lake associations, and initiate a "master milfoiler" program; 3) Seek a dedicated funding mechanism and long-term monitoring program for Lake Twelve. The total estimated cost for development of the plan is $20,000.00.

Most of the methods available for control of the plants that will be considered in developing the IAPMP will require continual maintenance and therefore a long term funding source. Harvesting if selected will need to occur a number of times every year, bottom screens will need cleaning and replacing, and even herbicides (if allowed) would need to be reapplied periodically. And, although control of the plant population should result in some decrease in plant biomass and therefore a decrease in internal loading and sedimentation, the lake will continue to fill in and will probably require an increasing level of effort to control plant populations. At the measured sedimentation rate of 2 mm/yr, it will take 50 years for the lake to reach an average depth of 4 m; the maximum depth of colonization for this lake. Thus, for all practical purposes the entire surface area would be colonizable by plants at that time. Control of watershed sources and control of plant biomass should result in some decrease in sedimentation rates and consequently a longer lifespan for the lake.

Watershed Management Measures

All of the watershed management measures as described in Chapter 3 are recommended for implementation as part of the Lake Management Plan. These include the basin-wide and developed area measures. Basin-wide measures include those for controlling runoff from forest and mining activities and especially those for control of street and construction site runoff, since these will likely show the greatest increase in the upcoming years. Implementation of these measures can occur through support of existing laws and ordinances. The applicable regulations include Chapter 9 of the King County Code "Surface Water Management", King County Ordinance #10636, and the King County Sensitive Areas Ordinance (#9614). As described previously, potential impacts from forest and mining activities are further regulated through State and Federal laws such as the Timber Fish and Wildlife Agreement and the National Pollutant Discharge Elimination System (NPDES) and others as promulgated through the Department of the Interiors' Office of Surface Mining.

Implementation of developed area measures such as septic system maintenance programs and use of proper landscaping techniques will occur through public awareness and education programs. Since this information for the most part has already been developed, implementation is more a function of disseminating the information. Brochures should be made available to lake and community residents, and presentations should be made at LTA and other community meetings to address each of the measures.

Direct costs associated with implementation of watershed control measures are related to those for identifying critical area buffers, roadside ditch maintenance and inspection, and septic system inspections. The total cost is estimated at $21,000. There are indirect costs associated with implementation of this portion of the watershed management plan, through providing support for staff positions involved in tasks such as review of forest management plans.

Monitoring and Documentation

In order to evaluate whether this plan is meeting the stated objectives, a continual plan for lake water quality monitoring will be necessary. Summertime monitoring of TP and Secchi Disk depth will be required to ensure that trophic state criteria are being met, and yearly or biannual mapping of macrophyte beds as well as monitoring of the user's perceptions of the aquatic plant situation will be needed to determine whether the aquatic plant community is being controlled to an appropriate level. Much of this monitoring can be done by citizen volunteers as part of the ongoing citizen monitoring program already being performed through Metro. However, it is recommended that more rigorous summertime sampling occur at least once every five years to measure changes in DO, pH, temperature, and nutrients, chlorophyll, and phytoplankton with depth in the lake. Water quality monitoring costs have been estimated at $1000/yr for the citizen monitoring with an additional $10,000 for the more intensive monitoring that would occur in five years. A total of $15,000 would be required for a five year period. In addition to water quality monitoring needs, the aquatic plant population will need to be monitored on a continual basis to evaluate the effectiveness of the IAPMP. The cost for aquatic plant monitoring has been estimated to be $5,000. The total cost for this element of the plan is estimated at $20,000.

Public Involvement and Education

Public involvement and education should occur through a number of mechanisms. The Master Milfoiler program funded as part of King County's Lake Stewardship Program would provide interested citizens

with an opportunity to learn to identify and map plant beds. Citizens will also be needed to continue the volunteer monitoring efforts and possibly perform the more extensive monitoring required for trophic state evaluation. Public education should include information on how residents impact lake water quality and how they can implement BMP's. A lake steward should be chosen to continue promoting the BMP's, to monitor development activities, review forest management and mine closure plans, and in other ways maintain communication between lake users, County staff and plan implementation needs. The total cost for the public education program is estimated at $25,000.

Public Access

The existing public facilities at Lake Twelve consists of a Washington Department of Fish and Wildlife boat launch located near the southeastern corner of the lake. There is space to turn and launch a boat with a few parking spaces, but no other amenities. Adjacent property on both sides of the launch is privately owned. The property to the east is owned by the Palmer Coke and Coal Company. This undeveloped property contains the floating sphagnum bog that is an essential part of the Class I wetland referred to in other portions of this plan.

Some improvements to the public access area are needed to meet existing grant requirements. These include addition of a park identification sign, installation and maintenance of garbage receptacles, a picnic area, and installation and maintenance of toilet facilities. The estimated cost of these additions is $15,000 for installation of the new facilities (this includes a concrete, vault type toilet) with an additional annual operating cost of $2,000. The total estimated cost for this element of the plan is $25,000.

If at a future time King County or another entity should wish to further improve public access at Lake Twelve, the plan should focus on the adjacent wetland. The size of the lake, restrictions on motor use, and existing fishery quality is not conducive to promoting increased boat use. The adjacent sphagnum bog is an excellent example of a high quality wetland and is an aesthetically pleasing feature of the lake. Assuming this property could be purchased, a boardwalk should be provided that allows pedestrian and handicapped access through the wetland. The boardwalk should include benches for resting and viewing and a dock that extends into the lake to allow fishing and perhaps swimming access. Educational signs, describing for example wetland values or lake/wetland interactions, should be placed at key locations along the boardwalk to promote public interest and support. Costs associated with this potential future development have not been included in this plan.

CONTINGENCY PLAN FOR LAKE TWELVE - - DREDGING

If adequate plant control is not achieved through the IAPMP, or if trophic state indicators or monitoring indicate that the condition of the lake has deteriorated, the contingency plan to dredge Lake Twelve is recommended. Dredging would control plant biomass through increasing depth and thereby decreasing light in affected areas, and also by direct removal of roots and tubers in the nearshore area. Concentrating dredging efforts in the western portion of the lake where recreational use is highest may be the most efficient dredging plan, although even this could be cost prohibitive if the existing coal mine can not be used for dredge spoil disposal. (Under existing Centennial Grant funding conditions it would be difficult to obtain a grant for dredging without first proving the sediments were a source of water quality problems. Therefore an alternative funding source would need to be identified, for example a County owned and operated dredge.)

SUMMARY

Table 4-1. lists each of the recommended management measures and their associated costs. Although the costs for development of the IAPMP will be met through the new grant, they have been included in the total estimated cost since development of the IAPMP is one of the key steps for implementation of this plan. The majority of the costs stem from the public education and monitoring programs. Successful control of watershed loading is entirely dependent upon having an informed, active citizenry that is participating on a daily basis in watershed protection measures. The total estimated cost for implementation of the Lake Twelve Management Plan is $111,000 over a five year period. This does not include funds necessary to implement the IAPMP. Cost for implementation of the IAPMP would include both a cost associated with the control method(s) selected and the cost for annual plant mapping and biomass estimates. The WSDOE could provide up to $75,000 in grant funds on a 75-25 percent match basis through the Aquatic Weed Management Fund for implementing the IAPMP.

A continual funding source will need to be identified to ensure the ongoing tasks associated with implementation of this plan and the soon to be developed IAPMP, are performed. Formation of a Lake Management District (LMD) has become the most popular means of funding lake management plans. An LMD is essentially a special taxing district that allows area residents to tax themselves in order to accumulate revenue to support lake management efforts. It is recommended that members of the Lake Twelve Association work with County staff to evaluate the advantages and disadvantages of setting up an LMD and discuss any further funding options that may be available.

Table 4-1 Summary of Recommendations and Estimated Costs for Implementation of the Lake Twelve Management Plan.

RECOMMENDATION	LEAD AGENCY	COST
Policy Changes		
Adopt Low Flow Ordinance (DA-1)	SWM[1]	N/A*
In-Lake Restoration		
Develop IAPMP	SWM	$20,000
Implement IAPMP	SWM & LTA[2]	N/A**
Watershed Controls		
Review Forest Mgmt Plans (BW-1)	SWM & LTA	N/A
Review Mine Reclamation Plans (BW-2)	SWM & LTA	N/A
Meet w/PCCC on berm removal issue (BW-2)	SWM & LTA	N/A
Identify Critical Areas & Buffers (BW-3)	SWM	$6,000
Roadside Ditch Maintenance & Inspec. (BW-4)	SWM & LTA & KCROADS[3]	$10,000
Livestock Management (BW-5)	SWM & LTA	N/A
Septic System Inspections (DA-1)	SKCDPH[4]	$5,000
Group Pump-out Scheduling (DA-1)	LTA	N/A
Public Education	SWM	$25,000
Water Conservation Practices (DA-1)		
Septic System Understanding & Maintenance (DA-1)		
Residential Site Runoff Control Practices (DA-2)		
Alternative Household Practices (DA-3)		
Pipeline Construction (DA-4)		
Monitoring		
Pond Discharge Monitoring	PCCC[5]	N/A
Citizen/Metro program	SWM & METRO	$5,000
Long-term Monitoring	SWM & METRO	$10,000
Aquatic Plant Surveys	SWM	$5000
Public Access	SWM	$25,000
TOTAL COST		$111,000

All costs are based on a five year period, though some of the implementation steps (e.g. septic system inspections would be done only once in the five year period.

* These costs are covered through existing programs.

** Costs are unknown at this time. They are dependent upon recommendations made in the IAPMP for Lake Twelve.

1. King County Surface Water Management
2. Lake Twelve Association
3. King County Roads Department
4. Seattle - King County Department of Public Health
5. Pacific Coast Coal Co.

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APPENDIX I

King County Program Information

NO INTEREST OR LOW INTEREST HOME REPAIR LOANS FOR LOW AND MODERATE INCOME HOMEOWNERS

EQUAL HOUSING OPPORTUNITY

KING COUNTY HOUSING REHABILITATION LOANS:

Housing Repair Program

- Maximum loan $13,500
- 0% interest
- No monthly payments -- loan is repaid at the time the home is sold or title transferred
- Mobile homes are eligible

Affordable Monthly Payment Loan (AMPL) Program

- Maximum loan $27,000
- Half of the loan funded by King County at 0% interest
- Half from a local lender at market rate, or homeowner's own funds
- County loan repaid at the time the home is sold or title transferred

3% Bank Loan

- Maximum Loan $33,500
- 3% bank loans for qualified homeowners
- Up to 20 years to repay

ELIGIBILITY REQUIREMENT

Income eligibility is determined by gross annual income of all household members. All income is included.

Family Size							
1	2	3	4	5	6	7	8
$26,900	30,700	34,550	38,400	41,450	44,550	47,660	50,700

Eligibility requirements include:

- Owner-occupied single-family home
- One year residency
- Asset limitations
- Sufficient home equity
- Necessary health and safety repairs are a priority

Homeowners who live in King County, outside the city limits of Seattle may apply. All programs are not available in all areas.

FOR INFORMATION CALL

King County Housing Hotline

296-7640

OR CALL TTY/TTD 296-0100

Caring For Your System — The Ten Essentials

1. ***Practice water conservation.*** The more wastewater you produce, the more the soil must treat and dispose. By reducing and balancing your use, you can extend the life of the drainfield, decrease the possibility of system failure, and avoid costly repairs.

   To reduce your water use:
   - Use water-saving devices.
   - Repair leaky faucets and plumbing fixtures.
   - Reduce toilet reservoir volume or flow.
   - Take shorter showers.
   - Take baths with a partially-filled tub.
   - Wash only full loads of dishes and laundry.

2. ***Keep accurate records.*** Know where your septic tank system is and keep a diagram of its location. Records of its size and location may be available at your local health agency. It is also wise to keep a record of maintenance on the system. These records will be helpful if problems occur, and will be valuable to the next owner of your home.

3. ***Inspect your system once each year.*** Check the sludge and scum levels inside your septic tank to assure that the layers of solids are not within the "early warning" levels. The tank also should be checked to see if the baffles or tees are in good condition. Periodically inspect the drainfield and downslope areas for odors, wet spots, or surfacing sewage. If your drainfield has inspection pipes, check them to see if there is a liquid level continually over 6 inches. This may be an early indication of a problem.

4. ***Pump out your septic tank when needed.*** Don't wait until you have a problem. Routine pumping can prevent failures, such as clogging of the drainfield and sewage back-up into the home. Using a garbage disposal will increase the amount of solids entering the septic tank and require more frequent pumping.

5. ***Never flush harmful materials into the septic tank.*** Grease, cooking fats, newspaper, paper towels, rags, coffee grounds, sanitary napkins, and cigarettes cannot easily decompose in the tank. Chemicals such as solvents, oils, paint and pesticides are harmful to the system's proper operation and may pollute the groundwater. Septic tank additives do not improve the performance of the septic tank, nor do they reduce the need for pumping. For information on the proper disposal of hazardous household waste, call the Recyle Hotline, 1-800-RECYCLE.

6. ***Keep all runoff away from your system.*** Water from surfaces such as roofs, driveways, or patios should be diverted away from the septic tank and drainfield area. Soil over your system should be slightly mounded to help surface water runoff.

7. ***Protect your system from damage.*** Keep traffic, such as vehicles, heavy equipment, or livestock off your drainfield or replacement area. The pressure can compact the soil or damage pipes. Before you plant a garden, construct a building, or install a pool, check on the location of your system and replacement area.

8. ***Landscape your system properly.*** Don't place impermeable materials over your drainfield or replacement area. Materials, such as concrete or plastic, reduce evaporation and the supply of oxygen to the soil for proper effluent treatment. They also can hinder getting to the system for pumping, inspection, or repair. Grass is the best cover for your system.

9. ***Never enter any septic tank.*** Poisonous gases or the lack of oxygen can be fatal. Any work to the tank should be done from the outside.

10. ***Check with your local health agency for help with system problems.*** Although some malfunctions may require complete drainfield replacement, many problems can be corrected with a minimum amount of cost and effort.

Additional Information

More information is available from the following Department of Health publications:

Water Saving Guideline 1, DSHS 22-643 (x) 5/88.

Septic Tank System For Your Home, DSHS 22-45A 11/83.

On-Site Sewage System Regulations, DOH 334-006A WAC 246-272.

These are available from your county health agency or by writing to:

Washington State Department of Health
Office of Community Environmental Health
Mail Stop LD-11
Olympia, WA 98504

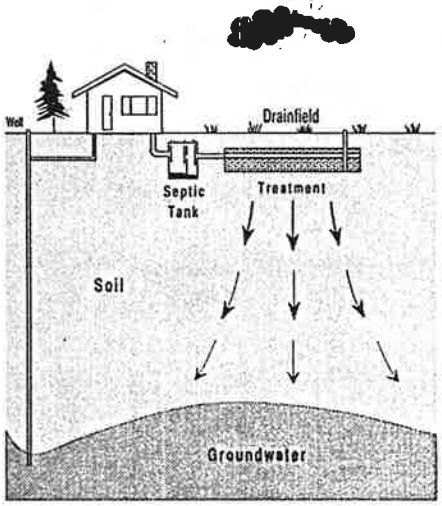
Other sources of information include your:

Local Health Agency
Soil Conservation Service Office
Cooperative Extension Office

Your Health Agency

Health
DOH Pub 334-009 (1/91)

Understanding And Caring For Your Septic Tank System



Washington State Department of Health

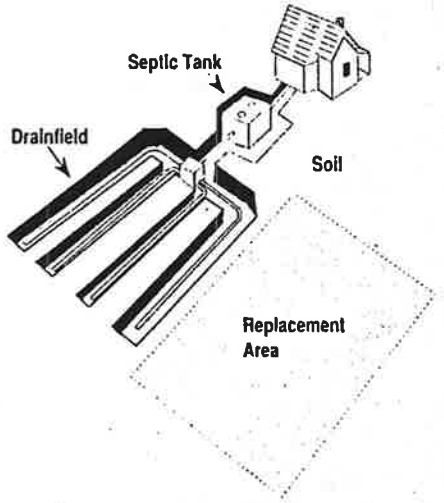
Washington State University Cooperative Extension Service

Households that are not served by public sewers usually depend on septic tank systems to treat and dispose of wastewater. A well designed, installed, and maintained septic system can provide years of reliable low-cost service. When these systems fail to operate effectively, property damage, ground and surface water pollution, and disease outbreaks can occur. Therefore, it makes good sense to understand and care for your septic tank system.

There are many different types of septic tank systems that can fit a wide range of soil and site conditions. The following information will help you to understand a simple type of septic system, and keep it operating safely at the lowest possible cost.

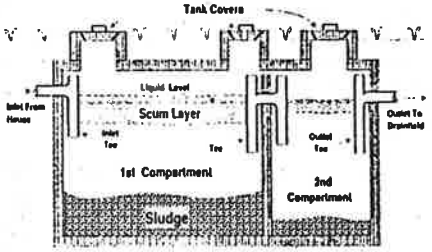
A "conventional" septic tank system has three working parts:

1. The septic tank.
2. The drainfield with its replacement area.
3. The surrounding soil.



The Septic Tank

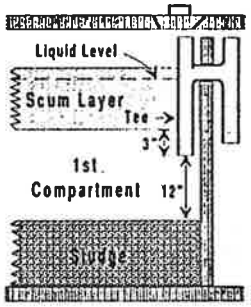
The typical septic tank is a large buried rectangular, or cylindrical container made of concrete, fiberglass, or polyethylene. Wastewater from your toilet, bath, kitchen, laundry, etc. flows into the tank. Heavy solids settle to the bottom where bacterial action partially decomposes them to digested sludge and gases. Most of the lighter solids, such as fats and grease, rise to the top and form a scum layer.



Septic tanks may have one or two compartments. Two compartment tanks do a better job of settling solids and are required for new systems. Tees or baffles are provided at the tank's inlet and outlet pipes. The intlet tee slows the incoming wastes and reduces disturbance of the settled sludge. The outlet tee keeps the solids or scum in the tank. All tanks should have accessible covers for checking the condition of the baffles and for pumping both compartments. If risers extend from the tank to or above the ground surface, they should be secure to prevent accidental entry into the tank.

Solids that are not decomposed remain in the septic tank. If not removed by periodic pumping, solids will accumulate until they eventually overflow into the drainfield. Most septic tanks need to be pumped every 3 to 5 years, depending on the tank size, and the amount and type of solids entering the tank.

"Early Warning" Levels Inside Your Septic Tank



The septic tank should be pumped whenever:

- the bottom of the scum layer is within 3 inches of the bottom of the outlet tee or baffle, or
- the top of the sludge layer is within 12 inches of the bottom of the outlet fitting.

Many products on the market, such as solvents, yeast, bacteria, and enzymes claim to improve septic tank performance, or reduce the need for routine pumping. None have been found to be of benefit. Some can cause solids to carry over to the drainfield, which results in early soil clogging and the need for a new drainfield. Products containing organic solvents contribute to groundwater pollution.

The wastewater leaving the septic tank is a liquid called effluent. It has been partially treated but still contains disease-causing bacteria and other pollutants. Discharging effluent onto the ground's surface or into surface and ground water is against Washington State law.

The Drainfield

The drainfield receives septic tank effluent. It has a network of perforated pipes laid in gravel-filled trenches (2–3 feet wide), or beds (over 3 feet wide) in the soil. Wastewater trickles out of the pipes, through the gravel layer, and into the soil. The size and type of drainfield depends on the estimated daily wastewater flow and soil conditions.

Every new drainfield is required to have a designated replacement area. It must be maintained should that the exisiting system need an addition or repair.

The Soil

The soil below the drainfield provides the final treatment and disposal of the septic tank effluent. After the effluent has passed into the soil, most of it percolates downward and outward, eventually entering the groundwater. A small percentage is taken up by plants through their roots, or evaporates from the soil.

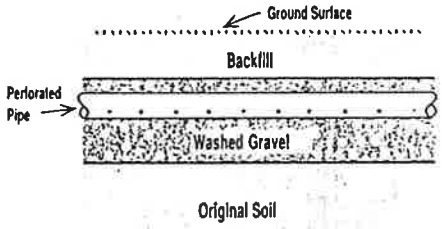
The soil filters effluent as it passes through the pore spaces. Chemical and biological processes treat the effluent before it reaches groundwater, or a restrictive layer, such as hardpan, bedrock or clay soils. These processes work best where the soil is somewhat dry, permeable, and contains plenty of oxygen for several feet below the drainfield.

System Failure

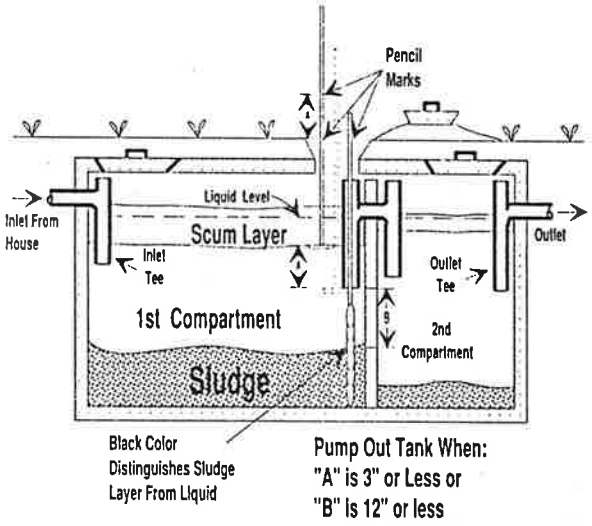
Warning signs of a failure:

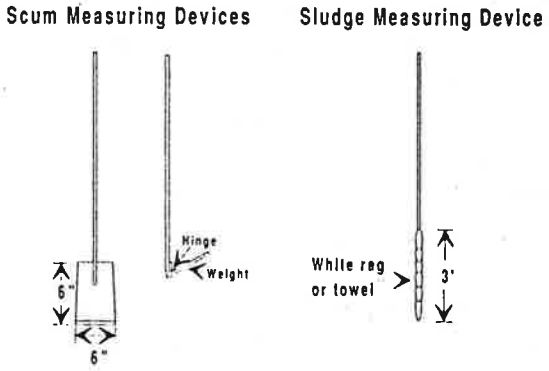
- Odors, surfacing sewage, wet spots or lush vegetation growth in the drainfield area
- Plumbing or septic tank backups
- Slow draining fixtures
- Gurgling sounds in the plumbing system

If you notice any of these signs or if you suspect your septic tank system may be having problems — contact your local health agency for assistance.



Inspecting Your Septic Tank





Washington State Department of Health

DOH Pub 334-016 (3/91)

Measuring the Scum Level

This procedure is for determining the distance between the bottom of the scum layer and the bottom of the outlet baffle or tee.

1. Establish a convenient reference point, such as a stick layed on the ground across the hole.
2. Attach a 6 inch square board to the bottom of a stick at least 6 feet long.
3. At the outlet end of your tank's first compartment, carefully push the stick through the scum layer to find the bottom of the baffle or tee.
4. Mark your stick at the reference point to indicate the bottom of the baffle or tee.
5. Raise the stick until you feel or see the stick contact the bottom of the scum layer.
6. Mark your stick again at the reference point to indicate the bottom of the sludge.
7. If the two pencil marks are 3 inches or less apart the tank needs to be pumped out. If the top of the scum is within 1 inch of the top of the outlet baffle the tank needs to be pumped.
8. Lay stick aside for later comparison with sludge level stick.

Measuring the Sludge Level

This procedure is for determining the distance from the bottom of the outlet baffle or tee to the top of the sludge layer.

1. Wrap 3 feet of a white rag or old toweling around the bottom of a stick at least 6 feet long and fasten it with tape or string.
2. Carefully lower the stick to the bottom of the first compartment. To avoid pushing it through the scum layer, lower the stick behind the outlet baffle or through the outlet tee.
3. Hold the stick in the tank for a few minutes to allow sludge particles to adhere to the towel. Mark the stick at the reference point to indicate the bottom of the tank.
4. Remove the stick carefully and note a distinct dark stain on the towel representing the sludge layer.
5. Lay the stick beside the scum stick. Line up the top pencil marks.
6. Measure the distance from the bottom of the scum stick to the top of the dark stain on the sludge stick.
7. If the distance is 12 inches or less, your tank needs to be pumped.

Septic Tank Maintenance

The lack of septic tank maintenance can cause sewage to back up into your house or solids to overflow to the drainfield. Once solids leave through the tank outlet, they can quickly clog a drainfield to the point where a new one is required. Most septic tanks need to be pumped every 3 to 5 years, depending on the tank size, and the amount and type of solids entering the tank. The inspection of the sludge and scum level is the only way to determine when a tank needs to be pumped. This is not necessarily a pleasant task, but can be done relatively easily. Septic tank pumping firms are available to perform this inspection.

Other Important Maintenance Information

1. Special septic tank additives will not reduce the need for regular pumping. These products can even cause solids to carry over to the drainfield causing early system failure. Some of these compounds have been shown to pollute the groundwater.

2. Materials not easily decomposed, including sanitary napkins, coffee grounds, cooking fats, bones, disposable diapers, and cigarette butts should never be flushed into a septic tank. They will not degrade in the tank, and will increase the need for more frequent tank pumping. They also can clog inlets, outlets, and the drainfield.

3. When pumping, leaving solids in the septic tank to aid in the starting of the system is not necessary. However, the septic tank must not be disinfected, washed, or scrubbed.

Preventive Maintenance Record

Date	Work Done / Comments	Firm	Cost

4. When the septic tank manhole is open, check the condition of the inlet and outlet baffles. Have the septic tank pumper replace them if they are in poor condition or are missing.

5. If you do not know where your septic tank is located, records of its location may be available at your local health department. If no record exists, probing with a steel rod gently tapped into the ground, starting five feet from where the sanitary sewer leaves the house, should help you find it.

6. Septic tank pumers are advertised in the yellow pages of the telephone directory. Lists of the licensed pumpers are also available from your local health department.

7. Garbage grinders should not be used unless additional capacity is built into the septic tank and drainfield. They use excessive amounts of water. The ground garbage increases the wastewater strength and the need for more frequent pumping of the tank.

8. Equipment is also commercially available to measure scum and sludge levels.

9. Never enter any septic tank. Poisonous gases or the lack of oxygen can be fatal. Any work on the tank should be done from the outside.

10. Keep accurate records of the location of your septic tank as well as dates when the tank has been inspected or pumped.

For more information about the King County Adopt-a-Road Program, mail this application to Jan Klippert, 900 King County Administration Building, 500 Fourth Avenue, Seattle, WA 98104. Or call Jan at 296-6510.

(Name of Organization) _____ (Date of Application) _____

(Mailing Address) _____ (Contact Person) _____

(City, State, ZIP Code) _____ (Best Day Time Phone) _____

Requested litter cleanup location _____ Best Evening Phone _____

ADOPT-A-ROAD
Program

Be Part Of The Solution
*
Together We Can Keep
King County
Clean And Beautiful!

Thanks For Helping
Beautify Our Community!

King County
Department of Public Works
500 King County Administration Bldg.
Seattle WA 98104
(206) 296-6510

Printed on Recycled paper

King County

Adopt-A-Road

An Opportunity To Beautify King County

Department of Public Works
Roads and Engineering Division

LITTER

... it's everyone's problem and now there's a way for everyone to help solve it.

Volunteer groups can "adopt" a two mile section of road by removing litter at least two times a year over a two-year period.

The King County Department of Public Works Roads Division Adopt-a-Road program is a litter-reduction campaign similar to programs that are successful in several states including Washington.

The program establishes a partnership between concerned citizens and the Department of Public Works by working together to provide a cleaner environment along neighborhood roads.

In return the Roads and Engineering Division will erect a permanent sign identifying the adopting group. Also the Department will provide trash bags, removal of filled bags, and provide a safety orientation for the volunteer crews.

Potential crew members must be in good physical condition and have good eyesight and hearing.*

* special project review and supervision is required for groups whose volunteers are under 15 years of age.

Adoptable Roads Guidelines

The Adopt-A-Road Program applies to all types of county roads; residential, collector, and arterials.

Volunteers should identify a section of roadway they would like to adopt.

Once identified the volunteers should call 296-6510 to confirm its availability for adoption. An application for adoption will be sent to the volunteers. After it is completed it will be processed by the Roads Division. Not all roads are adoptable. If the proposed road does not seem appropriate to the adopting group the County will suggest an alternative. Occasionally a special signing plan or traffic control plan will be necessary to help assure volunteer safety. The Roads Division will help develop these plans or identify an alternative work location.

The Adopt-a-Road coordinator will meet with the volunteers, give a safety orientation and review the project.

After the completion of the cleanup effort the County will install a sign recognizing the community service.

Neighborhood Beautification

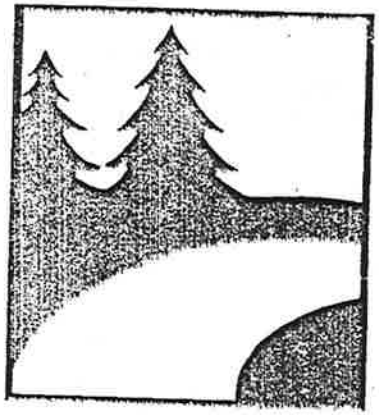
... a Community oriented litter cleanup program.

Anyone interested in volunteering may initiate an inquiry about the Adopt-a-Road Program.

Volunteers, including individuals and organizations may pick up litter in specific areas, neighborhoods or on a 2 mile length of road. Appropriate signs calling motorist's attention to the litter control effort and crediting the volunteers for their work will be erected by the Roads Division.

*
...Contribute To
Community Beautification
*
...Improve The Environment
*
...Gain Recognition For
Community Service
*
...Decrease Litter and Littering
*

Adopting a road offers a community many opportunities in addition to litter pick up, such as general maintenance including grass cutting, shrub pruning, tree/shrub planting, and maintenance.



ADOPT-A-ROAD
Program

Be Part Of The Solution

*

Together We Can Keep
King County
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King County
Department of Public Works
500 King County Administration Bldg.
Seattle WA 98104
(206) 296-6510

Printed on Recycled paper

King County

Adopt-A-Road

Volunteer Safety Guidelines

Department of Public Works
Roads and Engineering Division

Protect Yourself

Remember: You Are Working Near A Potentially Dangerous Environment . . . A Public Road

Use Common Sense

If in doubt act safely

Provide water for yourself

Avoid overexertion

Wear safety vest,

Light colored clothing

Wear long pants, shirt with long sleeves

Wear gloves

Wear boots or hard soled shoes

Avoid noxious weeds

Use sunscreen, sunglasses, as necessary

Use the hard hat

Avoid wearing headsets that could interfere with hearing

Be Prepared

Volunteers who have specific health or emergency needs such as allergic reactions to plants or insect bites should let their team leader know what action to take.

Give emergency phone numbers to your group leader.

Volunteers

DO

Be in good physical condition

Pick up litter, plastics, bottles, cans and glass

Stack bagged litter at predetermined locations

Do Not

Pick up unknown or hazardous materials such as animal bodies, broken glass, syringes, hypodermic needles. Report these to 296-8100.

Pick up heavy objects such as tires or appliances, etc. Report these to the Roads Division 296-8100 for pick up.

Pickup litter on bridges, overpasses or extremely narrow shoulders

Compact, squeeze, or overfill bags

Horse around or distract drivers

Use alcohol

For The Cleanup Team Leader

- Review safety rules each time the crew goes out
- The project supervisor should field check the project site before clean up begins
- The project supervisor should check the safety kit and assure there are vests and hard hats for all volunteers
- Be knowledgeable of first aid and emergency procedures
- Keep children in sight at all times
- Have at least one adult supervisor per four children
- Request special project review for volunteers under 15 years of age
- Work only during daylight hours
- Do not work in inclement weather
- Follow safety signing plan for sign location and vehicle location
- Use the warning flasher
- Work one side of road at a time
- Work facing oncoming traffic
- Carpool to and from project site
- Have transportation available
- Park vehicle off roadway and shoulders
- Plan for pick-up and volunteer shuttle
- Provide water or refreshments for the crew, take breaks, avoid heat stroke
- Keep group size to 10-12
- Be alert to conditions, holes, steep slopes, avoid construction sites and utility installation
- Where there is curbing the group can work up to the curb
- Do not work medians, pavement surfaces, or within 5' of pavement
- Do not cross travel lanes

King County
Division of Roads and Engineering
Department of Public Works
King County Administration Bldg.
500 Fourth Avenue - Room 900
Seattle, WA 98104-2339

1993 NO SPRAY REQUEST AND PROPERTY OWNER/KING COUNTY MAINTENANCE AGREEMENT

Please print

_____
Sign Location - Road/Address

NAME _____ Telephone: _____ home

ADDRESS _____ work/message

CITY _____ STATE _____ ZIP _____

Do you own the property? _____ YES _____ NO If you rent, please supply Owner's Name: _____

If additional or replacement signs are needed, please indicate quantity: _____

As a property owner in King County, I understand that King County will provide a 1993 Herbicide Vegetation Control Program to discourage undesirable brush growth and grass along the roadway shoulder.

I understand if I request the County *not* to spray adjacent to my property, then it becomes my responsibility to maintain the vegetation along said right of way. I further understand if I do not maintain the vegetation , this agreement becomes *null* and *void* and said right of way will be returned to the Herbicide Vegetation Control Program.

Therefore:

1. I request that King County Delete spray at the location indicated above.
2. I agree to post "Owner Will Maintain" signs on the borders of my property so the sign will be clearly visible from the driving lane.
3. I agree to control undesirable vegetation, including alder, willow, blackberry, and tansy ragwort, within the road right of way so traffic visibility is not hindered and the vegetation does not encroach onto the roadway surfaces.
4. I hereby accept the responsibility to install and maintain the "Owner Will Maintain" signs in the manner and at the location as set forth in this agreement. I further agree my performance under this agreement is at my sole risk and I shall indemnify King County, its agents and employees, and hold them harmless from any and all liability for damages, costs, losses, and expenses resulting from, arising out of, or in any way connected with this agreement, or from my failure to perform fully hereunder. I further agree to defend King County, its agents and employees, against all suits, actions, or proceedings brought by any third party against them for which I would be liable hereunder.

_____ Roderick E. Matsuno, Maintenance Engineer
Signature of Owner/Occupant

_____ _____
Date King County Issuing Person & Witness

Return to: King County Public Works
155 Monroe Avenue NE
Renton, WA 98056

NOTE: Alterations of this form will void agreement