Appendix C -

A Citizen's Manual for Developing Integrated Aquatic Vegetation Management Plans

WATERSHED AND LIMNOLOGICAL BACKGROUND INFORMATION

I. Watershed Features

Watershed Size / Boundaries

The size and topography of the watershed can significantly influence the water body. Watershed boundaries are marked by ridges and hilltops. The most obvious sources of drainage to a water body are inflowing rivers and streams (called **tributaries**). Other sources of inflow include surface flow or overland wash (often evident as water running over the ground, such as after a rainstorm). Water inflow below the surface of the ground to a lake or river is called **groundwater**. In cases where no streams flow into the water body, the watershed is the area from which groundwater is captured to supply the water body along with rainfall runoff.

Tributaries, Wetlands And Sensitive Areas

Tributaries: Identifying tributaries (rivers, streams, creeks) flowing into your water body can help you locate major sources of incoming waters. Land uses near these streams may also be important in controlling long-term water quality. Streams are "great sculptors", cutting into and scouring channels and creating sediment along the way. They are also "great collectors", carrying and eventually depositing nutrients, sediments, and other materials washed from the watershed.

Streams are shown on USGS quad maps and other general maps. The best source for stream mapping is the **Water Resource Areas Inventories,** available from your regional Department of Fish and Wildlife. These maps classify streams according to size and duration of flow, even down to seasonal streams that only flow in winter months. These maps also indicate waterbody use by salmon and obstacles to fish passage.

How to Determine Boundaries of a Watershed

A map showing the watershed boundaries (usually the area from which surface water flows toward the water body) is a very useful tool. Often a watershed map already exists for your lake or river. Watershed maps are sometimes available from Public Works or Planning Department of your county or city.

If a watershed map does not exist for your particular water body, you can construct one by using a topographic map. A topographic map shows a series of concentric circles called contour lines. Each contour line represents points on the surface that are the same elevation. The scale on topographic maps usually is presented in feet (or meters) above mean sea level (MSL). USGS quad maps also show contours, usually in 20 foot increments. Topographic or USGS quad maps can be obtained from local Public Works or Planning Departments, Department of Natural Resources, National Wetlands Inventory (US Fish & Wildlife), map stores or outdoor recreation stores. U.S. Geological Survey sometimes has regional groundwater maps, which would be useful for seepage lakes (groundwater-fed).

To find the watershed boundaries, read from the water body shoreline (the low point) outward on all sides to the highest elevation. Stop at the point before elevation readings begin to decrease. Once you have an initial boundary, check again to see you didn't stop too soon at a dip on the map. Often, local or county staff can assist you in checking watershed boundaries.

Wetlands and Sensitive Areas It is important to determine if there are any wetlands or **sensitive areas** adjacent to the problem water body. Certain aquatic plant control actions could impact these special, often fragile areas. National Wetland Inventory Maps (based on USGS quad series) can be obtained from Ecology, Wetlands Section. Check with your local or county Planning Department for a map of sensitive areas as defined by local Sensitive Areas Ordinances.

Land Use Activities In the Watershed

Human activities around a water body can have a significant influence on the aquatic system. Reducing pollutant inputs from livestock, croplands, forestry, residential properties and other sources can help protect the quality of the water body in the long term. These pollution sources, left unchecked, could make the water quality worse over time. Yet, while controlling these inputs helps reduce contamination, control of these sources alone is unlikely to provide a short-term solution to aquatic-plant problems. In most cases, in-lake management efforts form the primary means of dealing with the immediate problem of nuisance plants.

You can view recent **aerial photos**, if available, to get "the big picture" of the area around the water body. These may be obtained from your local or county Public Works or Planning Departments. The Department of Natural Resources in Olympia also has aerial photos in black and white and sometimes in color. Looking at aerial photos gives an important bird's-eye view of the watershed, but it may not be enough. For more detail on land uses, **zoning maps and land use maps** can help define the now as well as what the future may bring. Contact your local Planning Department for zoning maps and information on development trends in the region.

Point And Nonpoint Pollutant Source Locations

The watershed not only contributes water to maintain the water body, but also sediment, nutrients, organic matter and contaminants that can wash into the lake or river. Pollutants can originate from two types of sources: point and nonpoint. **Point sources** arise from a distinct source that can be easily traced; they typically discharge through a pipe, conduit or outfall structure. Sources of nutrients and contaminants that do not originate from a pipe are commonly referred to as **nonpoint sources**. These sources are more diffuse in nature and may not be as obvious as piped discharges. Nonpoint sources include runoff from agricultural areas, forests, urban runoff (lawns, driveways, roadways), construction sites, seepage from septic tanks, discharges from marina and recreational boating and other widespread sources. While nonpoint source loadings can originate from anywhere in the watershed, certain land use practices such as agriculture, construction, and city streets contribute greater inputs than other land uses such as forests and well-vegetated areas. Small quantities of pollutants from many sources in a watershed can have a cumulative effect, and can severely impact the quality of the receiving waters.

Since seeping or failing septic systems are often found to be sources of nonpoint pollution, areas with on-site waste treatment/disposal systems should be identified. A quick means of identifying potential nonpoint sources of pollution from septic systems around a water body can be accomplished by reviewing zoning maps from the Planning Department or as-built plans of developed communities. You can also contact local Public Health Department for more information.

Existing Watershed Management, Monitoring, Or Enhancement Programs

Integrated aquatic-plant management takes the holistic view, working in cooperation with other management efforts in the watershed. Certainly, there are things that everyone can do in the watershed to limit point and nonpoint inputs to lakes, rivers and streams. Use of **Best Management Practices (BMPs**) in agriculture, construction, home and yard practices are methods designed to prevent or reduce loadings of nutrients, sediments, pesticides, and other contaminants to receiving waters. In addition to zoning (information supplied by your local Planning Department), there may be watershed management programs such as agricultural BMP activities through your Conservation District or septic tank maintenance programs through your local Health Department or County Cooperative Extension Service.

The Presence Of Rare, Endangered, Or Sensitive Animals And Plants

Washington has a program called the Natural Heritage Information System, that maintains a database on endangered or high quality native plant and animal species. The Natural Heritage Information System is a administered jointly by Natural Resources" Washington Natural Heritage Program and Wildlife's Nongame Program. The Washington Natural Heritage Program is responsible for information on the state's endangered, threatened, and sensitive plants as well as high quality native plant communities and wetlands. Similarly, the Nongame Program manages and interprets data on wildlife species of concern in the state. Although the Natural Heritage Information System does not contain a complete inventory of all natural features in Washington, the database is continually updated.

The presence of rare, endangered or other state sensitive animal or plants species in the immediate area being considered for aquatic plant treatment may pose certain limitations on those activities. This is particularly true for use of certain aquatic plant control techniques, such as aquatic herbicides.

II. Water Body Features

Location, Size, Depth, And Shape Of Water Body

Location: A thorough description of where your lake is located is an important element in a Plan. A complete description should include the County, Township, Range, Section, and coordinates of your lake. This information can be obtained from topographic maps published by the U.

S. Geological Survey, or from soils maps consulted in your characterization of the watershed.

Size: The size, depth, and shape of a lake determines the area colonizable by aquatic plants and also influences the mixing that occurs in the lake. The timing and degree of mixing of lake water is a characteristic feature for each lake and is a key determinant of the productivity of the ecosystem. Size can vary from less than an acre to thousands of acres. Aquatic plants can typically cover a larger percentage of the lake area in small lakes and consequently play a larger role in the overall functioning of the ecosystem in small lakes than in large lakes.

Depth: The depth of a lake tells us much about the biology and productivity of the lake. In deep lakes, surface waters warm during the summer while bottom waters remain cool. This **thermal stratification** in deep lakes affects mixing of water in the lake. Deep waters do not mix with the surface waters. This can have profound impacts on the amount of nutrients entering the lake, the growth of algae, water clarity, and the area colonizable by nuisance aquatic plants. Shallow water bodies typically support more aquatic plant growth than deeper, steeper-sided basins.

The measurement of the shape of the lake basin is called **bathymetry**. Bathymetric lake maps are based on a series of depth measurements. Typically, depth is measured at intervals along transects. These measurements are plotted on a map of the lake and contours drawn to provide a topographic map of the basin. The depth and size (area) of a lake determine the lake volume, which, in turn, determines the **hydrology** of the system (see below).

Shape: The shape of the shoreline can also provide information about the lake's biology and physical/chemical characteristics. Lakes with many embayments and an irregular shoreline have more shallow areas, and are consequently more susceptible to nuisance plant growth. Similarly, a long narrow lake has a greater shoreline length, i.e., more shallow areas, than a more circular lake with the same area.

Water Sources (Tributaries, Groundwater) And Hydrology

A water body is defined by characteristics of water flow. As water is impounded in a basin, i.e., water is detained, a stream or river becomes a reservoir or lake. The period of detention of water in a basin is called the **hydraulic detention time**. The detention time can vary from days to years, depending upon the volume and flow through a particular water body. The inverse of detention time is the **flushing rate**, which is how fast the water in a lake is replaced. A lake with a detention time of 1 year has a water replacement, or flushing rate, of 1 lake volume/year. A lake with a $^1/_2$ year detention time has a flushing rate of 2 lake volumes/year, a 2 year detention time gives a flushing rate of $^1/_2$ lake volumes/year, etc. A short detention time (high water flow rates and low lake volume) results in a flushing rate that is so high that algal cells produced in the water column are washed out of the system faster than they can be replaced. Consequently, high flushing rates lead to low algal biomass, clear water, better and deeper light penetration into the lake, and better aquatic plant growth conditions.

Since water flow defines a water body and also influences its biological characteristics, it is important to consider the sources and volumes of water entering and leaving your lake. Are streams flowing in and out of the lake? Do they flow all year or seasonally? Is more water entering the lake than is flowing out? If so, the lake may be recharging the groundwater. If more is flowing out than is flowing in groundwater may be moving into the lake. Streams are also important in terms of fisheries support as well as possibly contributing to downstream movement of aquatic plant problems.

Physical, Chemical And Biological Characteristics Of The Water Body And Tributaries

Rooted aquatic plants compete with algae for light and nutrients in the water column. Removal of the aquatic plants may increase light availability and result in enhanced algae growth. If water column nutrient levels are high enough nuisance algae blooms may occur. Therefore, in order to prevent exchanging a nuisance aquatic plant problem for a nuisance algae problem you must consider whether the light, temperature, and nutrient environment of the lake and its tributaries may support nuisance algae growth. Some of the required information may be available from the sources listed at the beginning of this section. If the data are incomplete or inadequate a sampling program may be required to fill in the gaps.

Physical/Chemical (Water Quality) Characteristics

Transparency: Water transparency is one of the oldest and easiest methods for describing a lake. Over the years the method of measuring transparency has been standardized to allow comparisons of measurements taken by different people in different lakes. The standard method utilizes a **Secchi disk** to measure transparency. A Secchi disk is a large diameter, black and white plate that can be lowered into the water on a rope. The depth at which the disk disappears from view (the Secchi depth) is related to the amount of materials (algae, sediment, and dissolved organic material) suspended in the water column. The Secchi depth has been correlated with a number of indices that indicate the overall productivity of the lake, including the maximum depth at which aquatic plants can grow.

Temperature: Temperature profiles are important descriptive information because of the effect of temperature on biology and water density. Most biochemical reactions occur more rapidly at higher temperatures. Water temperature is an important determinant of photosynthesis rate in plants and respiration rates of plants and animals. Temperature determines the rate of growth of aquatic plants, and triggers the onset of growth in the spring and the fall dieback. Temperature also influences the density of water. Surface warming can lead to thermal stratification, as mentioned above, which can have significant impacts on nutrient availability, distribution and concentrations in lakes. In addition, extensive shallow areas (which typically have high aquatic plant densities) may undergo larger night/ day temperature fluctuations than deeper, off-shore waters, which can lead to onshore-offshore water currents that can shorten herbicide contact times and effectiveness.

Dissolved Oxygen: Measurement of dissolved oxygen profiles in the lake can provide much information about the overall functioning and productivity of the lake. All of the organisms that are commonly observed in lakes require oxygen to survive. In **stratified** lakes, oxygen in the cool, dark bottom waters can be used up by the bacteria that decay and decompose the dead algae cells that rain down from the warmer and more well-lit surface waters. Loss of dissolved oxygen in the bottom waters makes those waters inhospitable for fish and many other aquatic organisms. Loss of oxygen also causes chemical changes in the sediment that result in the release of nutrients that can fuel growth of algae and rootless aquatic plants, like coontail (*Ceratophyllum demersum*), in the lake.

Alkalinity: Alkalinity is a measure of the ability of water to resist changes in pH (a measure of acidity). Large fluctuations in pH can occur on a daily basis in lakes with low alkalinity and dense aquatic plant growth because of the chemical reactions of photosynthesis. Plant photosynthesis uses the energy of sunlight to convert the carbon in carbon dioxide and bicarbonate ions into plant tissue. The removal of carbon dioxide from the water causes pH to increase. During the night, respiration of plant tissues releases carbon dioxide into the water, causing pH to decrease. Extreme high and low pH can influence a number of chemical reactions that determine the availability of nutrients in the lake, and can lead to chemical toxicity problems for fish and insects.

Phosphorus: In many lakes the concentration of phosphorus in the water determines the growth rate of algae. Therefore, measurement of the concentration of phosphorus in the water is an indication of the potential productivity of algae in the lake. Two forms of phosphorus are generally measured in lakes. Dissolved, inorganic phosphorus is readily available for plant and algae uptake. Total phosphorus includes dissolved phosphorus and the phosphorus that is associated with algae, zooplankton, and particles in the water.

Phosphorus concentrations can vary considerably with depth in stratified lakes. Low dissolved oxygen concentrations in bottom waters of stratified lakes can result in a chemical reaction that causes phosphorus to be released from the sediment to the water. As a consequence, bottom waters can have much higher phosphorus concentrations than surface waters.

Nitrogen: Nitrogen often limits aquatic plant growth and can occasionally limit algae growth. As with phosphorus, there are inorganic and organic forms of nitrogen. Inorganic nitrogen can exist in three forms in lakes: nitrite, nitrate, and ammonia. Nitrite is usually present in only very small amounts. As with many other chemical constituents, the distribution of inorganic nitrogen varies with depth in stratified lakes. Nitrate is generally most abundant in the surface waters, and ammonia dominates the bottom waters. Presence of nitrates in the bottom waters may indicate that groundwater is entering the lake. High concentrations of ammonia and/or nitrates in the surface waters may suggest that there is septic pollution present.

Biological Characteristics

Your lake is a complex community made up of a variety of interacting plants and animals. Aquatic weeds and algae make up the plant community. Fish, **zooplankton**, insects, and wildlife interact with each other and the plant community to make a functioning aquatic ecosystem. The aquatic plant community is discussed in greater detail in Chapter 8- Map Aquatic Plants. This section describes other characteristics of the biological community that must be considered when developing a Plan.

Algae: The algae, or phytoplankton, community forms the foundation of the aquatic ecosystem and are the first link in the aquatic food chain. The algae in your lake can be used as indicators of the overall nutrient status of your lake and the likelihood of nuisance algae blooms. Certain algae, such as the blue-green algae (a.k.a. cyanobacteria), are characteristic of nutrient enrichment. Since algae and some aquatic plants both compete for dissolved nutrients, in certain cases, algae problems may increase if aquatic plants are removed. In other words, fewer weeds allow the algae to have a bigger share of the nutrient pie. As a result, the algae may flourish and create their own problems.

It is important to note that management for nuisance algae and management for nuisance aquatic plants in a waterbody require different tactics. The dominance of algae generally indicates a problem of excessive nutrients in the water column that could come from a variety of in-lake or offshore sources. Algae control usually necessitates both internal and external controls. Aquatic plant control is primarily concerned with in-lake treatment for long-term effectiveness. These may also be supplemented by watershed controls as a secondary aid.

The concentration of chlorophyll *a* in the water column is an index of algae abundance. Chlorophyll *a* is one of a family of pigments that make green plants green. It is the molecule that captures the energy in light and transfers it to a chemical form that provides the fuel for the entire ecosystem. High chlorophyll *a* concentrations in lake water indicate high algae densities, which influences the light available for aquatic plant growth.

Zooplankton: The zooplankton are microscopic aquatic animals that graze on the algae present in the water. Zooplankton graze algae like cows eat grass. High zooplankton densities can reduce algae abundance and result in high water clarity that permits aquatic weeds to proliferate. The efficiency of zooplankton grazing is dependent upon the relative size of the algae and zooplankton. Large zooplankton are the most efficient grazers, but they also look like big juicy steaks to hungry fish.

Fish: There is a fine balance between the algae, zooplankton and fish in your lake. Many small fish depend upon zooplankton for food. If zooplankton populations are reduced by the fish, algae can grow unchecked. Using the cow/grass analogy, if wolves (fish) eat the cows (zooplankton), the grass (algae) grows tall. If the wolves are eliminated by hunting (big fish eat little fish), the cow population increases, and the grass is short. Since algae determines light penetration of the water, changes in the fish community can affect aquatic weed growth in your lake.

Many lakes in Washington are stocked with catchable-size trout. Introduction of many large, fish into your lake can have a ripple effect all the way down the food chain, and can affect aquatic weed distribution and growth. The reverse is also true; changes in the aquatic plant community due to your control and management activities, can affect the fish population. Information on the native and stocked fish in your lake can be obtained from the Department of Wildlife.

Wildlife: Your lake may serve as a resource for a variety of waterfowl and wildlife. Some waterfowl feed on aquatic plants, while birds of prey, like eagles and osprey, may fish in a lake or river. Muskrats, beavers, otters, deer, and other animals may be residents or visitors. Your management activities may alter the habitat quantity or quality available for wildlife. A seasonal census of wildlife utilization of the lake should be included in a Plan. Local residents and the Department of Wildlife are good sources of information on the kinds and numbers of wildlife that depend upon your lake.

Shoreline Use

Your examination and characterization of the watershed will provide some information on land use on the shoreline. A more detailed look at the shoreline is necessary to evaluate the feasibility of some aquatic-plant management techniques. Some herbicides cannot be used near drinking water intakes; others require a waiting period before the water can be used for irrigation purposes. In addition, you may identify areas that could be a source of nutrients to the lake (e.g., failing septic systems and heavily-fertilized lawns) and contribute to water quality problems (See previous section on Point and Nonpoint Pollutant Sources).

Outlet Control And Water Rights

What you do in your lake may effect water users downstream and you must consider their water rights. Lake drawdown and subsequent refilling would affect flow below the outlet. Would altering flow affect someone's water rights or fish habitat downstream? Would herbicide use affect downstream uses? Water level manipulation requires some type of outlet structure. Who controls the outlet structure and lake water level? Are they willing to cooperate in your efforts to manage aquatic vegetation? **It is important to note that certain water rights and established in-stream flow rates are legally protected and must be maintained.**

Salmonids require special consideration. If salmonids migrate through your lake the management plan must accommodate their movements. Use of grass carp for control of aquatic plant growth usually requires containment structures to prevent their movement out of the lake. Because it is difficult and expensive to design a containment system that keeps grass carp contained, but allows free passage for salmon, Fish and Wildlife rarely issue permits for grass carp stocking in waterbodies with salmon. The Department of Fish and Wildlife can provide information about outlet control and information regarding salmon movement into and out of your lake.

References and Resources on Lake, River and Reservoir

Monitoring and Ecology

- Nonpoint Source Pollution Assessment and Management Program[7]
- Puget SoundBook[8]
- The Lake and Reservoir Restoration Guidance Manual[4]
- Ecology's Citizen Monitoring Project[E]
- Volunteer Lake Monitoring: A Methods Manual[9]
- A Citizen's Guide to Understanding and Monitoring Lakes and Streams[6]

Ambient Lake Water Quality Monitoring

The following monitoring parameters and schedules were suggested by the Thurston County Lakes Program staff. These parameters and schedule are intended to provide information on the basic nature of a lake system, such as whether stratification occurs, and to track trends in lake water quality.

Required Equipment

- Kemmerer bottle
- Secchi disk
- Haach kit or dissolved oxygen meter
- Bottles for laboratory analysis (provided by laboratory)

Field Parameters

Oxygen: Samples taken at four depths - surface, at 1/3 of lake depth, 2/3 of lake depth and near the bottom. Equipment: Haach dissolved oxygen kit (full range) or a dissolved oxygen meter.

Temperature: Samples taken at four depths - surface, at 1/3 of lake depth, 2/3 of lake depth, and near bottom. Equipment: Thermometer (can be in kemmerer bottle)

Visibility: Secchi disk

Laboratory Analysis

Chlorophyll a: Composite of epilimnion. Can be determined by: 1. Approximation of the photic zone. Calculate by multiplying aveage secchi depth times 1.5. or by 2. The temperature and dissolved oxygen profile.

Total phosphorus: Samples taken at two depths - surface and near bottom.

Observations

Weather, algae blooms and other features observed on sampling days.

Sampling Frequency

Minimum lake monitoring: Spring, summer, fall (three sampling events)

More intensive sampling: A more detailed picture of the lake can be obtained through more intensive sampling schedule, emphasizing the spring-fall months (total of eight sampling events): Monthly May through October, two sampling events in winter months.

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