Oregon DEQ Harmful Algal Bloom (HAB) Strategy

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DEQ
State of Oregon
Department of Environmental Quality

This report prepared by:

Andy Schaedel
Oregon Department of Environmental Quality
811 SW 6th Avenue
Portland, OR 97204
1-800-452-4011
www.oregon.gov/deq

Contact:
Dan Turner
(503) 229-6682
turner.daniel@deq.state.or.us

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Abbreviations and Acronyms

BEACH	Beach Environmental Assessment Communication and Health
BMP	Best Management Practices
BOD	Biochemical Oxygen Demand
CAFOs	Concentrated Animal Feeding Operations
CCL	Contaminant Candidate List
CBOD	Carbonaceous Biochemical Oxygen Demand
CDC	Centers for Disease Control
CLR	Center for Lakes and Reservoirs
CNPCP	Coastal Nonpoint Pollution Control Program
CSO	Combined Sewer Outflow
CWA	Clean Water Act
CWS	Clean Water Services
DEQ	Oregon Department of Environmental Quality
DEQ DWP	Department of Environmental Quality Drinking Water Program
DIN	Dissolved Inorganic Nitrogen
DLCD	Department of Land Conservation and Development
DMAs	Designated Management Agencies
DNA	Deoxyribonucleic acid
DO	Dissolved Oxygen
DOP	Dissolved Orthophosphate
DSL	Oregon Division of State Lands
EPA	U.S. Environmental Protection Agency
FERC	Federal Energy Regulatory Commission
FIFRA	Federal Insecticide Fungicide and Rodenticide Act
FPA	Forest Practices Act
FY	Fiscal Year
GAC	Granular Activated Carbon
GIS	Geographical Information Systems
GRTS	Grants Reporting and Tracking System
GWMA	Groundwater Management Area
HAB	Harmful Algal Blooms
HABHRCA	Harmful Algal Bloom and Hypoxia Research and Control Act
LA	Load Allocation
LWQA	Lake Water Quality Assessment
MERIS	Medium Resolution Imaging Spectrometer
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
N	Nitrogen
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
NTU	Nephelometric Turbidity Units
ODA	Oregon Department of Agriculture
ODF	Oregon Department of Forestry
ODFW	Oregon Department of Fish and Wildlife
OHA	Oregon Health Authority
OPHD	Oregon Public Health Division
OPRD	Oregon Parks and Recreation Department
OSU	Oregon State University

OWEB	Oregon Watershed Enhancement Board
P	Phosphorus
PAC	Powdered Activated Carbon
PCS	Potential Sources of Contamination
PWS	Public Water System
SRF	State Revolving Fund
SWP	Source Water Protection
TA	Technical Assistance
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
USACE	U.S. Army Corps of Engineers
USBR	U.S. Bureau of Reclamation
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
WA	Watershed Approach
WHO	World Health Organization
WLA	Waste Load Allocation
WMS	Water Monitoring System
WPCF	Water Pollution Control Facilities
WQMP	Water Quality Management Plan

State of Oregon Department of Environmental Quality

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As with any report, while a great deal of effort and a number of significant contributions were made by many, any and all errors found in the report are the fault of the author. Also, the fact that someone is named above does not mean that they necessarily agree with the content of this document.

As with any product developed for the first time, there is considerable room for improvement. It is the author's hope that this strategy, in some form, gets updated on an annual or biennial basis. Hopefully, both the information and recommendations will be useful to DEQ management and staff to better preventing and controlling HABs over time.

1. Organization of the Report

The purpose of this document is to describe and recommend improvements to an overall strategy that the Department of Environmental (DEQ) can implement in order to prevent and control, where possible, Harmful Algal Blooms (HAB) in Oregon. The primary audience for this strategy is DEQ management and staff. This document may also be useful to others, particularly the wide range of partners that are involved addressing HABs in Oregon.

This report consists of 6 sections (listed by section number below):

2. Introduction: this section discusses the purpose and scope of this document and outlines DEQ's current HABs strategy.

3. HABs in Oregon: this section provides:

   - a general background on HABs;
   - a description of Oregon's current HABs surveillance program and identifies waters where health advisories have been issued, the algal species of concern based on the advisories, and other waterbodies of potential concern; and
   - a general characterization of the HABs problems, based on what is known about the types of problems that Oregon is currently experiencing with HABs, with implications for their management;

4. General Approaches for Controlling and Preventing HABs: This section provides background on general methods used to control and prevent HABs;

5. HABs Management – The Big Picture: This section briefly describes current federal efforts to address HABs and nutrients and the likely impact of Climate Change on HABs;

6. DEQ Programs to Address HABs: This section describes many of DEQ's Water Quality Program subprograms that can be used to control and prevent HABs and makes a number of recommendations that can be considered for improving the DEQ's ability to control and prevent HABs.

7. Synthesis: This section pulls together the actions that have been recommended throughout the report, particularly in Section 6. Actions are grouped by DEQ subprogram or activity and the level of effort needed to implement the action is shown. This level of effort includes: actions that are currently being implemented and should be maintained; actions that require minor operational adjustments; actions that can be done as staff time becomes available; actions that would take additional funding; and actions that would likely require action by the Oregon Legislature or the U. S. Environmental Protection Agency (EPA). In some cases, an action may require multiple levels of effort.

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2. Introduction

2.1 Background – Why a HAB Strategy Document?

Since 2000, the Oregon Health Authority (OHA) has issued public health advisories for more than 40 waterbodies in Oregon, which include lakes, reservoirs, ponds and portions of rivers, due to the presence of Harmful Algal Blooms (HABs). These harmful blooms consist of cyanobacteria, also known as blue-green algae, that can produce toxins which are harmful to humans and animals. These blooms have resulted in a number of dog deaths, compromised recreational and drinking water uses of the affected waterbodies and have raised concerns regarding the suitability of these waters for other uses such as irrigation. Many of these blooms have occurred in popular recreational areas which has a negative effect on their water usage and has thereby affected local economies.

In 2010, the Department of Environmental Quality (DEQ) began to include waters with HAB health advisories on its 303(d) list of impaired waters, required under the Clean Water Act. The negative impact of the blooms on the beneficial uses of the waterbodies constitute a violation of state water quality standards. This listing requires DEQ to assess the waters to determine the causes of the blooms and establish a scientifically-based clean-up plan known as a Total Maximum Daily Load (TMDL).

Given the likelihood that the number of waters in Oregon that experience HABs is much larger, DEQ decided to develop a report that would describe DEQ's current strategy to identify and address (prevent and control) HABs in Oregon and make recommendations for its improvement. To assist in doing this, DEQ characterized HAB issues in Oregon and reviewed current efforts to address HABs in Oregon and elsewhere.

A variety of recommendations are made that will, when implemented (as time and budget allow), improve the capacity of DEQ to address HABs and their causes in Oregon. Some recommendations support continuation of actions that are currently being implemented or are starting to be implemented while other recommendations may involved minor changes in operations. Others recommendations may require additional budget for staffing or action by the Environmental Protection Agency (EPA) or by state or national legislative bodies.

The goal of this report is to provide DEQ with a plan of action that can be used over time to improve upon the prevention and control of HABs in Oregon, where possible.

2.2 Scope and Audience for this Report

This document focuses on Harmful Algal Blooms that occur in the fresh water environment and does not attempt to address blooms that occur in estuarine and marine environments[1] due to limitation of time and grant funding. However, many of the concepts and actions identified here can be used to address blooms in these waters.

The primary audience for this strategy is DEQ management and staff but it may be useful to others. The overall effort to address HABs in Oregon involves not only DEQ but a broad partnership which includes a wide range of federal, state and local partners. This partnership will be described in later sections of this report. Actions by all of the partners are vital in the implementation of actions to prevent and remediate

[1] Shellfish can be contaminated by events such as harmful algae blooms (HABs) or sewage spills. The Oregon Department of Agriculture (ODA) and Oregon Department of Fish and Wildlife (ODFW) jointly issue shellfish safety closures to protect recreational shellfish harvesters from consuming clams or mussels contaminated with harmful biotoxins or other contaminants

HABs. While the focus of this report is primarily focused on DEQ actions, many of the recommendations can affect partner agencies as well or could be done by others.

2.3 DEQ's Current HAB Strategy

Figure 2-1 provides an overview of DEQ's HABs strategy. The strategy can be described briefly as follows and will be discussed in more detail in the following sections, particularly Section 6:

Waters with HABs are determined in several ways:

- Primarily through the Oregon HABs surveillance program[2] which focuses on identifying waters that experience HABs, issuing health advisories and educating the public about their risks. Monitoring is generally done by management agencies or groups (e.g. lake associations) closely associated with lake or other waterbody and consists of watching for algal blooms and, if a bloom is present, collecting samples for algal identification and cell counts and/or algal toxins. Where there is no management agency or group associated with the waterbody, DEQ may do the sampling (depending on resources). The HABs surveillance program is discussed in Sections 3.3 and 6.1; and
- Through other monitoring efforts conducted by DEQ and others (agencies, regulated sources, universities, watershed groups, etc) that are aimed at determining general water quality and compliance with water quality standards. This effort is further described as part of the assessment process which is discussed in Section 6.2.

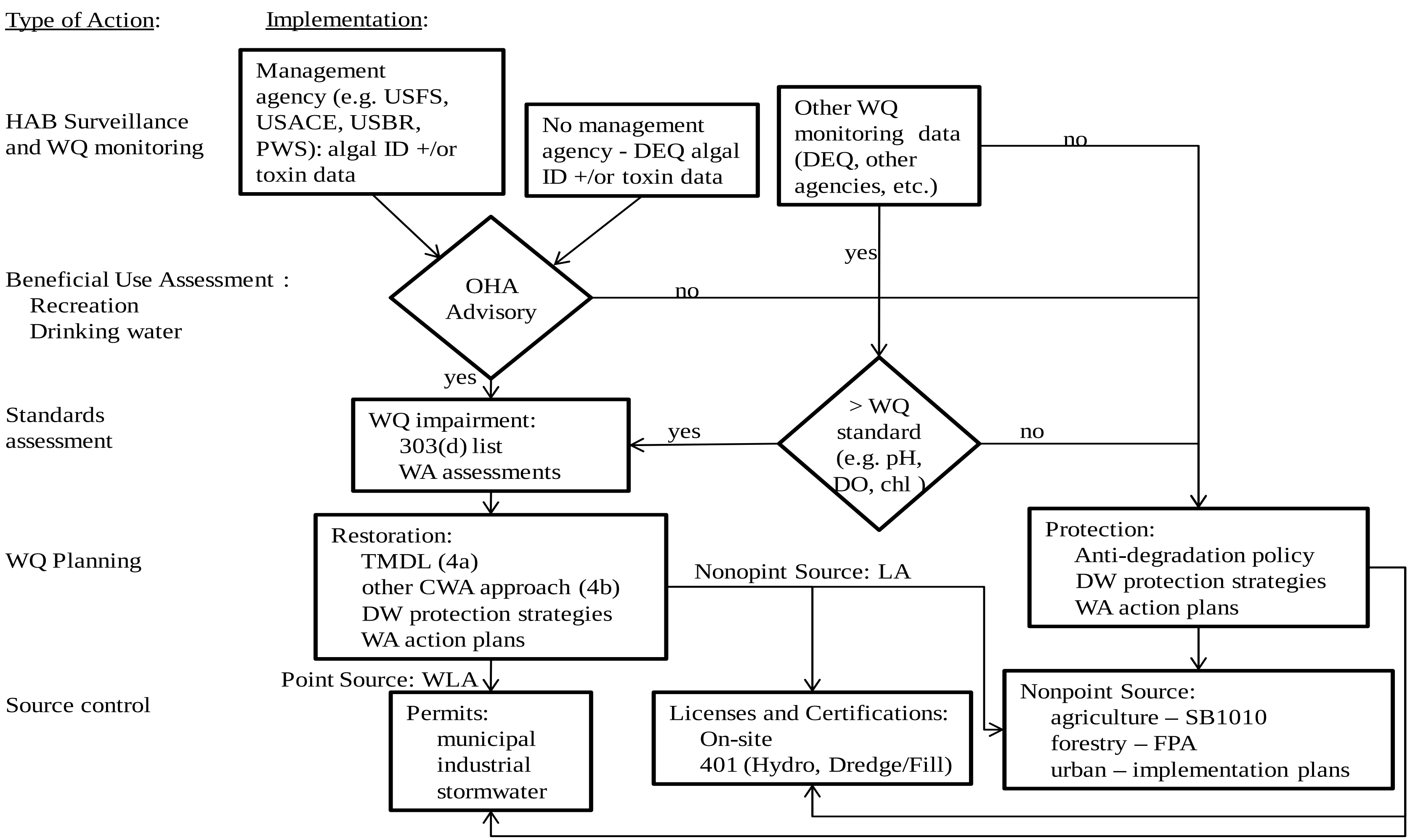
DEQ reviews these data and other available information to determine compliance with water quality standards through its water quality assessment process[3]. Waters not meeting standards are placed on the 303(d) list. Water quality standards and the assessment process are discussed in Section 6.2.

For waters on the 303(d) list, DEQ develops TMDLs or uses other strategies as a basis for plans to control HABs and restore water quality. TMDLs, which address HAB growth factors (described in Section 4), and other pollution reduction plans are discussed in Section 6.3. Waters not on the 303(d) list receive protection under DEQ's anti-degradation policy which is discussed in Section 6.2. DEQ's Drinking Water Protection program, which can address both types of waters, is discussed in Section 6.4.

Both the restoration requirements and protection policies inform various pollution control subprograms that DEQ manages that address HABs and their growth requirements including:

- Nonpoint Source Control[4] which is discussed in Section 6.5;
- On-site Systems[5] which are discussed in Section 6.6.1;
- Permited Point Sources [6] which are discussed in Section 6.6.2;
- 401 Program (Hydro Relicensing[7] and Removal and Fill[8]) which is discussed in Section 6.6.3

Figure 2-1 DEQ's HAB Strategy



3. Harmful Algal Blooms in Oregon

3.1 What are Harmful Algal Blooms (HABs)?[9]

HABs are a proliferation of photosynthetic organisms that can adversely affect human health, other organisms and the environment by the production of toxins. This is most often caused by blooms of cyanobacteria.

Cyanobacteria are a type of photosynthetic bacteria commonly referred to as blue-green algae. They are an ancient life form and are found naturally in ocean, freshwater and terrestrial environments. Cyanobacteria can grow as single-celled organisms, as a colony that may look like strands, or bunched together in mats or spherical clusters. Cyanobacteria are naturally occurring and provide key ecosystem functions and are links in aquatic foodchains. Many species of cyanobacteria are common, and not all produce toxins.

As with many bacteria, some cyanobacteria can produce toxins that are harmful to humans, pets, livestock and wildlife. When levels of nutrients, temperature, pH, and light are conducive to good growth, cyanobacteria can grow rapidly resulting in blooms[10] where the cyanobacteria become the dominant form of life in their environment. These blooms result in the appearance of visible green, blue-green or reddish brown foam, scum, or mats that float on or near the water surface. Some of these cyanobacteria species can release toxins, either while living or during the decomposition process that follows the bloom. These toxins can pose a public health hazard and a hazard to animals.

Cyanobacteria and along with other types of algal blooms can also negatively impact water quality by causing taste and odor problems in drinking water and causing fish to become unpalatable. In addition, these blooms can reduce the aesthetic and recreational value of the waterbody. Moreover, changes in water quality caused by the blooms, such as elevated pH levels, due to photosynthetic activity, and low dissolved oxygen levels from cell decomposition, can negatively affect aquatic life such as fish. In the United States alone, losses of recreational, drinking, and agricultural water resources due to HABs and other human-induced eutrophication were estimated as over $2 billion annually (Dodds et all, 2009).

3.2 Why are HABs a concern?[11]

At least 46 species of cyanobacteria can produce toxins (Chorus and Bartrum, 1999). Concern about the detrimental effects of freshwater cyanobacteria on water quality was heightened during the 1980s and 1990s as information acculmulated on the potency of their toxins (Oliver and Ganf in Whitton and Potts, 2000).

Cyanobacteria toxins are classified by how they affect the human body:

- Hepatotoxins which affect the liver;
- Neurotoxins which affect the nervous system; and
- Dermal irritants which affect the skin.

The most commonly reported symptoms of HABs are skin and eye/ear irritation and rashes on people or animals that have come into dermal contact with the blooms. Other algal toxin exposure symptoms

[9] From Stone et al, 2009; for an interactive, educational display about toxic blooms in Oregon,

[10] In potable and recreational waters, a bloom is often defined in terms of algal cells concentrations that cause a nuisances to humans and a lower limit may be set at ~ >10 ug/l chlorophyll a or >20,000 cells/ml (Oliver and Ganf in Whitton and Potts, 2000).

[11] From Stone et al, 2007 - and WHO website

include diarrhea, cramps and vomiting. In extreme cases, death may occur. For example, in Oregon, there have been several documented deaths of dogs as well as numerous reported but undocumented deaths of dogs, livestock, big horn sheep and other animals that have come in contact with HABs. Elsewhere, algal toxins have been associated with deaths of bald eagles and waterfowl[12].

Potential routes of exposure to cyanobacterial toxins include from oral ingestion, aspiration of water into the lungs, inhalation of mist and dermal contact. Exposure can result from a variety of cyanotoxin-containing water uses including: drinking water; water recreation (swimming, skiing, boating, etc); inhaling aerosols from water-related activity such as skiing, boating or irrigating; using dietary blue-green algae supplements that are contaminated with cyanotoxins; and dialysis[13]. Animals can be further exposed by cleaning algae off of their bodies by licking after being in the water. A recent food chain exposure of sea otters in California raises additional concerns about exposure via consuming contaminated shellfish (Miller et al, 2010) and a recent study found microcystin in fish tissue (Poste et al, 2011)

A list of toxins produced by cyanobacteria is shown in Table 3-1.[14] To date, Cyanobacteria genera common to Oregon lakes and reservoirs that have been the basis for Oregon Health Advisories are, most commonly, *Microcystis, Anabaena, Aphanizomenon and Gloeotrichia,* and, occasionally, *Lyngbya* and *Phormidium*.

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[12]

[13] Exposure through dialysis is rare but did happen in one documented case (Chorus and Bartram, 1999 – Chapter 4)

[14] It should be noted that the same species can have both toxic and non-toxic strains. It is not well known yet how the switch from non-toxic to toxic may be triggered.

Table 3-1. Specific toxins produced by genera of cyanobacteria worldwide (indicated by '+')[15]. Cyanobacteria that have been associated with Oregon Recreational Health Advisories are shaded (from Oregon Health Authority).

	Hepatoxins[16]			Neurotoxins[17]					Dermal Irritants		
Cyanobacterial Genera	Microcystin	Nodularins	Cylindrosper-mosin	Anatoxin-a	Anatoxin-a(s)	Homoanatoxin-a	Saxitoxins	ß-N-methylamino-L-alanine	Aplysiatoxin	Lipopoly-saccharides	Lyngbyatoxin
Anabaena	+		+	+	+		+	+		+	
Anabaenopsis	+									+	
Aphanizomenon			+	+			+			+	
Arthrospira	+									+	
Cyanobium	+									+	
Cylindrospermopsis			+				+			+	
Gloeotrichia	+									+	
Hapalosiphon	+									+	
Limnothrix	+									+	
Lyngbya							+		+	+	+
Microcystis	+			+				+		+	
Nodularia		+								+	
Nostoc	+							+		+	
Oscillatoria	+			+		+			+	+	+
Phormidium	+			+						+	
Planktothrix	+			+		+	+	+		+	
Raphidiopsis			+	+		+				+	
Schizothrix									+	+	+
Synechocystis	+									+	
Umezakia			+							+	

3.3 HABs Advisories in Oregon[18]

The World Health Organization (WHO) has suggested recreational and drinking water guidelines for protecting public health. Three potential routes of recreational exposure to cyanotoxins are listed by the WHO: 1) direct contact of exposed parts of the body, including sensitive areas such as the ears, eyes, mouth, and throat, and areas covered by a bathing suit; 2) accidental swallowing; and 3) inhalation of water. Cyanobacteria cell population has been more closely linked to health effects than specific toxin concentrations (i.e. Microcystin or Anatoxin), leading researchers to conclude that the recreational hazard appears to be due to additional or other unidentified cyanobacteria metabolites (Chorus and Bartram, 1999) but this is an area of on-going research.

Based on this understanding, the WHO has defined three levels of recreational guidelines associated with incremental severity and probability of adverse effects[19]:

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[15] This is an incomplete listing as toxins associated with cyanobacteria have not been fully characterized.
[16] Hepatotoxins affect the liver
[17] Neurotoxins affect the nervous system
[18] From the OHA website
[19]

- Relatively mild and/or low probabilities of adverse health effects: For protection from health outcomes not due to cyanotoxin toxicity, but rather to the irritative or allergenic effects of other cyanobacterial compounds, a guideline level of 20,000 cyanobacterial cells/ml (corresponding to 10 µg/l chlorophyll-a under conditions of cyanobacterial dominance).

- Moderate probability of adverse health effects: A level of 100,000 cyanobacterial cells/ml (equivalent to approximately 50 µg/l chlorophyll-a if cyanobacteria dominate) represents a guideline value for a moderate health alert in recreational waters.

- High risk of adverse health effects: The presence of cyanobacterial scum in swimming areas represents the highest risk of adverse health effects, due to abundant evidence for potentially severe health outcomes associated with these scums.

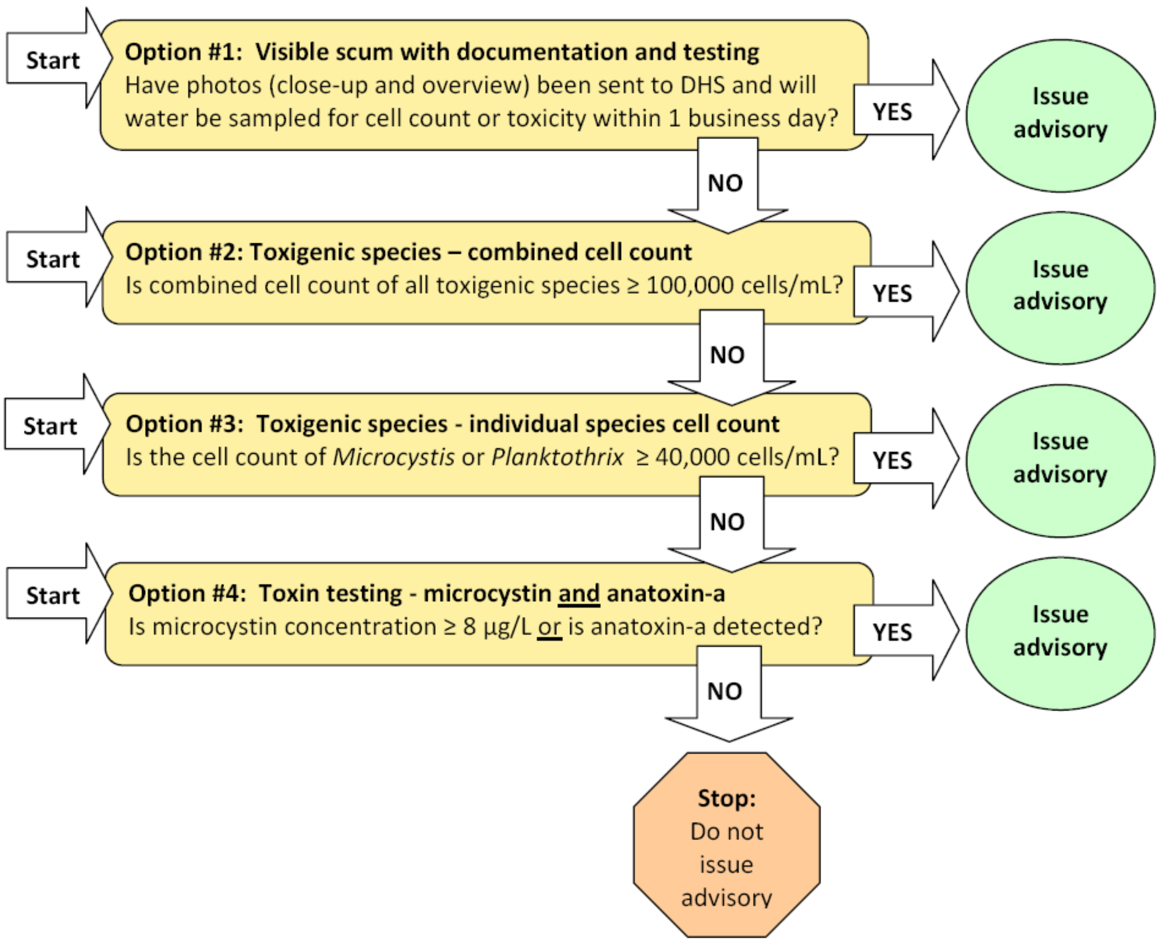
The WHO has also suggested a provisional drinking water guideline value of 1.0 ug/l for Microcystin-LR[20].

The Oregon Public Health Division (OPHD) of the Oregon Health Authority (OHA) runs the HAB Surveillance program which is working to gain a better understanding about the occurrence of toxic algae blooms in Oregon. This program advises the public when a bloom has been detected so people can take protective action to avoid illness – both for themselves as well as for pets and other animals. The HAB Surveillance program works with a variety of partners to share information, coordinate efforts and communicate with and educate[21] the public. Various partners collect water quality data from lakes that they manage lands, facilities such as dams or operate recreational sites (e.g. USFS, USACE, USBR, county or city park departments), withdraw drinking water (water supplies) or where they have an interest in protecting and improving lake water quality (e.g lake associations). DEQ will collect samples at sites where there is no clealy defined management agency or entity. OHA HABs criteria for issuing a recreational public health advisory is based on WHO guidelines and depends on the monitoring method selected. Options include: visible scum with supporting photographs and water analysis, cell counts, toxicity levels or a combination of two or more criteria options (see Figure 3-1). OHA issues Health Advisories and maintains a website that shows these advisories and contains other information regarding HABs[22].

Figure 3-1 OHA Criteria[23] for Issuing and Lifting a Recreational Public Health Advisory for HABs (as of April 2011)

Oregon Health Authority (OHA) is responsible for the decision-making and communication process of issuing and lifting public health advisories. While waiting for the OPH advisory process, local management may post warning signs as a precautionary measure to alert the public of the potential health risks associated with using the water during a harmful algal bloom.

OHA criteria for issuing a public health advisory depend on the method selected. Options include: visible scum (with supporting photographs and water analysis), cell counts or toxicity levels or a combination of two or more options.



OHA will lift advisories one week after tests show that the cell count and toxin concentration falls below the thresholds listed above. Cell count is required in addition to toxin testing to ensure there is minimal potential for further toxin release. The waiting period after testing is required to ensure that the same bloom doesn't re-surge.

To date, HAB advisories have been issued for over 40 waterbodies in Oregon (Table 3-2). These advisories have been issued by OHA or, in some cases, by partnering agencies that have posted warning signs or issued other public notices (e.g. City of Portland has posted advisory signs for Laurelhurst Pond when bloom occur).

Table 3-2. Harmful Algal Bloom (HAB) Advisories[24] (year of advisory shown)

Lake (Basin)	2011	2010	2009	2008	2007	2006	2005	2004	Algal Species With Cell Count Above OHA Criteria
Blue Lk (Willamette)		X	X						*Anabaena sp; Aphanizomenon flos-aquae, Microcystis aeruginosa*
Blue River Res (Willamette)		X							*Gloeotrichia echinulata*
Cougar Res (Willamette)	X								*Anabaena*
Crane Prairie Res (Deschutes)			X				X	X	*Anabaena flos-aquae*; *Anabaena planctonica*
Cullaby Lake (Northwest)	X								*Aphanizomenon*
Daly Lake (Willamette)[25]							X		*Anabaena sp.*
Detroit Res (Willamette)					X				*Anabaena flos-aquae*
Devils Lk (Mid Coast)			X	X					*Gloeotrichia echinulata*
Dexter Res (Willamette)	X	X	X	X					*Anabaena flos-aquae Anabaena circinalis*
Diamond Lk (Umpqua)	X	X				X			*Anabaena flos-aquae*
Dorena Res (Willamette)	X	X	X	X					*Anabaena flos-aquae; Gloeotrichia*
Elk Ck, Umpqua R (Umpqua)			X						
Fairview Lake (Willamette)		X							*Anabaena sp. Aphanizomenon sp.*
Fall Creek (Willamette)	X								*Gloeotrichia*
Fish Lk (Douglas Co, Umpqua)		X							*Anabaena flos-aquae*
Fish Lk (Jackson Co, Rogue)	X	X							*Anabaena flos-aquae*
Gerber Res (Klamath)	X	X							*Aphanizomenon flos-aquae, Gloeotrichia echinulata; Microcystis aeruginosa;*
Golden Gardens Pond (Will.)		X							*Anabaena flos-aquae; Microcystis aeruginosa;*
Haystack Res		X	X						*Aphanizomenon flos-aquae, Microcystis aeruginosa*
Hills Ck Res (Willamette)			X	X	X	X	X		*Anabaena flos-aquae; Gloeotrichia echinulata; Microcystis aeruginosa;*
Hyatt Res (Klamath)						X			
Lake Oswego (Willamette)[26]								X	*Microcystis aeruginosa*
Laurelhurst Pond[27] (Willamette)		X	X	X	X	X			*Microcystis aeruginosa*
Lava Lk (Deschutes)								X	*Anabaena flos-aquae*
Lemolo Lk (Umpqua)	X	X	X	X	X	X			*Anabaena flos-aquae*
Lookout Pt Res (Willamette)							X		*Gloeotrichia*
Lost Creek Res (Rogue)	X	X	X	X	X	X			*Anabaena flos-aquae Aphanizomenon flos-aquae, Microcystis aeruginosa*

[24] Health Advisory issued by OHA unless otherwise noted
[25] USFS posted the Health Advisories for Daly Lake
[26] Lake Oswego Corp posted the Health Advisory for Lake Oswego
[27] City of Portland posted the Health Advisory for Laurelhurst Pond

Lake (Basin)	2011	2010	2009	2008	2007	2006	2005	2004	Algal Species With Cell Count Above OHA Criteria
Marion Lake (Willamette)[28]							X		*Anabaena flos-aquae*
Mercer Lake (Mid Coast)									*Microcystis aeruginosa* – 2002 Advisory
North Fork Res (Willamette)	X	X							*Anabaena flos-aquae*
Odell Lk (Deschutes)			X	X	X		X	X	*Anabaena flos-aquae*
Paulina Lk (Deschutes)			X			X		X	*Anabaena flos-aquae*
Selmac Res (Rogue)								X	*Anabaena sp; Microcystis aeruginosa*
Siltcoos Lk (Mid Coast)				X	X				*Anabaena plactonica;* *Anabaena sp*
South Umpqua R (Umpqua)	X	X							*Phormidium favosum; Microcystis*
Sru Lk (South Coast)	X	X	X						*Anabaena circinalis*
Suttle Lk (Deschutes)								X	
Tenmile Lk (South Coast)	X	X	X					X	*Aphanizomenon flos-aquae, Microcystis aeruginosa, Anabaena plactonica;*
Timothy Lk (Willamette)	X								*Anabaena*
Upper Klamath Lk and Agency Lake (Klamath)									*Microcystis aeruginosa* - 1996 Advisory; *Aphanizomenon flos-aqua* present
Wapato Lk/Tualatin R (Willamette)				X					*Anabaena flos-aquae*
Whetstone Pond (Rogue)		X	X						*Anabaena circinalis*
Wickiup Res (Deschutes)			X	X				X	*Anabaena flos-aquae; Gloeotrichia echinulata; Microcystis aeruginosa*
Willow Lk (Rogue)		X							*Aphanizomenon flos-aquae; Microcystis aeruginosa*
Willow Ck Res (Umatilla)	X	X	X	X	X	X			*Anabaena flos-aquae; Aphanizomenon flos-aquae; Microcystis aeruginosa*

3.4 Algal Species of Concern in Oregon Fresh Water Environments

As shown in Table 3-2, most of the health advisories issued in Oregon have been due to high cell counts for *Anabaena flos-aquae.* Other cyanobacteria for which advisories have been issued include: *Anabaena circinalis, Anabaena planctonica, Aphanizomenon flos-aquae, Gloeotrichia echinulata, Microcystis aeruginosa and Phormidium favosum.* [29] This section discusses some of the features that can give Cyanobacteria a competitive advantage under a variety of water quality conditions and discusses some of the features for the more common Cyanobacteria genera associated with Health Advisories in Oregon.

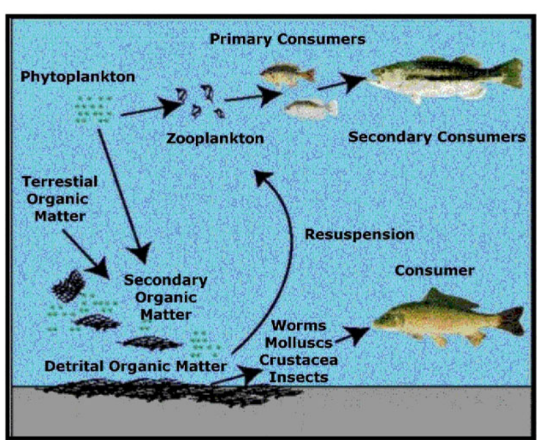
General Information on Cyanobacteria[30]: Cyanobacteria are widely distributed ancient prokaryotic[31] organisms capable of performing photosynthesis. They are generally considered responsible for the dramatic increase in oxygen concentrations on earth, early in the development of life on earth. They are typically abundant in warm, shallow, nutrient rich waters (especially waters enriched with phosphorus) but can be found in a variety of environments. Cyanobacteria play an important role in freshwater

[28] USFS posted the Health Advisory for Marion Lake
[29] It should be noted that optical taxonomic identifications to the species level is difficult. Identifications to the species level may be questionable and have greater uncertainty. Identifications to the genera level are more reliable.
[30] From Oliver and Ganf in Whitton and Potts, 2000; Huisman et al, 2005; Crawford, 2008; Oberholster et al, 2004 -
[31] Lacking a cell nucleus, typically unicellular bacteria

ecosystems because of their ability to produce oxygen, fix nitrogen from the atmosphere, and serve as the base of aquatic food chains.

Cyanobacteria have several unique characteristics:

- **Buoyancy:** Some cyanobacteria, typically those that cause a surface bloom, have gas vesicles that allow them to control their buoyancy and move to a favorable light and/or nutrient condition. This allows them access to significant pools of ammonium which are often found close to the sediments and move back up to favorable light conditions. Most other algae will settle during quiescent conditions, away from favorable light. Cyanobacteria with gas vesticles can form a surface scum to shade out other phytoplankton underneath the scum.
- **Nitrogen fixation:** About one third of all cyanobacteria species are able to fix nitrogen (Oberholster et al, 2004), meaning that they can convert nitrogen gas from the atmosphere into reactive forms. They use specialized cells called heterocysts, with the nitrogen-fixing enzyme nitrogenase, which gives them a distinct advantage when inorganic nitrogen concentrations fall below 100 ug/l (Oliver and Ganf in Whitton and Potts, 2000); nevertheless, these populations will ultimately be limited by available phosphorus.
- **Inorganic Nitrogen:** Nutrient uptake rates and half saturation constants differ among cyanobacteria, making some species more adept at utilizing different forms of nitrogen than others. Heterocystous cyanobacteria species such as *Anabaena* tend to have higher uptake rates for nitrate, while non-heterocystous species such as *Microcystis* have high uptake rates and low half saturation constants for ammonium compared to nitrate.
- **Phosphorus:** Generally speaking, cyanobacteria are poor competitors for phosphorus in comparison to other groups of algae such as diatoms and green algae which explains why cyanobacteria seldom reach dominance in oligotrophic[32] waters where phosphorus is a major limiting factor (Huisman and Hulot, 2005).
- **Nitrogen:Phosphorus ratio (N:P):** N:P ratios are used to asses the likelihood of nitrogen-fixing cyanobacteria occurring. However, nutrient ratios alone are not reliable indicators because concentrations of inorganic nitrogen must be less than the critical limiting concentration for nitrogen fixation to occur. Cyanobacteria have generally correlated better with absolute concentrations of TN and TP (Huisman et al, 2005).
- **Light:** Cyanobacteria have phycobilins, a group of three accessory pigments, which help to promote light absorption, especially under low-light conditions.
- **Anaerobic Conditions:** Some cyanobacteria are capable of living under or tolerating anaerobic conditions. Algal blooms often cause anaerobic conditions as cells die off and decay, consuming large amounts of dissolved oxygen which results in conditions that are unfavorable to most aerobic organisms which depend upon oxygen for survival.
- **Akinetes:** Cyanobacteria may form resting cells (Akinetes) that allow them to withstand environmental extremes, such as drought. An Akinete is a spore produced from a vegetative cell, often considerably larger than the original vegetative cell with similar contents. These are resting cells for some species of cyanobacteria and unicellular and filamentous green algae and serve as a survival structure. Akinetes are often found in sediments and can be used as an indication of past blooms in sediment core samples.
- **Grazing:** Phytoplankton, such as algae and cyanobacteria, are primary producers and are a food source for the next trophic level up such as zooplankton. Cyanobacteria are typically subject to lower grazing pressure from zooplankton than other genera of phytoplankton due to a variety of factors



[32] Waters low in nutrients and plant life

including their ability to form large colonies with mucilaginous membranes, their relatively low nutritional value and their production of toxins. Zooplankton grazing can reduce the biomass of cyanobacterial populations provided they are present before the cyanobacteria attain a size larger than the animals can manage.

- **Temperature:** In general, cyanobacteria tend to dominate later in the summer which has led to the belief that they can grow better in warmer temperatures than other groups of algae. However, high temperatures are also associated with thermal stratification and less turbulent mixing which provide an advantage to gas vacuolate cyanobacteria rather than temperature (Oliver and Ganf in Whitton and Potts, 2000). High temperature tolerances may allow cyanobacteria to survive better in warm waters.
- **pH:** The observation that cyanobacteria dominate lake phytoplankton at times when pH is high has led to the hypothesis that they are able to outcompete other algae during these conditions. Some studies tend to support this hypothesis but others conclude that the high pH (low carbon dioxide) conditions are a result of the bloom (Oliver and Ganf in Whitton and Potts, 2000).

These characteristics can give cyanobacteria a competitive edge over other forms of algae when environmental conditions are suitable for them.

Appendix A contains more about the population dynamics of cyanobacteria and some characteristics of commonly found cyanobacteria in Oregon. It is not complete or exhaustive but is intended to provide more information and links to the interested reader.

3.5 Waterbodies of Potential Concern for HABs

As described in Section 3.3, the HAB surveillance program currently conducted in Oregon relies on partner organizations to collect and share data. The U.S. Forest Service (USFS) and Army Corps of Engineers (USACE) are two of the most active partners in this program, as they manage lands and recreational facilities on a number of lakes, particularly near the Cascade Mountains. The lakes that have advisories shown in Table 3-2 reflect this active involvement of those two agencies in sampling for HABs as many of these lakes are USACE reservoirs or are lakes surrounded by USFS lands. As shown in Figure 3-2, most of the lakes that have HAB advisories are located in the Cascades, Klamath Mountain, Willamette Valley, and Coast Range ecoregions[33] with very few in Eastern Cascades, Blue Mountain, Columbia Plateau, Northern Basin and Snake River Plain Ecoregions. This could be due to the distribution of sampling efforts by active partner agenciess in the surveillance program rather than the true geographic distribution of the HAB problem. In other words, the list of lakes for which Health Advisories have been issued probably does not reflect the extent or the total number of lakes that might be experiencing HABs in Oregon.

To get a better estimate of the potential extent of the HAB problems in Oregon waterbodies, DEQ gathered data from several readily available sources that have information related to presence and magnitude of cyanobacteria and algal blooms in Oregon. A list of lakes that are of 'potential concern' for HABs was developed from the following three sources of information:

- Atlas of Oregon Lakes (Johnson et al, 1985): The Atlas assembled data from 202 lakes (each greater than 50 acres) and reservoirs (each greater than 100 acres) throughout Oregon. This report provided a summary of the lakes including major studies that were carried out prior to the early 1980s. This data source was reviewed for the 1994/1996 303(d) list of impaired waters resulting in the identification of over 90 lakes as having potential aquatic growth problems. The potential aquatic growth problems could be macrophytes, HABs or other forms of algae. These were identified based on levels of nutrients, chlorophyll a, pH, and dissolved oxygen and algal/macrophyte identifications. These lakes had been entered into DEQ's Integrated Report

[33] Ecoregions of Oregon

data bases and are shown as either Category 5 (impaired and TMDL needed), Category 4 (impaired and TMDL completed and approved by EPA or other pollution controls are in place) or Category 3 (potential concern, need additional data) depending of if a TMDL had been developed or if there was sufficient amount of data to meet the Category 5 listing criteria. The above identified waterbodies (Categories 3, 4 and 5) are included in the list of waterbodies of potential concern for HABs below if OHA has not posted the lake in the past.

- An Analysis of Phytoplankton of Oregon Lakes (Sweet, 1985): This report was a lesser-known companion piece to the Atlas and summarized information on the common phytoplankton species in Oregon lakes. The report included results of 127 samples collected from 108 lakes that were part of the effort that went into producing the Atlas and summarized available phytoplankton data from earlier published reports on algae in Oregon lakes. The most abundant algal species were summarized by lake. Approximately 60 lakes had abundant cyanobacteria species. These lakes are included on the potential concern list below if they have not been posted by OHA in the past. This analysis was more specific to potential HABs problems.

- Remote Sensing of Chlorophyll *a* Concentrations to support the Deschutes Basin Lake and Reservoir TMDL (Turner, 2010)[34]: This study analyzed 10 years (1999 – 2008) of Landsat image data that covered the Deschutes Basin and portions of adjacent basins (Willamette, Umpqua, Rogue, Klamath, Hood and Sandy). The Landsat satellites collect data at a spatial resolution of 30 meters, in the visible and infrared wavelengths with a 16-day repeat cycle. Reflectance data are collected in bands within a designated portion of the electromagnetic spectrum. Bands 1 to 3 are in the visible portion of the spectrum: blue, green and red, respectively. Band 4 collects data in the near-infrared portion of the spectrum. The ratio of band 2 (blue) to band 1 (green) was found to have the best regression, based on R^2 values, with chlorophyll *a*. Data were collected for lakes generally greater than 3 acres. Based on this analysis, DEQ identified 42 lakes that may have had significant algal blooms in the 10 year study period. These lakes are included on the potential concern list below if they have not been posted by OHA in the past. This analysis did not distinguish between HABs and other algal blooms (e.g. diatoms, green algae, etc).

Based on data from these three reports and other information that was gathered, a total of 132 lakes and 4 segments of rivers (summarized in Figure 3-2 and Table 3-3, waterbodies are listed in Appendix B) were identified as being of potential concern for HABs or other potentially harmful aquatic growth. At the time of this report, some of these waters were on, or are proposed for, the 2010 Section 303(d) list (see discussion in Section 6.2 related to Section 303(d) listing of impaired waters). It should be pointed out that the type of analysis done here to evaluate lakes of potential concern was not specific to or predictive of cyanobacteria concentration for advisory purposes. Other deleterious growth. either macrophyte (aquatic weeds) or other, non-toxic forms of algae, may occur that can interfere with beneficial uses rather than HABs.

As shown, lakes at risk for experiencing HABs or other types of excessive aquatic growth can be found throughout the state. To give some perspective on the magnitude of the potential concern, the total number of lakes by size range was calculated for the state, ecoregion, and basin from the National Hydrography Data Base. The lakes of potential concern were broken into similar groupings. As the lakes of concern analysis focused on the larger lakes (typically greater than 50 acres), the numbers are more representative of the larger lakes, especially those greater than 100 acres and likely those greater than 50 acres. As shown in Table 3-3, the 132 lakes and reservoirs that are of concern for aquatic growth represent approximately 25% of the lakes in the state that have an area greater than 50 acres.

34

Figure 3-2 Waterbodies of Concern for HABs including lakes, reservoirs and rivers

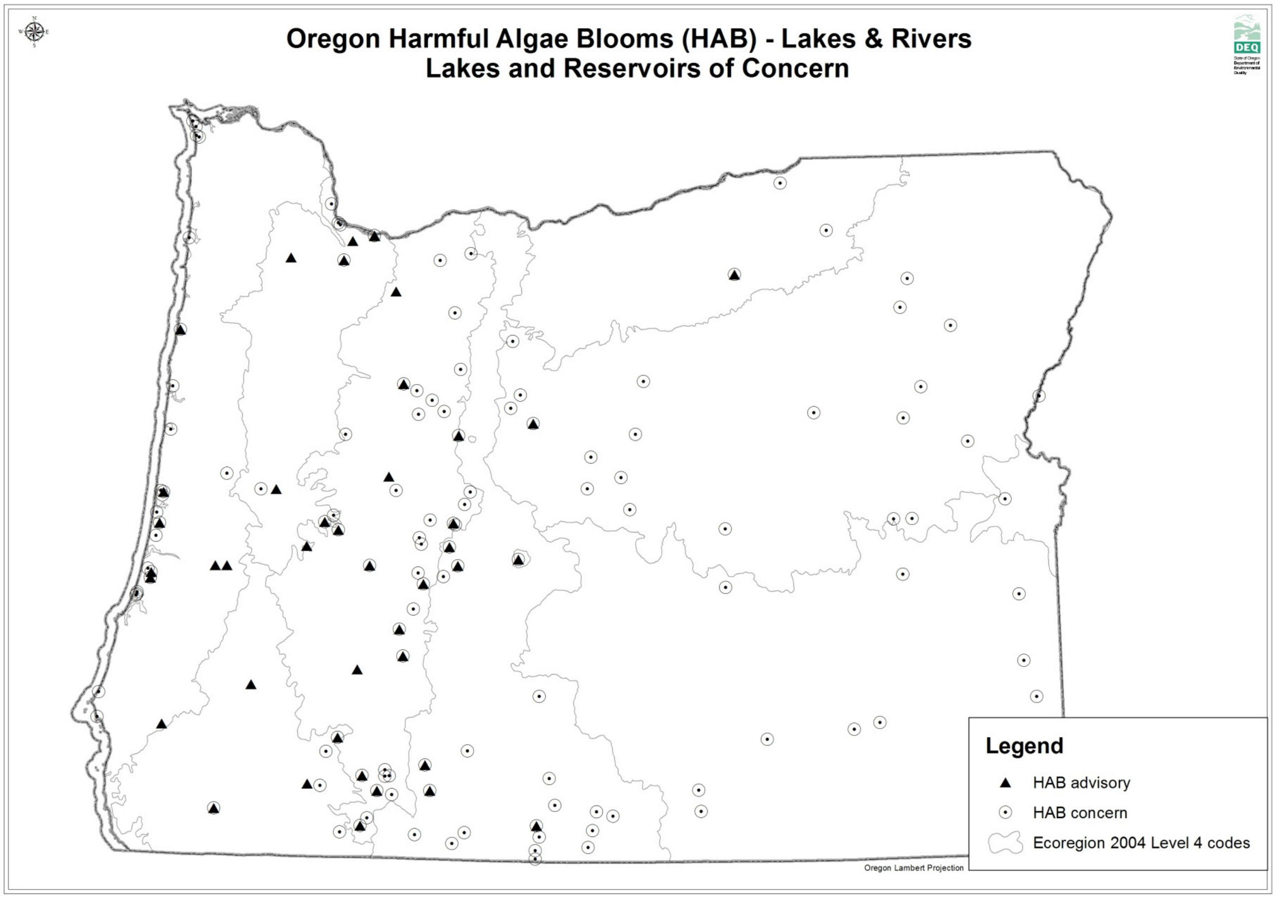


Table 3-3. Comparison of the lakes and reservoirs of potential concern in Oregon to the total number of lakes and reservoirs.

Number of Lakes & Reservoirs in State by size ranges						Lakes of Concern Statewide					Percent concern	
State-wide	**Size Range (acres)**				**Total**	**Size Range (acres)**				**Total**	% >100	% > 50
Waterbody type	<10	10 to 50	50-100	>100		<10	10 to 50	50-100	>100		acres	acres
Lake, Pond or Reservoir	35,041	1,133	160	252	**36,586**	3	25	13	91	132	36%	25%
						0%	2%	8%	36%	0%		

Number of Lakes & Reservoirs in State by Ecoregion						Lakes of Concern by Ecoregion						
	Size Range (acres)				**Total**	**Size Range (acres)**				**Total**	% >100	% > 50
Ecoregion Name	<10	10 to 50	50-100	>100		<10	10 to 50	50-100	>100		acres	acres
Blue Mountains	7,883	136	23	24	8,066		3	3	12	18	50%	32%
Cascades	7,621	197	32	54	7,904		13	4	23	40	43%	31%
Coast Range	3,171	92	15	25	3,303	1	3	5	15	24	60%	50%
Columbia Plateau	931	23	-	8	962				3	3	38%	38%
Eastern Cascades	2,703	93	20	44	2,860		3	1	16	20	36%	27%
Klamath Mountains	3,361	57	2	10	3,430		2		3	5	30%	25%
Northern Basin and Range	3,284	333	54	68	3,739		1		9	10	13%	7%
Snake River Plain	237	3	1	3	244				1	1	33%	25%
Willamette Valley	5,850	199	13	16	6,078	2			9	11	56%	31%
Total	35,041	1,133	160	252	**36,586**	3	25	13	91	**132**	36%	25%

Number of Lakes & Reservoirs in State by WRD Basin						Lakes of Concern by Basin						
	Size Range (acres)				**Total**	**Size Range (acres)**				**Total**	% >100	% > 50
Basin Name	<10	10 to 50	50-100	>100		<10	10 to 50	50-100	>100		acres	acres
North Coast	1,205	46	4	7	1,262		1	1	3	5	43%	36%
Mid Coast	648	18	4	9	679		2	2	6	10	67%	62%
Umpqua	1,519	35	3	9	1,566			1	2	3	22%	25%
South Coast	979	33	5	9	1,026	1		2	6	9	67%	57%
Rogue	2,540	46	2	7	2,595		3		6	9	86%	67%
Willamette	10,890	290	30	38	11,248	2	6	2	19	29	50%	31%
Sandy	263	8	1	4	276		1			1	0%	0%
Hood	359	10	3	1	373			1		1	0%	25%
Deschutes	4,594	103	19	33	4,749		4		14	18	42%	27%
John Day	1,415	21	2	2	1,440		1			1	0%	0%
Umatilla	677	17	-	7	701				3	3	43%	43%
Grande Ronde	2,549	35	9	2	2,595		1	1		2	0%	9%
Powder	724	39	3	8	774				4	4	50%	36%
Malheur	816	23	6	8	853			1	4	5	50%	36%
Owyhee	411	11	-	4	426				3	3	75%	75%
Malheur Lake	1,408	61	11	22	1,502		1	1	3	5	14%	12%
Goose & Summer Lakes	2,004	253	41	47	2,345		1		6	7	13%	7%
Klamath	2,040	84	17	35	2,176		4	1	12	17	34%	25%
Total	35,041	1,133	160	252	**36,586**	3	25	13	91	**132**	36%	25%

3.6 Characterization of HABs Problems in Oregon and Implications for their Management

Understanding HABs in Oregon waters is a key to the planning and implementation to prevent and control them. Selected summaries of waters with HAB related Health Advisories have been developed as part of this project, in part, as a means to better characterize the waters that experience HABs and to inform the strategy development. Forty-three lakes/rivers have had public health advisories either issued by OHA or acknowledged by OHA through 2010. Thirty-one of these waterbodies have been summarized as part of this strategy drawing from a variety of readily available sources including: the Atlas of Oregon Lakes, OHA data bases, Turner (2010) and available studies for each lake. All thirteen Willamette reservoirs were summarized as a package so that they could be examined and discussed as a system with the USACE (however, there was not sufficient time to do this as part of the grant). In other words, an additional 7 USACE reservoirs were summarized as 6 of these have had HABs advisories.[35] This is a total of 38 lakes/rivers that have been summarized in a two to four page format (Table 3-4). These summaries can be found in the Appendix C.

Table 3-4. Waterbodies with HAB Health Advisories summarized in Appendix C

Waterbodies with HAB Health Advisories Summarized as Part of this Strategy:

Blue Lake (Willamette)	Odell Lake (Deschutes)
Crane Prairie Reservoir (Deschutes)	Paulina Lake (Deschutes)
Devils Lake (Mid Coast)	Selmac Lake (Rogue)
Diamond Lake (Umpqua)	Siltcoos Lake (Mid Coast)
Elk Creek, Umpqua River (Umpqua)	South Umpqua River (Umpqua)
Haystack Reservoir (Deschutes)	Suttle Lake (Deschutes)
Hyatt Reservoir (Klamath)	Tenmile Lakes (South Coast)
Lake Oswego (Willamette)	Upper Klamath and Agency Lakes
Laurelhurst Pond (Willamette)	Wapato Lake and Tualatin River
Lava Lake (Deschutes)	Wickiup Reservoir (Deschutes)
Lemolo Lake (Umpqua)	Willow Lake (Rogue)
Lost Creek Reservoir (Rogue)	

USACE Willamette Basin Reservoirs with Health Advisories through 2010 – Blue River, Detroit, Dexter, Dorena, Hills Creek, Lookout Point Res.; Summarized but no advisories through 2010: Big Cliff, Cougar, Cottage Grove, Fall Creek, Fern Ridge, Foster, Green Peter;

Waterbodies with HAB Health Advisories Not Summarized as Part of this Strategy:

Daly Lake (Willamette) - USFS advisory in 2005, limited data available
Fairview Lake (Willamette) –2010 advisory, insufficient time to summarize
Fish Lake (Umpqua) – 2010 advisory, insufficient time to summarize
Fish Lake (Rogue) – 2010 advisory, insufficient time to summarize
Gerber Reservoir (Klamath) – 2010 advisory, insufficient time to summarize
Golden Gardens Pond (Willamette) – 2010 advisory, insufficient time to summarize
Marion Lake (Willamette) – USFS advisory in 2005, insufficient time to summarize
Mercer Lake (Mid Coast) – 2002 advisory, insufficient time to summarize
North Fork Reservoir (Willamette) – 2010 advisory, insufficient time to summarize
Sru Lake (South Coast) – limited data available
Whetstone Pond (Rogue) – limited data available
Willow Creek Reservoir – Atlas and reports not available, insufficient time to summarize

[35] The USACE Reservoir summaries will need quite a bit more work as the Corp has a fair amount of data that has not been summarized or published. As noted in Section 3.6.3, it will be useful to work futher with the Corp as there as a great deal of information available on the reservoirs that would be useful as a basis for developing reservoir management plans, particularly for Willow Creek Reservoir which is being studied by University of Idaho.

A number of lakes that have had HAB Health Advisories did not get summarized (Table 5-1). The summaries were developed early in this project (Spring/Summer 2010) so lakes which had OHA issued Health Advisories prior to 2010 did not get summarized. Therefore, six lakes which only had 2010 advisories and two lakes that had advisories which were issued by the USFS did not get summarized. Additionally, three other lakes were not summarized as this effort keyed off of readily available information (e.g. Atlas of Oregon Lakes, published lake studies) and pulled in remote sensing information that was collected in the Cascades. Information for these lakes was not readily available.

These summaries were used as part of the basis for a problem characterization that helped to inform the HABs strategy development. HAB problems in Oregon have been initially characterized as follows:

3.6.1 Control of External Loadings of Excess Nutrients From the Watershed

External loadings of excess nutrients from the watershed are a major driver for HABs in many lakes and rivers, as would be expected. There is ample evidence that controlling nutrient input, principally phosphorus concentrations, but in some cases nitrogen concentration, is the primary key to reducing eutrophication[36].

Vollenweider first linked eutrophication to phosphorus input and the mean depth and retention time of lakes. The link between phosphorus and algal biomass was often illustrated with a log-log TP-chlorophyll regression indicating that long-term changes in algal biomass are explained by changes in phosphorus concentration. A large number of lakes have successfully recovered based on nutrient control (Cooke et al, 2005). Lake Washington near Seattle is a well studied example of lake recovery through control of phosphorus from the watershed where once common blooms of the cyanobacteria *Oscillatoria rubescens* no longer occur[37]. Long term, whole-lake manipulation studies have also been carried out in experimental lake areas demonstrating the impacts of nutrient additions (Schindler, 2006).

Thus, it was concluded that controlling nutrients was key to controlling cultural eutrophication. This is often called a “bottom up” hypothesis for lake management where the productivity and dynamics of a lake ecosystem are controlled by almost exclusively by nutrient and energy inputs at the bottom of the food chain. This is not to say that external sources of nutrients are the sole driver, as internal sources of nutrients within lakes should be examined and addressed as part of the management strategy as well, but decreasing inputs of nutrients, principally phosphorus, is the key for controlling eutrophication and HABs. More detailed discussion of nutrients, nutrient limitation and ratios of nitrogen to phosphorus (N:P ratios) can be found in Appendix D.

Development and implementation of TMDLs which address nutrient loading from the watershed are a key strategy for controlling HABs in these lakes. Examples of TMDLs in Oregon that place limits on external nutrient loads include: Klamath, Oswego and Tenmile Lakes and the South Umpqua River. These waterbodies have TMDLs that address phosphorus loadings from the watershed. Blue, Devils and Siltcoos Lakes are likely part of this grouping but TMDL-related studies are underway.

[36] Eutrophication is the general term used to describe the suite of symptoms that a lake exhibits in response to nutrient enrichment. Symptoms include: dense algal blooms or weed growth, associated elevated pH, and low DO in deeper part of the lakes from decay of sedimenting plant material (Schindler et al, 2008)

[37]

3.6.2 Introduced Fish Species Appear to Play a Significant Role Driving the Internal Loadings in Some Lakes

Introduced fish[38], either non-native, invasive or potentially through over fish-stocking, can result in alterations in lake food webs depending on the trophic[39] position of the fish. Depending on the diet of the introduced fish, the biomass or abundance of organisms in other trophic levels can be affected, including primary consumers such as zooplankton and primary producers such as phytoplankton (including cyanobacteria). For example, the introduction of fish that consume zooplankton may reduce zooplankton populations with a resulting increase in phytoplankton abundance. This concept is often termed “trophic cascade” and is defined as reciprocal effects of predator on prey that alter the abundance, biomass or productivity on a population, community or trophic level across more than one link in the food web (Carpenter, 2001). Introduction of a higher level predator, or removal of the zooplankton-eating fish, could result in lower levels of phytoplankton. This approach is an example of “top-down” control of primary producers (Carpenter et al, 1985) . While still debated, it is now accepted that trophic cascades, in some situations, can be manipulated to manage plant biomass of lakes (top-down hypothesis).

The cascading response of phytoplankton biomass to fish manipulation in lakes represents a major piece of evidence in support of the top-down hypothesis but there remains uncertainty and variability to the mechanisms driving the phytoplankton response fish removal. There is evidence to suggest that the decrease in biomass results from an increase in grazing pressure from herbivorous zooplankton (Sarnelle and Knapp, 2005). However, as many cyanobacteria species are unpalatable or difficult to graze upon given the formation of colonies or through effects of cyanotoxins, it has been shown that zooplankton have difficulty suppressing cyanobacterial blooms, once they occur. There is also evidence to suggest that a reduction in the supply of inorganic nutrients, as a result of the loss of fish excretion, is responsible for the decreased biomass (Eilers et al, 2011 – in press). It is very likely combinations of both factors are involved and is very dependent on conditions within a lake. Even after 25 years of research, there is a great deal more to be understood about the trophic cascade hypothesis.

Diamond Lake has been well studied and is a primary example the role that fish can play in altering nutrient cycling in lakes and resulting in HABs (Eilers et al, 2007; Eilers et al, 2011 - in press). A TMDL was developed and management plan implemented to significantly reduce the internal nutrient loading by reducing the tui chub populations (using rotenone) and adaptively managing the fish stocking program in order to address the HABs[40]. Odell Lake may have similar issues due to a different fish species (Kokanee) and the relationship between fisheries, nutrient cycling and HABs is currently under study. Other Cascade lakes which experience HABs where the fishery may be an important factor include: Lemolo, Lava, Paulina, Suttle, Wickiup, Crane Prairie, Fish (Rogue) and Marion. Lava, Lemolo, Fish and Paulina Lakes, all of which experience HABs, have active programs that are attempting to control and manage tui chub populations. Additionally, the impacts of introduced fish species are of concern in other lakes such as Devils (Grass Carp) and the Tenmile Lakes (a variety of warm water fish species) on the coast and Mann Lake (Goldfish) in Eastern Oregon. These impacts can be from legally and illegally introduced fish species.

DEQ will need to work with Oregon Department of Fish and Wildlife (ODFW) and a variety of other partners to further investigate the role of introduced fish species in lake eutrophication in Oregon.

[38] An **introduced** or **non-native species** is a species living outside its native distributional range, which has arrived there by human activity, either deliberate or accidental.

[39] The **trophic level** of an organism is the position it occupies in a food chain. A food chain represents a succession of organisms that eat another organism and are, in turn, eaten themselves. The number of steps an organism is from the start of the chain is a measure of its trophic level. Food chains start at trophic level 1 with primary produces such as plants, move to herbivores at level 2, predators at level 3 and typically finish with carnivories at level 4 or 5.

[40]

3.6.3 A Number of Reservoirs Experience HABs

Sixteen of the 43 waterbodies (37%) that have had health advisories issued through 2010 are reservoirs. Additionally, five other lakes with health advisories are natural lakes with water levels that have augmented with a dam. This number of identified reservoirs with HAB problems reflects, in part, that dam operators have been active participants in the Oregon HAB surveillance program. It also reflects the differences between reservoirs and natural lakes that can account for the large number of reservoirs experiencing HABs.

Reservoirs differ from lakes in their geologic history and setting, basin morphology and hydrologic factors. Some of these differences include (from Cooke et al, 2005):

- Location – reservoirs are located primarily where flooding may occur or where water shortages require water storage whereas natural lakes are often located in more “distinctive” regions (e.g. coastal dunal lakes, cascade lakes). Reservoirs typically are not sited based on water quality considerations;
- Assimilative capacity[41] changes when a river is changed into a reservoir and often creates an environment suitable for HABS (quiet water, warmer surface waters) whereas previously it would not likely support HABs (faster water; cooler temperature; less sunlight);
- Watershed area draining into a reservoir is usually much larger, often an order of magnitude greater, than natural lakes. Reservoirs are located toward the downstream boundary of the watershed whereas lakes tend to be more centrally located in a fairly symmetrical drainage often accounting for a higher areal water and pollutant loading.
- Average nutrient and sediment loads coming into a reservoir from a watershed are typically higher for reservoirs than natural lakes, given the higher volume of flow to the reservoir, and this material may have undergone a far longer period of in-stream processing than material loaded to natural lakes. Water often enters lakes via smaller streams that are likely to traverse wetland or littoral areas, whereas reservoirs may have characteristics of a river for long distances into the reservoir;
- Outlet structures – whereas a natural lake outflow is at its surface, reservoirs can have a variety of outlet structures which can affect in-reservoir mixing processes and affect internal nutrient loading. Reservoir operations for storage and release of water can greatly influence their limnological characteristics as well. Outlet structures and operations can also provide an opportunity for managing the reservoir.
- Shape – reservoirs are often elongated and dendritic or branching and can have a fair amount of interaction with large areas of shallow, warm sediments that can set up processes that allow sediment nutrient release and transport to the water column.

While reservoirs are different from lakes in many ways, they can be rehabilitated as well. Many reservoir rehabilitation projects, like many lake rehabilitation projects, involve the treatment of symptoms in the short term while the longer term issues are being addressed, such as loadings from the watershed or modifications to outlet structures (Cooke et al, 2005).

DEQ will need to work in close cooperation with the organization that operates the dam, both during the study phase of a TMDL and while that organization develops a management plan. There is a good opportunity for address a number of reservoirs at the same time as many reservoirs may be part of the same project or are located in similar areas.

The USACE, which is an active participant in the HABs surveillance program, operates 13 dams in the Willamette Valley, two dams in the Rogue, Willow Creek Reservoir near Heppner, along with four dams

[41] **Assimilative capacity** refers to the ability of a body of water to cleanse itself; its capacity to receive waste waters or toxic materials without deleterious effects and without damage to aquatic life or humans who consume the water.

in the Columbia between Oregon and Washington. HAB advisories have been issued at eight of these reservoirs (Willow Ck, Lost Creek, Blue River, Detroit, Dexter, Dorena, Hills Creek, and Lookout Point). USACE has developed a technical note that examines, in general, the impact of HABs on USACE operations and identifies management actions that can influence algal blooms (Linkov et al, 2009).

The Bureau of Reclamation (USBR) built 27 reservoirs in Oregon, mostly located in central and eastern Oregon and the Rogue basin. Five of these reservoirs have had HAB advisories (Hyatt; Gerber; Crane Prairie, Wickiup and Haystack with the latter three are part of the USBR Deschutes Project). Most of the other reservoirs were identified on the Waters of Potential Concerns for HABs in Appendix B.

Additionally, there are numerous reservoirs operated for power, water supply and irrigation purposes. HAB advisories have occurred at two reservoirs operated by power companies (North Fork Reservoir operated by Portland General Electric and Lemolo Reservoir operated by Pacific Power and Light) and one reservoir operated by a water suppler (Willow Lake operated by the Medford Water Commission).

3.6.4 A Number of Small Ponds and Wetlands in Urban and Agricultural Areas Experience HABs

A number of small ponds and lakes, and lakes that are turning into wetlands have experienced HABs including Laurelhurst Pond (Portland), Golden Garden Pond (Eugene), Whetstone Pond (Medford), Wapato Lake (Tualatin Basin). An active surveillance program will likely identify many more of these types of waters.

There are characteristics of small lakes and ponds that can make them more prone to experiencing HABs including (from Cooke et al, 2005):

- Small lakes and ponds typically do not thermally stratify in summer months or have small hypolimnetic[42] volumes and, with wind action, can mix continuously. Waters with large areas of shallow, warm sediments and with small hypolimnetic volumes provide ideal circumstances for processes that allow sediment nutrient release and transport to the water column (internal loading) which greatly stimulates algal growth. Plant productivity is often negatively correlated with mean depth and with the ratio of mean to maximum depth (i.e. the shallower the lake, the more algae and macrophytes) due to the factors mentioned above.
- Shallow lakes are typically less sensitive to significant reductions in external nutrient loadings because sediment/water interactions tend to maintain high nutrient levels. The nutrients released from bottom sediments tend to affect the entire water column as opposed to deep, stratified lakes (Welch and Cooke, 2005). Nutrient release may be very high from bioturbation[43], wind disturbance, the effects of gas bubbles released from the sediments, high pH from intense plant photosynthesis and from low levels of dissolved oxygen at the sediment-water interface.
- Shallow lakes are more likely to exist in one of two alternative and often stable states. The algal-dominated turbid state is almost a certainty at high nutrient concentration. Whereas the clear water state, possibly with macrophytes across the well-lighted sediments, will occur at low concentrations. Between these extremes, either the clear or turbid water state can exist, largely based on biotic interactions. Lakes with dense populations of planktivorous and benthivorous fish (e.g. carp, shad, bullheads) and herbivorous birds, are likely to have few phytoplankton grazers (large-bodied zooplankton), high internal phosphorus loading, turbid water and little chance of extensive establishment of native submersed plants. In contrast, shallow lakes dominated by piscivorous fish and birds (e.g. Great Blue Heron) may have abundant algal

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[42] The **hypolimnion** is the dense, bottom layer of water in a thermally-stratified lake.. It is the layer that lies below the thermocline (layer where there is a rapid change in temperature. Typically the hypolimnion is the coldest layer of a lake in summer.
[43] Sediment reworking by plants and animals

grazers, stable sediments, clear water, and populations of submersed plants, even at nutrient concentrations identical to the algae-dominated lakes (Moss et al, 1996)

In most cases, a shallow lake or pond will have either a community of macrophytes or turbid water with phytoplankton. A shallow lake that is free of both aquatic plants and algae is uncommon. Therefore, many small, shallow waterbodies will typically have more algal or rooted plant growth than a larger, deeper lake. Expectations and results of lake management techniques in these lakes can and should differ.

There is much discussion in the literature and at lake management forums about managing shallow lakes differently than deep lakes. Again, shallow lakes are often defined as ones where the euphotic zone extends to the bottom and do not thermally stratify. Quite often, they are waters less than 15 feet (5 meters) deep. Direct implementation of Management Plans, such as the one being implemented at Laurelhurst Pond, may be the more appropriate way to address these than using a TMDL approach. While management plans need to look at external sources of nutrients, particularly from stormwater and wildlife (e.g. geese), other internal factors such as vegetation, fish species and sediment need to be examined and addressed. Shallow lake rehabilitation often requires intensive in-lake management strategies (e.g. see Laurelhurst Pond Summary in Appendix C). These plans will need to address: the influence of the sediments on nutrient loadings and will often require sediment treatment or removal to a sufficient depth; plant vegetation – often removing invasive species and replanting the lake or pond with native species; and removing abundant bottom feeding and/or planktivorous species of fish and possibly replacing with piscivorous fish and birds to control fish populations and encourage zooplankton which graze on algae. Aeration is another option to increase lake circulation and to provide oxygen for the desired species. Some wetland plants also have been known to secrete substances that inhibit the growth of some forms of algae and can also be beneficial for controlling blooms (allelopathy).

Additionally, there is potential that small stormwater retention ponds may be good habitats for HABs. In the rapidly urbanizing South Carolina coastal zone, intensive landscape maintenance and turf management are significant sources of nonpoint source pollutant loadings. The stormwater best management practice of choice in this region is wet detention ponds, the majority of which are brackish lagoons. Typically, stormwater is piped directly into the ponds, and their capacity for processing pollutants is limited. These highly eutrophic brackish ponds are “hot spots” for harmful algal blooms – over 200 blooms from 23 different species were documented, many associated with measured toxins, fish kills or shellfish health effects. South Carolina has put together a task group[44] on HABs. One of its functions is to hold workshops on HABs and best management practices (BMPs) to aid in minimizing the presence of HABs. One BMP is use of the constructed wetland is designed to enhance denitrification, reducing nitrogen input to the pond, improving pond water quality, and decreasing stormwater and groundwater nutrient transport to downstream estuaries. These types of waterbodies may be of concern for HABs in Oregon and a similar approach as South Carolina’s may be useful.

As it is likely that more small lakes and ponds will be listed for HABs, it would be useful for DEQ staff to become more knowledgeable about in-lake management techniques for small shallow lakes.

3.6.5 A Number of Rivers Experience HABs and Have Resulted in Animal Deaths

HABs can be found in small pockets of water and side channels of rivers and streams during low flow and do not necessarily reflect the water quality in main part of the river. The toxins created by HABs can mix into and be found in the main stem however. Given the extensive river network in Oregon, it is a challenge to develop a surveillance program that can warn users in advance of specific areas where toxins may occur. Unfortunately, these areas have often been identified through animal deaths. Several notable incidents where dogs have died due to cyanotoxins occurred at several sites in the Umpqua Basin - Elk Creek and Umpqua River near Elkton; South Umpqua River below Canyonville in 2009 and 2010 respectively. Other animal deaths have been reported near the John Day River at Priest Hole, near the Owyhee Reservoir (Jacoby and Kann, 2007) and the Snake River in the Brownlee Reservoir pool.

Approaches for best addressing these situations need to be further explored but TMDLs that address nutrients and temperature and management plans that encourage restoration of flow and habitat are appropriate actions.

4. General Methods for Controlling and Preventing HABs[45]

Cyanobacteria can grow rapidly in favorable conditions, such as warm, calm, nutrient-rich waters. This section describes general methods to control and prevent HABs.

Many methods to manage HABs (e.g. dredging, circulation) are more specific to lakes as freshwater HABs most often occur in lakes. However, HABs do occur in a variety of riverine environments (slow moving segments, tidal segments, sloughs, etc) and many of these strategies or concepts can apply or be tailored to those environments as well.

Along with methods to prevent and/or control blooms within a waterbody, two other actions are often needed to reduce the risk to the public:

- educating the public as well as a wide range of professional staff about the risk of drinking, recreating or using waters that experience high densities of cyanobacteria; and
- treating the water to remove cyanobacteria and their toxins from drinking water supplies or providing alternative sources[46].

The importance of education and water treatment are not intended to be diminished although they are not the focus of the discussion below.

4.1 Controlling and Preventing HABs

Control and prevention of cyanobacteria blooms can best be addressed by attempting to manage their growth requirements – nutrients, habitat, light and temperature. These strategies include the following:

- Restricting nutrient availability (most typically forms of phosphorus and nitrogen):
  - External loading from the watershed that drains into the waterbody;
  - Internal loading from within lake or reservoir;
- Preventing quiescent, stagnant waters and reduce residence time by creating movement of water
- Reducing light availability;
- Reducing water temperature.

Plant growth regulators, such as various herbicides, barley straw, bacterial additions, can have short-term effects in controlling algal blooms but often treat the symptoms rather than the causes and need to be applied in an on-going fashion.

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[45] WHO website; Cooke et al, 2005; Carmichael, Wayne from *Workshop on Cyanobacteria Harmful Algae Blooms and Water Quality;* May 24-25, 2010; Corvallis, OR;

DOE website ; Cyanodata website

[46] For more information on treatment of water supplies

Restrict Nutrients

Phosphorus and nitrogen are most often the limiting nutrients[47] for algal growth. Phosphorus receives the most attention as it has often been found to be limiting in most freshwater systems (Vollenweider, 1968, Schindler, 2008). Phosphorus has also been viewed as the more controllable nutrient as certain forms of cyanobacteria can fix atmospheric nitrogen and their populations may be less sensitive to decreases in nitrogen loading. While there is much debate in the literature and studies of the specific waterbody in question are needed to determine the limiting nutrient, N and P co-limitation appears to be quite common in eutrophic systems. Therefore, constraints of both phosphorus and nitrogen input are likely needed for control of cyanobacteria (Paerl et al, 2011). A more detailed discussion about nutrients can be found in Appendix D.

External Loadings From the Watershed

The most important way of restricting nutrient availability is to reduce external sources of nutrients. The first step in any lake restoration project should be to assess the primary sources of nutrients. If external sources are predominant, then their control is essential for long-term water quality improvement. Several Oregon lakes (Lake Oswego, Klamath and Tenmile Lakes) and rivers (South Umpqua) that experience HABs have nutrient TMDLs established which require reductions in nutrient loadings.

Nutrients can come from a variety of sources on land, including natural[48] and human-related sources. Controls related to human-caused sources of phosphorus include:

- Point Source Controls (regulated under NPDES permits):
  - Wastewater Treatment Plants;
  - Confined Animal Feeding Operations;
  - Urban and transportation-related stormwater (under Municipal Separate Storm Sewer System (MS4) permits)
- Nonpoint Source Control - Land Management Activity including management of nutrients directly (e.g. fertilizer, pet and animal waste, waterfowl) or associated with runoff:
  - On-site Septic Systems
  - Urban and transportation-related sources – not regulated under DEQ permit (e.g. Storm Water Permits, Construction Permits, etc);
  - Agriculture – regulated by ODA under the Agricultural Water Quality Management Act (SB1010);
  - Forested Lands – regulated by ODF under the Forest Practices Act or under Federal Management Plans;

Nutrient loadings to a water body can be addressed at any one of several steps involved in the movement of the nutrient to a waterbody including:

- controlling the nutrient at its source (maintaining soils in their place, not adding fertilizer, wastewater treatment, etc);
- managing nutrient application (application, timing, placement of fertilizer or animal wastes; on-site system placement and maintenance; etc); and
- factors involved in nutrient transport[49] (rainfall, erosion, drainage systems, etc). Maintenace and restoration of shoreland, riparian and wetland vegetation is important to maximize their capacity for filtering out nutrients[50].

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[47] The nutrient in the shortest supply relative to other needed nutrients will be used up first and thus limit cellular growth

[48] Phosphorus in the Pacific Northwest may be naturally elevated due to phosphorus from volcanic igneous rock containing apatite minerals

[49]

Several potential actions for reducing nutrient inputs will be discussed further as they relate to DEQ programs (discussed in Section 6): waste water discharges, on-site systems, nonpoint sources, and lawn fertilization. There are a variety of documents that describe specific management practices that can be applied in a watershed to address nutrient management for various land uses (e.g. urban[51], agriculture[52] and forestry[53]) and will not be discussed in detail here.

Internal Loadings

Internal nutrient loads loads differ from external nutrient loads in that they are generated within the waterbody (e.g. nutrients released from the sediment or excretion from fish). Internal loads can account for a significant portion of the overall nutrient load and, in the case where most of the external loads are from natural sources, the internal loads may be the loads that can be managed. For example, in Diamond Lake, the internal load of phosphorus associated with the introduced tui chub was estimated to be four times higher than the external load and the control strategy focused on the elimination of the chub from the lake (Eilers et al, 2011 - in press). Controlling internal nutrient loading is particularly important because lakes may be slow in responding to changes in the external loading. For example, it may take years before lakes cleanse themselves of accumulated nutrient loads, particularly those accumulated in the sediments of shallow lakes. Additional in-lake management methods may be needed to rehabilitate the lake.

Internal loading may be due to biological processes (e.g., microbial activities, burrowing animals), chemical processes (e.g., high pH from photosynthesis) and physical processes (e.g., turbulence from the wind) (Cooke et al, 2005).

In-lake management techniques that can address internal loadings include:

- Phosphorus inactivation via chemical precipitation (e.g. alum)
- Dredging;
- Hypolimnetic aeration or hypolimnetic withdrawal;
- Sediment oxidation;
- Dilution and flushing;
- Biomanipulation[54] (including fisheries management)

Table 4-3 is a brief overview of these techniques. These methods are discussed in much more detail in the sources provided below.[55] These sources provide more information on the effectiveness, potential negative impacts and costs.

Prevent Quiescent, Stagnant Waters

Techniques for preventing quiescent, stagnant waters include actions that keep water moving such as through: aeration; circulation; and fountains (see Table 4-1). These techniques are usually more effective in ponds and smaller lakes. For example, Laurelhurst Pond in Portland will be adding four aerators and two circulators as part of its rehabilitation plan. However, circulation is being tested in larger lake systems such as Blue Lake (Multnomah Co) and Willow Creek Reservoir (near Heppner) and aeration is part of the overall management strategy used in Lake Oswego.

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54 Methods based on food web management and biological interventions.

55 Cooke et al, 2005; NALMS, 1990; Cyanodata

Reduce Light Availability

The most common means for reducing light availability include: chemical colorants and dyes; covers; and natural clay turbidity. These techniques are most effective in small ponds and, depending on the technique used, may require a permit if used in waters of the state. For streams, restoration of streamside vegetation and restoring the stream channel are techniques for increasing shade. Australia has used shade covers to prevent algal growth for protection of a number of water supplies.

Reduce Water Temperatures

There are limited means for reducing water temperature of a lake sufficiently to control a bloom and this is will be of further concern given climate change (see Section 5.3). However, a number of rivers that have HABs do not meet water quality standards for temperature. Addressing temperature through riparian restoration and management to increase shading as well as by other factors such as maintaining or enhancing flow and the stream channel improvements are also viable methods for controlling HABs that occur in Oregon rivers. Impoundments, especially small impoundments built on streams, can be a source of heating depending on how they are managed.

Use of Plant Growth Regulators

There are various compounds that can affect plant growth and have been used with mixed success:

- Herbicides, or more specifically, algicides can be applied to directly kill plants. These are most often used to address macrophytes. Copper Sulfate has been used for treating algal to address taste and odor problems in water supply reservoirs. However, copper sulfate treatments can have significant detrimental affects (copper builds up in sediment, release of toxins if applied to cyanobacterial blooms, etc).

- Barley straw appears to have algistatic properties when allowed to decompose in oxygen-rich waters (Cooke et al, 2005). Oregon State has been doing some research on barley straw, generating as many questions as answers, and has a website that has links to other useful and balanced resources on the use of barley straw for algal control[56].

- Microorganisms such as viruses (cyanophages) and bacteria are being investigated as a means to prevent or possibly control blooms (Foflonker, 2009).

Table 4-1. In-Lake Management actions for controlling excessive algal growth[57]

Method	Action	Short-Term Effect	Long-Term Effect	Cost	Potential for Negative Effects	Comments
Phosphorus Inactivation	Salts (iron, calcium or aluminum), typically alum, or synthetic polymers combine or sorb with phosphorus and settle; alum on sediment can block release of phosphorus under the right conditions. Algal levels decline because phosphorus levels decline. Lake Oswego uses alum along with Green Lake and Long Lake in Washington	E	E	G	L	Best done in waters where nutrients from watershed have been controlled; potential toxicity concerns
Dredging	Nutrient rich sediment is directly removed and depth is increased. Mirror Pond (Bend) and Vancouver Lake (Vancouver, WA) have been dredged.	F	E	P	F	Costly and concerns about effects from operation and spoil disposal; permit required
Artificial Circulation	A variety of methods have been used to move water, often destratifying a lake, to do a variety of things including: prevent algae from remaining in the photic layer, prevent quiescent conditions favorable to cyanobacteria and oxygenate the hypolimnion to prevent phosphorus release. A number of lakes have used or have tested circulation including Blue Lake and Willow Creek Reservoir	G	?	G	F	
Hypolimnetic Aeration	A method aimed at oxygenating the bottom waters and reduce the release of phosphorus from sediments but maintain thermal stratification by returning the oxygenated water to the hypolimnion. Lake Oswego and Willow Creek Reservoir have used aeration along with Lake Newman in Washington.	G	?	G	F	Most suitable for deep lakes
Hypolimnetic Withdrawal	Removal of nutrient-rich, oxygen-free water through a deep outlet, pumping or siphon. This can be effective at accelerating phosphorus export (although can have downstream impacts), reducing surface phosphorus concentrations and improve hypolimnetic oxygen content.	G	G	G	F	Downstream impacts
Sediment Oxidation	Decrease phosphorus release from sediments through a series of chemical additions (dependent on chemical conditions of sediments) = RIPLOX method.	G	E	F	?	

[57] From: NALMS, 1990, Cooke et al, 2005

Method	Action	Short-Term Effect	Long-Term Effect	Cost	Potential for Negative Effects	Comments
Dilution/Flushing	Nutrient poor water is added to dilute phosphorus concentrations and, at higher flow rates, can flush algal cells out of the waterbody. Limited to waters where there is an available source of lower nutrient water. Sturgeon Lake used flushing for a while using Columbia River water rather than Willamette/Multnomah Channel water along with Green and Moses Lakes in Washington.	G/F	G/F	F/F	L/L	Highly dependent on a sufficient volume of low(er) nutrient water.
Algicides	Various compounds can directly kill plants, most often to address macrophytes. Copper Sulfate has been used for treating algal biomass and taste and odor problems in water supply reservoirs although it can have significant detrimental aspects (copper build up in sediment, release of toxins if applied to cyanobacterial blooms, etc)	G	P	G	H	Short term control only and can have a number of negative impacts
Biomanipulation	Generally involves removal of fish that graze on zooplankton as zooplankton graze on algae or elimination of bottom browsing fish that stir up sediment and release nutrients through poisoning, physical removal or increased piscivory. Diamond Lake has used rotenone to remove tui chub and limited restocking of game fish. Several lakes including East, Fish (Rogue), Lava, Lemolo and Paulina lakes have harvested tui chub.	G	P	E	?	

E = Excellent; G = Good; F = Fair; P = Poor; H = High; L = Low

4.2 Management Plans and Means for their Implementation

The key to lake, river and watershed management (whether addressing HABs or other water quality issue) is to have a plan and the ability in implement it. Improvements will take time to occur and actions will often need to be adaptively managed based on what is learned along the way. In most cases, in addition to implementing measures to restore a waterbody, a long-term commitment is needed to maintain the work that has been put in place to achieve water quality standards.

This is section not meant to be a detailed discussion about management planning and implementation but is to intended to briefly identify a key resource for developing aquatic vegetation management plans and identify some approaches that have been developed in Oregon for implementing these management plans.

Management Plans: Lakes and reservoirs are complex ecosystems and management measures that are implemented to address one concern can create conditions that result in other concerns. Lakes have three distinct and interacting biotic communities: wetland-littoral zone and its sediments; open pelagic zone; and the benthic or deep water zone (profundal) zone and sediments (Cooke et al, 2005). Problems or actions in one zone can directly affect other zones and successful restoration requires a holistic view of the lake and watershed processes. All too often, efforts to address one problem (e.g. aquatic weeds removal) will result in other problems (excess algal growth) as nutrients are not being removed by the macrophytes and are available to the algae. Also, the macrophytes no longer stabilize sediments from the impact of waves thereby increasing sediment resuspension and internal nutrient loading. This is most notable in attempting to achieve a balance between algal and macrophyte growth as experienced in Blue, Devils and Oswego Lakes.

A "Guide for Developing Integrated Aquatic Vegetation Management Plans in Oregon[58]" (CLR, 1999) has been developed to assist with development of plans. The Center for Lakes and Reservoirs at Portland State University and a number of consultants are available to assist in the development of Management Plans.

Implementation: Implementation of a management plan often requires a long-term commitment to managing the project. Many projects, such as fish removal, maintaining sediment basins, aeration, etc., require long-term monitoring and maintenance. Nature is not static and human actions and behaviors are very dynamic, meaning that effectiveness must be monitored and changes need to be made to management plans, when necessary (Cooke et al, 2005).

In some cases, there may be an obvious management agency that will have the sole responsibility for the implementation of the management plan (e.g. Lake Oswego Corporation manages Lake Oswego Lake and has funding mechanisms to support its activities). However, in most cases, there are a variety of potential partners and interests for developing an implementing management plans which, while it may provide broad support for moving forward on implementation, may make it difficult to come up with a means for actually carrying it out.

There have been a variety of methods and entities formed in Oregon to oversee and fund lake study and implementation activities including:

- Water Improvement Disticts (e.g. Devils Lake -Devils Lake Water Improvement District[59]);
- Watershed Associations – (e.g. Tenmile Lakes - Tenmile Lakes Basin Partnership[60]
- Corporations - (e.g. Lake Oswego - Lake Oswego Corporation[61])

- Cities – (e.g. Laurelhurst Pond - City of Portland)
- Reservoir Managers - (e.g. Willow Creek Reservoir -USACE[62])
- Partnerships of watershed and resource managers (e.g. Diamond Lake - USFS, ODFW, DEQ, etc)
- Partnerships of local government and lake associations – (e.g. Blue Lake (Multnomah Co) - METRO and Blue Lake Homeowners Association
- Partnerships of Hydroelectric Projects and watershed and resource managers (e.g. Lemolo Reservoir – PacifiCorp, USFS, ODFW, DEQ…)

Most notable of these is Devils Lake. The Devils Lake Water Improvement District (DLWID) is the first water improvement district of its kind in the State of Oregon, formed as a water improvement district under ORS 552[63] in 1984. As a special taxing district, DLWID receives funding from area property owners to work for the improvement of the many aspects of Devils Lake

5. HABs Management: The Big Picture

It is worthwhile to examine some national efforts to control and prevent HABs and the impact of Climate Change to provide some context and to inform the review and recommendations of DEQ's programs.

This section will take a brief look at some of the work done under the Harmful Algal Bloom and Hypoxia Amendments Act of 2004, EPA's Nutrient Strategy and by the Oregon Climate Change Research Institute.

5.1 Harmful Algal Bloom and Hypoxia Research and Control Act

In 1998, Congress passed the Harmful Algal Bloom and Hypoxia Research and Control Act (HABHRCA, Public Law 105-83) which established an Interagency Task Force to develop a national HABs assessment and authorized funding for existing and new research programs on HABs. The funding went to support two multi-year research programs at the National Oceanic and Atmospheric Administration (NOAA) that focus on HABs – the Ecology and Oceanography of HABs (ECOHAB) and the Monitoring and Event Response for HABs (MERHAB) programs.

In 2004, HABHRCA was reauthorized by Public Law 108-456, which required assessments of HABs in different coastal regions and in the Great Lakes and included plans to expand research to address the impacts of HABs. The law also authorized research, education, and monitoring activities related to the prevention, reduction, and control of harmful algal blooms and hypoxia and reconstituted the Interagency Task Force on HABs and Hypoxia. The reauthorization expired in 2008, however, the Consolidated Appropriations Act of 2008 (P.L. 110-161) provided authorizations through 2010.

HABHRCA called for the reestablishment of the Interagency Task Force, who oversaw the production of several mandatory assessments and reports. This Task Force was co-chaired by representatives from the NOAA and the Center for Disease Control (CDC).[64] The legislation required the generation of five reports to assess and recommend research programs on harmful algal blooms (HABs) and hypoxia in U.S. waters: 1) National Assessment of Efforts to Predict and Respond to Harmful Algal Blooms in U.S. Waters (Prediction and Response Report); 2) National Scientific Research, Development, Demonstration, and Technology Transfer Plan for Reducing HAB Impacts (RDDTT Plan); 3) Scientific Assessment of Freshwater Harmful Algal Blooms; 4) Scientific Assessment of Marine Harmful Algal Blooms; and 5) Scientific Assessment of Hypoxia.[65]

The report "Scientific Assessment of Freshwater Harmful Algal Blooms" (Lopez et al, 2008) [66] examines the causes, consequences, and economic costs of freshwater HABs, 2) establishes priorities and guidelines for a research program on freshwater HABs, and 3) makes recommendations to improve coordination among Federal agencies with respect to research on HABs in freshwater environments. Research and infrastructure priorities and goals to advance freshwater HAB research and response are shown in Table 5-1.

Additionally, the 2004 reauthorization directed NOAA, in coordination with the Task Force, to conduct local and regional scientific assessments if requested by state, tribal, or local governments or for affected areas identified by NOAA. Funding was also authorized for ongoing and new programs and activities such as: competitive, peer-reviewed research through the ECOHAB program; freshwater harmful algal blooms added to the research priorities of ECOHAB; a competitive, peer-reviewed research program on management measures to prevent, reduce, control, and mitigate harmful algal blooms supported by the MERHAB program; and activities related to research and monitoring of hypoxia supported by the competitive, peer-reviewed Northern Gulf of Mexico program and Coastal Hypoxia Research Program administered by NOAAs National Ocean Service.

The HABHRCA authorized funds to conduct research and reduce HABs and hypoxia in U.S. marine waters, estuaries and the Great Lakes. In its role as a task force participant, the Environmental Protection Agency (EPA) has signed memorandums of understanding to fund competitive research in these areas. However, since the completion of the freshwater report in 2008, EPA has ceased participation in freshwater HAB research and mitigation activities, asserting that its obligations regarding implementation of the report recommendations have been addressed. As a result, although EPA oversees a wide array of programs specifically designed to protect and preserve the coastal and marine waters of the United States, including watershed protection programs working through partnerships and an array of regulatory programs, the agency currently has no research and development effort that directly addresses freshwater harmful algal blooms.[67]

With the exception of the Great Lakes, which fall under NOAA's jurisdiction, freshwater systems that are impacted by HABs have not been comprehensively addressed under the NOAA programs. This is because NOAA's mandate includes the Great Lakes and estuaries up to the freshwater interface, but does not include the many rivers, ponds, lakes, and reservoirs that are subject to freshwater HAB problems.

The reauthorization of HABHRCA in 2004 expanded the Act to include blooms in all U.S. freshwaters. The Act mandated an assessment of freshwater HABs, leading to an interagency monograph that described science and research needs (Lopez et al, 2008). This effort to address freshwater HABs at the national level was hampered because the Act did not contain a mandate or funding authorization for the EPA, which is the appropriate Agency to establish and maintain such a plan. All U.S. freshwaters are within the purview of the EPA, as defined in the Clean Water Act and the Safe Drinking Water Act. Although the EPA recognizes the need for a National Research and Control Plan for Freshwater HABs (Lopez et al., 2008), the Agency has not begun development of a plan primarily due to the lack of clear Congressional direction and funding[68]

The 2010 bill to reauthorize HABHRCA contained the EPA mandate, a modest funding authorization, and direction for the Agency to use those funds to support research and control projects for freshwater HABs by becoming a partner with NOAA in the several existing NOAA grant programs. That bill passed in the House with bipartisan support, but did not come up for a vote in the Senate. At the time of this report, hearings are taking place on the HABHRCA Amendments of 2011.

Table 5-1 Research and infrastructure priorities and goals to advance freshwater HAB research and response (bolded goals were considered immediate goals and critical steps to advancing freshwater HAB research and response; from Lopez et al, 2008)

Priority	Goals
Improve methods for detecting HAB cells and toxins	• **Develop quick screening methods** • Develop standard methods for analysis • Develop methods for toxins in complex matrices • Identify bioindicators of toxin exposure and effects
Improve understanding of toxin uptake, metabolism, and health effects in humans and other animals	• **Make purified toxins available for research** • Research toxin synthesis • Research effects of toxins and toxin mixtures, including chronic, low-level exposures • Research toxin transfer in foodwebs
Improve human health and ecological risk assessments	• Conduct epidemiological studies to characterize dose-response and identify susceptible populations • Identify bioindicators of toxin exposure and effects • Conduct toxicology studies for specific toxins of concern, for environmentally relevant exposure routes, and for effects of chronic exposures; investigate sub-lethal effects on key aquatic biota • Research toxin fate in aquatic environments and transfer through foodwebs • Consider natural exposures to cyanotoxins occurring in sequence and together for risk assessments
Improve knowledge of bloom occurrence through better monitoring	• **Identify and monitor at-risk waterbodies** • Monitor implicated foods and supplements to identify those at-risk for cyanotoxin contamination • Develop automated detection methods for HABs; couple with observing systems • Determine temporal and spatial trends through long-term monitoring • Collect and store data on bloom characteristics, environmental conditions, and health effects data during blooms
Improve bloom prediction	• Research factors governing algal growth and toxin production • Conduct retrospective analysis to investigate role of human activities • Conduct long-term ecosystem studies on causes and dynamics • Develop predictive ecosystem models for freshwater HABs
Develop HAB prevention and control methods	• Develop HAB prevention strategies based on knowledge of causes • Develop HAB control methods with minimal environmental impacts • Improve drinking water treatment technologies • Conduct cost-benefit analysis for implementation of these strategies
Improve HAB research and response infrastructure	• **Improve availability of toxin standards and other reference materials** • Provide facilities for algal toxin and cell identification • Develop a national database for freshwater HABs • Develop a national-level monitoring strategy • Cultivate taxonomic and toxin expertise for HABs • Educate public to safeguard against exposure and minimize impacts on humans • Improve coordination among programs that address HABs

5.2 EPA Nutrient Reduction Partnership with States

On March 16, 2011, EPA Headquarters issued a memo[69] to its Regional Administrators that reaffirms EPA's commitment to partnering with states and collaborating with stakeholder to make greater progress in accelerating the reduction of nitrogen and phosphorus loading to the nations waters. A "Recommended Elements of a State Nutrients Framework" was provided as a tool to guide onging collaboration between EPA Regions and states in their joint effort to make progress on reducing nitrogen and phosophorus pollution. The recommended elements of the framework were:

1. Prioritize watersheds on a statewide basis for nitrogen and phosphorus loading reductions;
2. Set watershed load reduction goals based upon best available information;
3. Ensure effectiveness of point source permits in targeted/priority sub-watersheds including municipal and industrial wastewater treatment facilities, Concentrated Animal Feeding Operations, and Urban Stormwater sources that are significant sources;
4. Agricultural Areas - develop watershed scale plans that target effective practices and innovative approaches;
5. Storm water and Septic Systems – identify tools to address communities not covered by Municipal Separate Storm Sewer Systems (MS4) permits including septic systems, low impact development/green infrastructure approaches and/or limits on phosphorus in detergents and lawn fertilizer;
6. Accountability and verification measures – including identify how reductions will occur, verification of load reduction practices in place and assessment of progress in achieving goals;
7. Reporting - Annual public reporting of implementation activities and biannual reporting of load reductions and environment impacts; and
8. Numeric Criteria – work plan and schedule for numeric criteria development.

The framework is provided as a planning tool, intended to initiate conversation with states, tribes, other partners and stakeholders on how best to proceed to achieve near- and long-term reductions in nitrogen and phosphorus pollution in the nations waters.

It has long been EPA's position that numeric nutrient criteria targeted at different categories of water bodies and informed by scientific understanding of the relationship between nutrient loadings and water quality impairment are ultimately necessary for effective state programs. Support for numeric standards expressed in a variety of document including the "Ambient Water Quality Criteria Recommendations, Information Supporting the Development of State and Tribal Nutrient Criteria" series of documents (Discussed further in Section 6.2.2).

DEQ did previously outline its process for controlling nutrients and protecting uses of Oregon's waters in a January 31, 2007 letter to EPA (Attachment E). The letter outlines the use of various numeric and narrative starndards that protect beneficial uses from the adverse effects of excessive nutrients and the use of the TMDL program to establish appropriate nutrient targets and to implement approaches to resolve problems. This approach is described in Section 6.

To date, detailed discussions between EPA and DEQ on the latest framework have not occurred.

5.3 Climate Change

In 2007, the Oregon State Legislature charged the Oregon Climate Change Research Institute with assessing the state of climate change science including biological, physical and social science as it relates to Oregon and the likely effects of climate change on the state. An assessment report[70] was developed in 2010 to act as a compendium of the relevant research on climate change and its impacts on the state of Oregon (Dello, 2010). The report stated that human activities are primarily responsible for the observed 1.5º F increase in the 20th century temperatures in the Pacific Northwest.

Future predicted regional climate changes in Oregon include (Dello, 2010):

- Increases in temperature around 0.2-1ºF per decade;
- Warmer and drier summers with a likely 14% decrease for summer precipitation by the 2080s.;
- Extreme precipitation will likely increase;
- Sea levels will rise, possibly by 2-4 feet by 2100.

Key findings include[71]:

- Summer water supply will decrease as a result of reduced snowpack and summer precipitation;
- Availability, quality and cost of water will likely be the most limiting factor for agricultural production systems under a warmer climate;
- Wildfire is projected to increase in all Oregon forest types in the coming decades;
- Frequency and magnitude of coastal flooding events may continue to increase;
- Many plant and animal species on land, in freshwater, and in the sea have and will shift their distributions and become less or more abundant – invasive species and **harmful algal blooms may become more abundant;**
- Changes to the marine environment including increasing water temperatures;
- Oregon's economy, like many other states, is likely to be affected by a changing climate and by policies addressing projected changes;
- The important drivers of greenhouse gas emissions are population, consumption and the emission intensity of the economy;
- We are already experiencing the impacts of climate change in Oregon.

As noted, HABs would likely become more abundant in Oregon with climate change. Changing conditions, both warmer and drier climate and lower flows (based both on shifts in precipitation and demand for water), would result in warmer water and more standing water which is more favorable to cyanobacteria growth. Therefore, it is likely that blooms would occur longer, in more places and perhaps with greater magnitude (Paerl et al, 2008).

[70] Oregon Climate Change Research Institute Website
[71] From the Oregon Climate Assessment Report – Legislative Summary

6. DEQ Programs to Prevent and Control HABs

This section describes in more detail the current strategy (which was outlined in Section 2.3) that DEQ uses to prevent and controls HABs. It describes how various subprograms of the Water Quality Program currently address HABs and their growth requirements (which were discussed in Section 4 - principally nutrients) and makes recommendations for improvements. In the case of surveillance, standards and assessment and pollution reduction planning related to HABs, a more detailed assessment of some of the program strengths and weaknesses was made. The recommendations are suggested to better align the Water Quality subprograms for the prevention and control of HABs.

6.1 Surveillance/Monitoring for HABs

DEQ is an active partner in Oregon's surveillance program for HABs. Monitoring to determine the occurrence of HABs, which is a shared activity by a wide range of partners, is evaluated and recommendations are made for further consideration. This section does not review other types of monitoring such as that done to determine the causes of the HABs. The health advisory process, which is under OHA authority, is not evaluated in this document.

6.1.1 Current HAB Related Surveillance Approaches

OHA works with a variety of federal, state and local partners to coordinate monitoring, response and risk communication related to HABs[72]. Oregon's program relies primarily on monitoring by management agencies or groups (e.g. watershed councils) that are:

- responsible for recreational sites, water access or water uses such as drinking water;
- operate dams;
- manage activities in the lake or reservoir and its watershed; or
- have water quality responsibilities.

Partners included include DEQ, USFS, USACE, USGS, ODFW and a number of local watershed groups, health departments, parks and recreation agencies and drinking water providers. Through this effort, a limited surveillance program has been established, with monitoring occurring primarily at or near recreational facilities maintained by the USFS or the USACE. If there is no clear Designated Management Agency (DMA) that would be responsible for monitoring the HAB, DEQ provides monitoring staff to collect, preserve and ship samples. An Interagency Agreement between OHA and DEQ has been developed to define and partially fund this activity.

While there is variation in monitoring protocols[73] including the number, frequency and types of sample analysis - algal identification or toxin, it generally consists of the following:

- Observation of conditions in the lake or reservoir. This is usually done by a partner agency who has someone who is often at the waterbody and, over time, is familiar with its conditions.
- When visible scums or blooms occur, samples are collected by the partner agency for algal identification and enumeration. In some cases (such as with the USFS), secchi disk depths are used to trigger the process.

[72] OHA also does public education regarding the risk to human and animal health that HABs pose as part of their overall program.
[73] OHA developed HABs sampling guidelines and has been working with a number of labs to better standardize identification and enumeration techniques in 2011.

- An advisory is issued by OHA if combined cell counts for toxigenic cyanobacteria exceed 100,000/ml. Typically advisories are posted on the OHA website, at the waterbody and are sent to media outlets.
- The advisory stays in effect and is lifted on the basis of no visible bloom and both cell counts and toxicity testing showing that both are below advisory values. There is a one week waiting period after testing to ensure that the same bloom does not re-occur (Figure 3-1).

The HAB surveillance program in Oregon has been in place since the late 1990s and was augmented in 2008 when OHA received a five-year CDC grant to support HAB risk communication and reporting in Oregon. The enhanced effort has resulted in an increased number of advisories. It is not known whether the increase is due to increased awareness of HABs and/or an actual increase in HABs in Oregon. OHA typically hosts an annual meeting with partners to review and refine the HABs surveillance program.

6.1.2 Other Potential Methods that could Supplement HABs Surveillance

There are a number of technologies or methodologies that are available that could improve aspects of the Oregon HABs Surveillance Program that are briefly described below:

Genetic Monitoring and Identification Based on DNA Sequences[74]: Microscopic identification of cyanobacteria as is currently used for routine monitoring suffers from some limitations. It is not uncommon for identical samples that are sent to different experts to be differently identified; there is general agreement at the level of genus, but less so at the level of species. Colony morphotypes do not always allow accurate identification because the same isolate can sometimes assume different, distinct colony morphologies (Otsuka et al., 2000). There is ample evidence that incorrect species assignments have been common for cyanobacteria whose DNA sequences have been determined. The closest relatives in the GenBank database on the basis of DNA sequence do not all have the same identifications (genus and species names) that they should have. There can also be important differences between blooms that cannot be detected microscopically, but that have been documented by genetic means, such as transitions from highly toxic *Microcystis* blooms early in the season to less toxic *Microcystis* blooms at later times (Briand et al., 2009; Bozarth et al., 2010).

Genetic monitoring may be expected to ultimately replace visual monitoring for bloom identifications, especially as new very high throughput DNA sequencing technologies become readily accessible. DNA-based techniques that aim to quantify cell numbers are being explored and should become viable alternatives to microscopic enumeration. Implementation of genetic techniques for routine monitoring will require a database of cyanobacterial DNA sequences to be constructed, perhaps region by region, before the expected utility of this approach would be realized. Validation for suitability in guiding management decisions (e.g., as criteria in a scheme such as that in Fig. 3-1 that determines whether or not to issue an advisory) will need to be assessed in direct comparison with current microscopic identification and enumeration techniques.

The expected benefits of genetic monitoring are:

- more accurate identification;
- identification to the strain level, which could allow discrimination between strains with relevant differences, such as toxigenicity, or to provide information on how blooms are spread;
- sensitivity that could allow development of early warning programs;
- high throughput form of analysis brings cost per sample down and provides opportunity for more complete sampling of a water body;
- economical per sample and rapid.

[74] Information regarding genetic monitoring and identification based on DNA Sequences supplied by Dr. Theo Dreher, Department of Microbiology, Oregon State University.

Remote Sensing: Remote sensing refers to the collection and interpretation of information about an object without being in physical contact with the object. For lake water quality studies, numerous instruments are available based either on aircraft or satellite (Chipman et al 2009). Among the different sensors, there is a trade-off between spatial resolution, spectral resolution, spatial coverage and temporal coverage. Moderate to coarse spatial resolution sensors, such as Landsat (30 m, 7-bands, 8 day repeat) and MERIS (300 m, 15 bands, 3 day repeat) have been used for regional assessments. Mid-western states have successfully assessed lake water clarity using moderate-resolution systems (see Chipman et al 2009 for case studies). The majority of the cost of such an assessment would be analyst time rather than image acquisition. In an assessment of Cascade and central Oregon lakes using 10-years of Landsat images, Turner (2010) was not able to make regional predictions of chlorophyll *a* concentrations but used relative information to classify lakes and examine seasonal and spatial patterns.

Numeric Modeling: Numeric modeling based on available data could be considered as a means for better identifying waters at risk for HABs and would enhance the assessment that was done in Section 3.5. Factors such as landscape and climatic characteristics could potentially be linked to waters with cyanobacterial blooms and other related water quality problems (e.g. high pH) to aide in identifying monitoring gaps, augment knowledge regarding HABs and help in setting priorities for research and management.

6.1.3 Assessment of Current HAB Related Surveillance Program

Oregon current program advises the public on potential risks at a number of lakes but could be improved. Oregon's program has been developed in a cooperative, partnership fashion since the mid-1990's to better address the risks related to HABs. The program has grown over time and is most effective where there is a willing partner who has the means (e.g. staff to collect samples, funds to ship and analyze the sample) and interest to monitor along with the willingness to share data with OHA and warn the public about the potential risk of HABs. The value of this program and commitment of its partners should not be discounted, especially during times of limited budgets and funding.

The current HAB surveillance program should be maintained and partners should continue to explore ways to expand the program and overcome some of its limitations. Some of the HAB surveillance program limitations include:

- The HAB surveillance program relies on and places a burden on many of the monitoring partners. Typically, if there is no apparent partner or if a partner is unwilling or unable to sample, for whatever reason, there is no data for that waterbody. In 2010, OHA and DEQ did develop a MOA under which DEQ would collect samples in limited situations. Some of the burdens placed on the partners under this program can include: the costs for sample collection, shipping, sample analysis and data sharing are borne by the partner; related costs and consequences of an advisory are often bourne by the partner such as responding to the public and the press, conducting on-going surveillance until the Advisory is lifted, and loss of revenue from users not coming to the lake; etc. All of these concerns may discourage partners from becoming involved in the program and thereby put water users at risk.

  DEQ and OHA briefly examined several other state programs and found that the State of Washington has a HAB program that could serve as a model for Oregon. Programs from four other states were also examined (Washington, Nebraska, Wisconsin, Minnesota). The State of Washington program could serve as a model program for Oregon. Key elements include:

  - Use of trained volunteers which also include local health department, other agency and citizen volunteers;

   - A volunteer coordinator to run the program. This position in Washington serves as a "bloom expert" and is able to do phone triage to figure out which lakes need further sampling, etc.
   - Analysis for cell counts and toxins is paid for by the program rather than by the organization doing the monitoring (the monitoring organization does pay for shipping of samples). Use of outside laboratories was generally favored given the current quality of data and data turn around although working through an existing state lab or developing the capability through a university could also be viable. Washington contracts with King County.
   - Sustainable funding source - Washington funds its program using vessel registration fees.
   - Data base and other information related to HABs posted on a public website.

- The Oregon HABs surveillance program is limited in scope and does not provide coverage for the majority of lakes that may be experiencing HABs. As of 2010, over 40 waterbodies have had health advisories issued due to HABs. This includes about 8% (35 of 412) of the lakes and reservoirs greater than 50 acres. As discussed in Section 3.5, approximately 135 lakes and reservoirs have been identified as being of concern for aquatic growth which includes 25% (104 of 412) of the lakes and reservoirs greater than 50 acres. While not all of these waters would have HABs problems and there are likely many more waters that experience HABs that were not identified by this analysis (e.g. small ponds, rivers), it does provide some context for indicating that the program currently addresses a small portion (e.g. potentially less than 1/3 of the lakes and reservoirs over 50 acres) of the waters that experience HABs. Additionally, HABs in rivers are identified and monitored only after animal deaths.

- The Oregon program primarily relies on visual observations of bloom supported by cell count information as this is the most economical approach[75]. While the cell counts are the valid indicators of potential risk, it is the toxins that are of public health concern. More information is needed on toxins but it can more costly and could present other concerns (e.g. the possibility of more frequent sampling, etc). Kits to measure specific toxins are becoming more available for doing screening analyses for specific toxins in the field. Additonally, emerging methodologies such as genetic monitoring and identification based on DNA gene sequences hold promise for future benefit for determining toxigentic strains.

- DEQ has done limited HABs monitoring but did collect samples in Elk Creek/Umqua in 2009 and in the South Umpqua River in 2010 as a follow up the deaths of several dogs due to cyanotoxins. The Umpqua Basin Coordinator was the responder both time. Based on these responses, DEQ has improved its preparation for HABs response (e.g. generic monitoring plans that can be adapted on short notice, increased availability of sampling equipment, etc). DEQ should continue to develop its response capability as it will likely need to respond to other HABs concerns given increase public awareness and increased likelihood of HABs.

6.1.4 Recommendations on HAB Surveillance Approaches

- The current HABs Surveillance Program should be maintained. DEQ, OHA and the program partners should continue to look for opportunities to expand and build the program by adding other partners, lakes, and other features to the program. A number of additional lakes of concern along with potential partners for monitoring those lakes can be found in Appendix B.

[75] The HAB surveillance program is asking for toxin data as a basis for lifting an advisory in 2011.

- The annual partnership meeting is a good forum to evaluate the program and look for opportunities to grow – both for surveillance as well as for addressing HABs. Ways to enhance the current program can include:
    - the development of an MOA to clarify and better define the partnership and secure commitments; and
    - expanding the annual meeting to address both the HABs surveillance program that OHA oversees and to discuss the means for better preventing and controlling HABs that DEQ oversees. OHA and DEQ should discuss co-chairing these meetings so that both the surveillance and implementation-related activities can be discussed.
    - Incorporate genetic techniques, satellite and numeric modeling work in surveillance programs as opportunity occur to better to better identify toxic strains (genetics) and to better identify lakes of concerns, trends, etc (remote sensing, numeric modelling).

- DEQ, OHA and the partners should pursue grant and other opportunities to better determine the magnitude of the problem in Oregon and to enhance the current programs to address HABs[76]. While running a program on grant funding is not necessarily sustainable over the long period, Oregon should investigate various grant opportunities. Additional funding could be used to develop a HABs surveillance program similar to Washington's and support to the sampling of additional lakes and reservoirs, such as those identified in Appendix B, to determine if these waters are experiencing HABs. There are two opportunities that are available annually – OWEB monitoring grants [77] and federal 319 grants. EPA recommends[78] that states use at least 5% of its 319 funding allocation to address the needs of lakes and reservoirs (see Section 6.7 for further discussion).

- There is a need for a more sustainable program as HABs are likely to occur more frequently, in more places and with greater intensity. DEQ, OHA and partners should seek a more sustainable means of addressing HABs as they will likely be a significant issue for the coming years and one that will take on going management (see Section 6.7 for more discussion of potential means of funding a program). This could be done as a policy option package for the 2013-2015 biennium and should be a multi-agency (e.g. DEQ, OHA, others)/university (e.g. OSU, PSU) effort for monitoring, notification, education and other work in order to better characterize the extent of HABs in Oregon and to communicate the health risk. The Washington HABs surveillance program is a good model for Oregon. Oregon may also want to consider a Task Force approach similar to South Carolina's[79] as a more comprehensive approach for addressing HABs. This could build on partnership approach that is currently being used but could be boosted with legislative support.

- DEQ should have a HAB core group to better respond to HABs while they are occurring. This response would include sampling and analysis (as identified in an interagency agreement between DEQ and OHA) and improving coordination with the various entities that become involved in

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[76] OHA received a CDC 5-year grant to staff its expanded HABs surveillance program and DEQ received a grant to develop this HABs strategy.

[77] An OWEB grant application to fund an Oregon HAB surveillance program similar to that of Washington's was submitted in 10/2010 by the Portland State University Center for Lakes and Reservoirs (CLR) with match support from DEQ, OHA, USFS, Corp and others. OWEB did not fund the grant. Overall, the reviewers saw great value in this project and a need for a state-wide comprehensive monitoring program for algal blooms. However, there was concern expressed about the long term ability to support and manage such a program through an annual grant process and whether funding for watershed restoration monitoring was the best fit. Funding and support from human health organizations would appear to be a much better fit for this program. Reviewers expressed that pursuit of many of the unknowns around when and why HABs occur, the linkages to land use actions, and potential influences from climate change seemed to be a much better focus of OWEB funds. The reviewers recommended forwarding this need to the Governor's Office so that a strategy for developing the monitoring and outreach program could be more widely shared and strategized.

[78]

[79]

HAB related work (e.g. OHA and local health departments who do advisories and communicate health risks, etc) as well as improving response to the public and media. At a minimum, this group would consist of a lab lead worker, basin coordinator(s), the HQ technical lead on HABs and appropriate managers (internally known as the Healthy Stream Partnership Group or HSPIG). Actions for this group can include but not be limited to:

- Development of a generic HAB sampling plan that can be quickly modified for a particular event/location;
- Access to monitoring and safety equipment as well as training for safely collecting and handling samples;
- Developing checklists to help out in responding to the HABs including suggested agencies and groups with which to communicate;
- Insuring steps to get data into the LASER or other appropriate data bases;
- Annual follow-up meetings for process improvements.

A minimum level of HAB response should be written into the work plans of the core group to reflect commitment to this effort.

- DEQ should consider developing a HAB website that can complement the OHA HAB site and include information related to its programs for addressing the causes of HABs, studies related to HABs (including this strategy) and useful links. Development and/or access to a HAB database should be considered.

6.2 Standards and Assessments

Water quality standards are benchmarks established to protect the quality of Oregon's rivers and lakes for fish and other aquatic life, recreation, drinking, agriculture, industry and other uses. Water quality standards are also regulatory tools used by the DEQ and the federal Environmental Protection Agency (EPA) to prevent pollution of our waters[80].

According to the federal Clean Water Act (CWA), States are to review their water quality standards at least once every three years. This process is referred to as the "triennial review." During the review, States revise standards to incorporate the latest scientific information and to make any other revisions that the State determines are needed.

Also, according to the federal Clean Water Act, DEQ is to assess water quality and report to EPA on the condition of Oregon's waters every two years. DEQ prepares an integrated report (assessment) to meet the requirements of the federal Clean Water Act for Section 305(b) and Section 303(d). Waters not meeting standards are identified as “water quality limited” and are assigned to a category for further action:

Category 5: Water is water quality limited and a Total Maximum Daily Load (TMDL) is needed – this is the Section 303(d) list.

Category 4: Water is water quality limited but a TMDL is not needed. This includes:

- **4A:** TMDL approved **-** TMDLs needed to attain applicable water quality standards have been developed and approved by EPA.

- **4B:** Other pollution control requirements are expected to address all pollutants and will attain water quality standards.
- **4C**: Impairment is not caused by a pollutant (e.g., flow or lack of flow is not considered a pollutant.)

Category 3: Insufficient data to determine whether a standard is met.

- **3B:** Potential concern - Some data or information indicate non-attainment of a criterion, but data are insufficient to assign another category.

DEQ prepares Total Maximum Daily Load (TMDL) and Water Quality Management Plan (WQMP) documents for waterbodies in Oregon designated as water quality limited and on DEQ's 303(d) list of impaired waters. A TMDL uses scientific data collection and analysis to determine the amount and source of each pollutant entering streams. A TMDL is the maximum amount of pollutant that can be present in a waterbody while meeting water quality standards. These maximum allowable pollutant loads are assigned to contributing sources, typically to point sources (wasteload allocations) and land use authorities (load allocations). The WQMP provides the framework for management strategies to attain and maintain water quality standards. The framework is designed to work in conjunction with detailed plans and analyses provided in sector-specific or source-specific implementation plans. The plan designates organizations to prepare and carry out source-specific TMDL implementation plans including the U.S. Forest Service and Bureau of Land Management, the Oregon Departments of Agriculture and Forestry, Counties, Cities and others. The implementation plans identify management measures that will be use to achieve and maintain water quality standards. Use of other pollution control requirements to address pollutants and attain standards can substitute for developing a TMDL (this is a category 4B approach under EPA's assessment methodology described above).

The following discussion describes current water quality standards and assessment methodology that relate to HABs, evaluates the process and make recommendations for further consideration. TMDLs and related planning work will be discussed in more detail in Section 6.3.

6.2.1 Current HAB Related Water Quality Standards and Water Quality Assessment Methodology

Oregon does not currently have a water quality standard that specifically addresses HABs. It does have a statewide narrative criterion which has been used to identify harmful aquatic weed and algal growth[81]:

> **OAR 340-041-0007 Statewide Narrative Criteria** … (10) The development of fungi or other growths having a deleterious effect on stream bottoms, fish or other aquatic life, or that are injurious to health, recreation, or industry may not be allowed;

Prior to the development of Oregon's 2010 Integrated Report, the listing for algae under this criteria required:

> "documented evidence that algae, including periphyton (attached algae) or phytoplankton (floating algae), are causing other standards to be exceeded (e.g. pH, chlorophyll a or dissolved oxygen) or impairing a beneficial use[82]."

[81] It has been used the biennial water quality assessment (Section 305(b) report) and 303(d) list of impaired waters under the "Aquatic Weeds and Algae" parameter (the 305(b) report and the 303(d) list are now combined into the Integrated Report)

[82]

No listings were made based on HAB advisories under this protocol, up to and including the 2004/2006 Integrated Report, but nine lakes that have had HABs advisories were listed based on other exceedances of related water quality criteria such as dissolved oxygen, pH, nuisance phytoplankton growth (chlorophyll a). These lakes were: Blue, Devils, Diamond, Klamath, Lava, Odell, Oswego, Siltcoos and Tenmile Lakes.

The 2010 Integrated Report added OHA HABs health advisories as a basis for listing. In the 2010 assessment methodology[83], DEQ added the following wording for using HAB Health advisories as a basis for listing under the "Aquatic Weeds and Algae" parameter:

> "Health advisories issued by the Oregon Department of Human Services, in conjunction with other federal, state, county, city or local agencies, warning that potentially harmful levels of toxins produced by blue-green algae (cyanobacteria) are present in a water body."

Health Advisory information was added as supporting data for listing for 42 waters with 33 listed as Category 5 (need TMDL), six as Category 4A (TMDL completed), one as Category 4B (other requirement), and two as being of Potential Concern (shown as Insufficient Data). The focus of updating the Integrated Report in 2010 was to update the Category 5 and 4 listings; DEQ did not update the Category 3 listings (Potential Concern) in 2010 (see Appendix B).

There are several numeric water quality criteria that relate to other effects of HABs on the water column including:

OAR 340-041-0021 pH: … pH values may not fall outside the following range:

- 6.0 to 8.5: Cascade Lakes above 3000 feet altitude
- 6.5 to 8.5: Deschutes Basin, Hood Basin, Mid Coast Basin, North Coast Basin, Rogue Basin, Sandy Basin, South Coast Basin, Umpqua Basin, Willamette Basin
- 6.5-9.0: Grande Ronde Basin, John Day Basin, Klamath Lake Basin, Powder/Burnt Basin, Umatilla Basin, Walla Walla Basin
- 7.0 - 8.5: Columbia R, Marine Waters
- 7.0-9.0: Snake R, Malheur Lake Basin, Malheur River Basin, Owyhee Basin
- 7.5 to 9.5: Goose and Summer Lakes Basin

OAR 340-041-0019 Nuisance Phytoplankton Growth: The following average Chlorophyll a values must be used to identify water bodies where phytoplankton may impair the recognized beneficial uses:

- Natural lakes that thermally stratify: 0.01 mg/1[84];
- Natural lakes that do not thermally stratify, reservoirs, rivers and estuaries: 0.015 mg/1;

OAR 340-041-0016 Dissolved Oxygen: see Table 21 of Oregon's Water Quality Standards[85]. Lakes and reservoirs are generally not considered spawning areas (unless designated) so applicable cold or cool water criteria have been applied year round.

There are other criteria that could be used to address the toxic nature of HABs. These include:

OAR 340-041-0033 Toxic Substances: (1) Toxic substances may not be introduced above natural background levels in waters of the state in amounts, concentrations, or combinations that may be harmful, may chemically change to harmful forms in the environment, or may accumulate

[83] Methodology for Oregon's 2010 Water Quality Report and List of Water Quality Limited Waters, DEQ, May 2009 Draft
[84] "In potable and recreational waters a bloom is frequently defined in terms of cells concentration that cause a nuisance to humans and a lower limit may be set at ca. 0.010 mg/l of chlorophyll a (ca. 20,000 cells/ml)." Whitton et al, 2000
[85]

in sediments or bioaccumulate in aquatic life or wildlife to levels that adversely affect public health, safety, or welfare or aquatic life, wildlife, or other designated beneficial uses.

OAR 340-041-0007 Statewide Narrative Criteria: … (11) The creation of tastes or odors or toxic or other conditions that are deleterious to fish or other aquatic life or affect the potability of drinking water or the palatability of fish or shellfish may not be allowed;

DEQ has not used these criteria for identifying and listing HABs.

The **Antidegradation Policy** (**OAR 340-041-0004**) provides a means for maintaining and protecting water by requiring that all activities with the potential to affect existing water quality undergo review and comment prior to any decision to approve or deny a permit or certificate for the activity[86]. The High Quality Waters Policy (**OAR 340-041-0004(6)**) states: "Where the existing water quality meets or exeeds those levels necessary to support propagation of fish, shellfish, and wildlife and recreation in and on the water, and other designated beneficial uses, that level of water quality must be maintained and protected."

6.2.2 Assessment of Current HAB Related Water Quality Standards and Water Quality Assessment Methodology

Nutrient Standards: Oregon does not have numeric nutrient standards. The option of developing a numeric nutrient standard was explored in 1986 but the Environmental Quality Commission chose to use chlorophyll a action levels (OAR 340-041-0019). Part of the reason for not developing a nutrient standard, at that time, was the diverse nature of natural background concentrations of nutrients, particularly phosphorus, found in Oregon made it difficult to come up with reasonable target values. Other factors, such as the rate at which nutrients cycle through a system such as a lake, are also important considerations along with the loading to the system (Eilers et al, 2011 – in press).

In developing TMDLs to address HABs and other nuisance algal blooms, specific targets are set for the waterbody through the TMDL which are incorporated, by reference, in the basin specific standard. These targets often include nutrients (phosphorus) or other related parameters (e.g. sediment load to Tenmile Lake or eradication of an invasive fish species as related to cyanobacteria biomass in Diamond Lake). A summary of nutrient TMDLs is shown on Figure 6-1 and in Table 6-1.

Figure 6-1. Waters with Nutrient TMDLs (see Table 6-1 for detail)

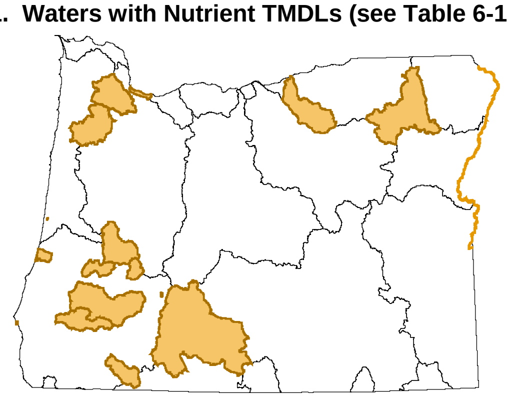

Table 6-1 Pollutants and estimated instream targets from nutrient TMDLs - for summary information only, see specific TMDLs for exact nutrient targets. Waters listed in chronological order of the TMDL approval date.

Waterbody (TMDL date)	Limitation	Cause	Pollutant	Nutrient Instream Target	Notes
Garrison Lake (1988)	pH, Chla	phytoplankton	TP	576 lbs / year	Port Orford 0 lb / year
Tualatin (1988, 1994; revised 2001)	pH and DO	phytoplankton	NH3, TP, BOD, settable solids	TP: 40 to 110 µg/L	CWS: nutrient removal; Lake Oswego, which receives water via a canal from the Tualatin, has had a HABs advisory; Wapato Lake drainage was the source of an algal bloom in the lower Tualatin in 2008
Bear Creek (1992; revised 2007)	pH and DO	periphyton	TP and BOD	TP: 100 µgP/L	Ashland
Clear Lake (1992)	Drinking water	prevention of aquatic growth	TP		
Yamhill (1992)	pH and DO	phytoplankton	NH3, TP, DO, BOD, TSS	TP: 50 – 70 µgP/L	McMinnville
Coast Fork Willamette (1996)	pH and DO	periphyton	DOP,	DOP: 11 µgP/L	Cottage Grove: 60 ugP/L DOP
Columbia Slough (1998)	pH, DO, chlorophyll a, phorphorus	phytoplankton, macrophytes, and periphyton	TP and DOP		CSO, stormwater, groundwater; Fairview Lake, part of the Slough system has had a HABs advisory
Grande Ronde, Catherine Creek (2000)	pH and DO	periphyton	DOP, DIN	DOP: 7 µgP/L DIN: 20 µgN/L	La Grande: no discharge Union: no discharge
Umatilla (2001)	pH	temperature	heat		
Upper Klamath Lake (2002)	pH	phytoplankton	TP	~110 ug/l annual lake mean TP; ~30 ug/l spring (March – May) lake mean TP; ~66 ug/l annual mean TP from all inflows;	Targets background loading. 40% reduction in phosphorus loading; Lake has had HABs Advisories
Snake River (2004)	Nuisance algae, DO	periphyton	TP	TP: 70 µgP/L	Mechanical plants 80% reduction; Brownlee Reservoir has experienced HABs
Diamond Lake (2007)	DO, pH, Chla, HABs	phytoplankton	Fish	Not reported	Targets natural loading; Lake has had HABs Advisories
South Umpqua River (2007)	DO, pH, Chla,	periphyton	TP and DOP	DOP: 8 µgP/L*	RUSA, Winston-Green, Myrtle Creek, Canyonville,

Waterbody (TMDL date)	Limitation	Cause	Pollutant	Nutrient Instream Target	Notes
	phosphorus			TP: 14 µgP/L	Tiller WWTPs
Cow Creek (2007)	pH and DO	periphyton	TP and DOP	DOP: 10 µg/L* TP: 20 µg/L	Riddle and Glendale WWTPs
Jackson Creek (2007)	pH	periphyton	DOP and DIN	DOP: 35 µg/L* DIN: 45 µg/L	Approx. Natural concentrations.
Steamboat Ck (2007)	pH and DO	periphyton	DOP and DIN	DOP: 21 µg/L* DIN: 30 µg/L	Approx. Natural concentrations
Calapooya Ck (2007)	pH and DO	periphyton	Phosphorus and organic solids	TP: 20 µg/L*	
Deer Creek (2007)	DO, spawning	BOD	BOD	BOD: 0.7 mg/L	
Tenmile Lake (2007)	Aquatic weeds and algae	phytoplankton	Sediment Load with a TP target	0.07 tones/ha/yr with a 50% reduction within 25 years; TP target of 7.1 µg/L	Lake has had HABs Advisories
Malheur River (2010)	To meet Snake River TMDL		TP	TP: 70 µgP/L	
Draft Klamath River	DO, pH, Chla, ammonia toxicity	phytoplankton, periphyton, BOD	TP, TN, 5-day BOD	TP: 27 µg/L * (1) TN: 520 µg/L * (1) BOD: 1.7 mg/L (2)	Upper Klamath Lake predicted to have a wide range of nutrient concentrations under natural conditions. Klamath Falls and South Suburban WWTPs 50% load reduction
Draft Lost River	DO, Chla, pH, ammonia tox.	macrophytes, BOD	CBOD, DIN	Not reported	

DO – dissolved oxygen; NH3 – ammonia; TP – total phosphorus; DOP – dissolved orthophosphate; BOD – biochemical oxygen demand; DIN – dissolved inorganic nitrogen
* Estimated from graphs; when longitudinally variable, the maximum is reported
(1) based on a conservative natural condition estimate from UKL TMDL
(2) from upstream boundary condition

EPA has made development of nutrient criteria a national priority[87] and one of their goals was to accelerate the progress of state adoption of numeric Water Quality Standards while building the scientific and technical infrastructure for developing new criteria to address nitrogen and phosphorus pollution (Section 5.2).

In the early 2000's, EPA published a number of documents that recommended criteria for total phosphorus, total nitrogen, chlorophyll a and turbidity for rivers and streams by Level III Ecoregion. EPA's expectation was to develop nutrient criteria that would cover the four major types of waterbodies: lakes and reservoirs, rivers and streams, estuarine and coastal areas, and wetlands across fourteen major Ecoregions of the United States. The criteria were to be used as a starting point for states to develop their water quality standards. Values suggest for Oregon Ecoregions are in Table 6-2 based on 25th percentile data for reference conditions using all season data for data collected from 1990 to 2000. Factors, such as the amount and variability of the nutrient data for reference sites, limited the use of this initial work along with the fact that Oregon has focused on developing other standards during the 2000's.

Table 6-2 EPA suggested nutrient criteria for reference conditions in Oregon rivers and streams by ecoregions – 25th percentile with the range in parenthesis[88]

Ecoregion	Total Phosphorus (ug/l)	Total Nitrogen (mg/l)	Chlorophyll a (ug/l)
Blue Mountains	32 (7.5 – 420)	0.3 (0.3 – 0.3)	1.4 (0.4 – 15.5)
Cascades	9 (0 - 242)	0.06 (0 – 2.86)	1.0 (0.6 – 12.7)
Coast Range	10 (0.6 – 522)	0.13 (0.05 - 1.9)	2.5 (1.9 - 14.2)
Columbia Plateau	30 (2.5 – 2070)	0.22 (0.08 – 3.1)	1.8 (0.8 – 27)
Eastern Cascades	11 (4.4 - 752)	0.52 (0.11 - 3.1)	2.9 (0.43 – 53)
Klamath Mountains	32 (5.6 – 455)	0.53 (0.53 – 0.53)	1.2 (0.75 – 6.3)
Northern Basin/Range	55 (10 – 334)	0.48 (0.42 – 1.7)	2.8 (0.6 – 4.3)
Willamette	40 (2 – 816)	0.32 (0 – 3.0)	1.8 (0.4 - 31)

Region X developed a Regional Technical Advisory Group in 1999 that initiated work to explore the development of regional nutrient criteria. Initial work focused on lakes in the Coast Range Ecoregion (Vaga et al, 2002) but found that additional data and analysis would be needed.

In 2007, DEQ (Hubler et al, 2010) participated in the National Lakes Survey[89] which was a probabilistic survey that included nutrient reference sites where *least-disturbed* lakes were sampled to establish benchmarks for physical, chemical and biological parameters (see Appendix D). Additionally, DEQ has been doing various types of probabilistic monitoring surveys[90] on other waterbodies including streams, estuaries and wetlands. These various sources of data could be a basis for again exploring a means for developing nutrient standards for Oregon.

DEQ has previously outline its process for controlling nutrients and protecting uses of Oregon's waters in a January 31, 2007 letter to EPA (Appendix E). The letter outlines the use of various numeric and narrative starndards that protect uses from the adverse effects of excessive nutrients and the use of the TMDL program to establish appropriate nutrient targets and to cause effect approaches to resolve problems.

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March 16, 2011 EPA Memorandum "Working in Partnership with States to Address Phosphorus and Nitrogen Pollution through Use of a Framework for State Nutrient Reductions

Another approach to addressing concerns related to HABs could be through development of standards for specific cyanotoxins. Microcystins are not regulated by EPA in drinking water, but are unregulated microbial drinking water contaminants listed on the EPA's Contaminant Candidates List (CCLs) 1 and 2 as cyanobacteria and their toxins. Specifically, Anatoxin-A, Microcystin-LR and Cylindrospermopsin are on the CCLs. The WHO has established a provisional guideline of 1 ug/L for microcystin-LR.[91]

In summary, some conclusions regarding the need for numeric nutrient criteria and HABs are:

- Known HAB problems can be identified on 303(d) list using the current narrative standard. The 303(d) listing approach of using OHA Health Advisories as the basis of determining beneficial use impairment under deleterious growth narrative criterion (OAR 340-041-0007) as well as listing based other related numeric water quality standard violations (e.g. pH, DO, Chlorophyll a) allows DEQ to identify and address waters with documented HABs problems.

- The identification of waters with HABs is limited by the adequacy of the monitoring and surveillance program for HABs (as discussed in Section 6.1) than by the lack of a nutrient standard. Identifying and adding additional lakes and reservoirs (such as many of those in Appendix B) as Category 3B (potential concern) in the Integrated Report could help resource management agencies and health authorities target lakes and reservoirs that need additional data collection efforts

- The 303(d) process deals with existing problems and does not prevent problems. While this approach can recognize and begin to deal with problem waterbodies, it does not help prevent the problem (see Section 6.3 for further discussion related to prevention). A nutrient standard could provide a more specific numerical reference for use under the Antidegradation Policy. DEQ has developed an Internal Management Directive that provides methods and direction for implementing the Antidegradation Policy for NPDES Permits and Section 401 Water Quality Certifications. During the development and approval process of the toxic standard in 2011, DEQ has committed to developing an IMD for other activities such as nonpoint sources.

- The need for re-examining if nutrient standards are appropriate appears warrented at this time, especially given the number of waterbodies with nutrient targets and the greater availability of probabilistic data on Oregon's lakes and streams, which would allow DEQ to determine regional and waterbody specific nutrient differences. In recent years, DEQ has been doing an extensive review of its toxics and turbidity standards as part of its triennial standards review. The next triennial standards review will start when the development of these standards is completed (likely in 2012).

6.2.3 Recommendations related to Current HAB Related Water Quality Standards and Water Quality Assessment Methodology

- DEQ should explore development of a nutrient standard in the next triennial review. Currently two major standard revisions are underway – toxics and turbidity. These are anticipated to be completed by in 2011**,** after which, the Department proposes to develop an issue paper that that will explore the topic of nutrient standards for Oregon in more depth and be a vehicle for statewide discussion on the potential need and possible approaches for developing a nutrient standard.
- DEQ should develop an IMD for Antidegradation Policy Implementation for nonpoint sources.
- DEQ should continue to list waters with HABs Health Advisory as category 5 (or other appropriate category based on management activities) based using OHA Health Advisories as the

basis of determining beneficial use impairment under deleterious growth narrative criterion (OAR 340-041-0007) in its biennial Integrated Report (303(d) list). DEQ should also list waters with supporting data that do not meet OHA guidelines but did not have Health Advisories issued.

- The "potential concern" category (Category 3B) should be used as a means to focus future data collection activities. Adding information can be an additional workload but could be done through the Watershed Approach that DEQ has initiated, which targets three geographic areas/year (one in each region), covering the state in five years. This would help identify potential problem areas, taking advantage of local knowledge in those basins, and can be the focus of future data collection.
- EPA should develop Water Quality Criteria for Cyanotoxins.

6.3 Pollution Reduction Plans (e.g. TMDLs and other Management Plans)

Section 303(d) of the Clean Water Act requires States to:

- identify waters that do not meet water quality standard (303(d) list);
- establish priorities for the listed waters for developing Total Maximum Daily Loads (TMDLs) taking into account the severity and uses of the waterbody; and
- develop TMDLs for the pollutants causing the standard violation at a level necessary to bring the waterbody back into compliance with the standard.

The following discussion describes current approaches that the Department uses for developing TMDLs that relate to HABs, evaluates the process and makes recommendations for further consideration. Other pollution control requirements and management plans can substitute for TMDLs and are discussed here as well. Additionally, the Watershed Approach that DEQ began in 2010 is briefly discussed.

6.3.1 Current HAB Related TMDL Approaches

DEQ has developed a number of TMDLs (Table 6-1) covering impaired waters in which nutrient or other pollutant loading targets (sediment, invasive fish) were established for waters that did not meet standards related to aquatic growth (pH, dissolved oxygen, chlorophyll a, aquatic weeds or algae) since 1988. Several of these waters (Diamond, Klamath, Oswego, Tenmile Lakes and the South Umpqua River at Lawson Bar) experience HABs and the TMDLs have been developed to reduce nutrient loadings and thereby address HABs.

With the inclusion of HAB Health Advisories as a criterion for listing, an additional 28 waterbodies (mostly lakes) were added to the 303(d) list in 2010. Five waterbodies, which were already listed for other parameters (e.g. pH, chlorophyll a), had HAB Health Advisories added as another reason for listing. This makes 33 waterbodies that currently need TMDLs or their equivalent to address HABs. As pointed out in Section 3.5 and 6.1, this is likely an underestimation of the number of waterbodies that experience HABs, based on limitations in the current surveillance program, so this number is likely to grow if additional surveillance occurs.

The development of TMDLs to address aquatic growth has occurred at a relatively slow but steady pace of approximately two TMDLs every three years (16 TMDLs have been developed over a 24 year period, 1986 – 2010). During this time period, the Department has typically focused on developing TMDLs for pollutants that are of concern on a basin-wide scale (rather than for specific waterbodies) and has focused on parameters that more directly affect Threatened and Endangered Fish Species (e.g. temperature). This approach has been in response to commitments made under the Oregon Plan to address T&E Species and commitments to achieve a certain number of TMDLs by 2010 under the TMDL Consent Decree (there were considerable number of temperature listings on the 303(d) list compared to HAB related listings).

Most of the HABs listings occur in lakes (90% or 36 out of 40 category 4 and 5 listings). While DEQ has attempted to develop TMDLs for all waters and parameters listed in a basin (e.g. Diamond Lake was included in the Umpqua TMDL and Klamath Lake in the Upper Klamath TMDL), often lake TMDLs have been done separately given a variety of factors including: different stakeholder groups to work with compared to the basin-wide concerns; the need to get intensive data specifically within a lakes watershed; the differences in modeling techniques; and limited agency expertise for working on lakes compared with rivers. DEQ has often used outside consultant expertise in modeling and developing lake TMDLs to make up for some of these limitations. DEQ is currently in the process of doing studies on additional waters that are now listed for HABs (Blue, Lava, Lemolo and Odell Lakes) that could lead to TMDL development or other action.

Beginning in 2010, DEQ has started a Watershed Approach (WA) to assist in managing water quality in the State of Oregon. This approach will provide a broad assessment of the status of water quality and other environmental indicators within a basin, greater opportunities for stakeholder involvement and interagency cooperation. This approach will hopefully address some of the limitations of the TMDL process and improve internal DEQ sub-program coordination. The WA is intended to provide a basin-scale resource assessment process with more opportunities for direct, interactive feedback from local stakeholders than the TMDL process. Unlike a TMDL, the WA process is not limited to addressing 303(d) listings. It addresses surface water status for both 303(d) listings and other surface water related concerns, as well as groundwater and upland conditions providing an evaluation of the environmental status of the basin as a whole. While the WA process is being designed to address some of the limitations of the TMDL process, it will not replace TMDLs. The WA does not have the regulatory authority of a TMDL and should be viewed more as a guidance document than a regulatory requirement. Priorities for the basin, including TMDL priorities, will be identified in the WA.

The approach includes developing plans for each basin, or in some cases sub-basins, in the state. The plans will consist of a Status Report and an Action Plan that summarizes the important water quality problems and the strategies that need to be implemented. Together, the Status Report and Action Plan will allow for the adaptive management of water quality in that geographic area.

It is intended that the WA process will eventually be implemented state-wide. It is hoped that this broad-based approach will allow greater flexibility in the assessment process and more assurance that the WA will be iterative in nature. It is currently envisioned that each DEQ region (Eastern, Western and Northwest Oregon) will complete a WA for one basin each year. There are approximately 15 basins within the state. This would allow the findings of the WA to be revisited and updated every 5 years. In 2010, plans were developed for the Deschutes, North Coast and Rogue Basins. In 2011, plans will be developed for the Burnt/Powder, Clackamas, and South Coast Basins.

In both the Rogue and Deschutes WA, HABs were identified as substantial and moderate concerns for water quality respectively. Studies to identify the drivers for HABs in these basins and to be the basis of loading targets and management plans are underway on selected lakes in these basins (Odell Lake in the Deschutes and Willow Lake in the Rogue).

6.3.2 Assessment of Current HAB Related TMDL Approaches

- TMDLs are an effective approach for developing appropriate pollutant pollutant loads to address the causes of HABs. TMDLs are not only required under the Clean Water Act but they are a good tool for doing the necessary studies to determine factors that are causing HABs and setting appropriate goals for addressing HABs. As indicated in Table 6-1, a variety of targets have been set in the TMDLs that have been developed to address aquatic growth including nutrients (a variety of forms of phosphorus and nitrogen), fish, sediment and temperature targets. The TMDL approach is a sound approach for developing these targets but does not need to be the only approach.

- Addressing HABs on a lake by lake basis will take considerable time. DEQ's TMDL pace has been slow to address HABs, in part due to a primary focus on T&E fish listings and addressing temperature concerns and in part due to the complexity of gaining a sufficient understanding of factors within a watershed that cause the excessive aquatic growth. For illustration purposes only, at the current rate (2 aquatic growth related TMDLs every three years), it would take approximately 50 years to address the 33 waterbodies listed for HABs on the 2010 303(d) list. An approach that addresses a problem lake at a time will not address the overall issue in a timely manner.

- The number of waters listed for HABs will likely increase. There are currently 33 waterbodies listed for HABs. This number of listings is likely to go up, given the likelihood that there are many more lakes experiencing HABs and, with increased awareness, there will be likely be increased surveillance. Additionally, factors such climate change and the increased demand for uses of water will further stress Oregon's water resources and will likely result in declining water quality and increased HABs.

- TMDLs can address lakes experiencing HABs but will not prevent other lakes from developing HABs: The Department's TMDL approach currently being applied on a lake by lake basis with TMDLs that set a target for a specific lake can ultimately address waters on the list, but would not address nearby lakes that may be declining or could be experiencing HABs. For example, the 2007 Umpqua TMDL addressed blooms in Diamond Lake and the South Umpqua River but, in 2010, four other listings for HABs were added in the Umpqua (Lemolo and Fish Lakes, Elk Creek and the Umpqua River).

- Currently, DEQ does not have a TMDL specialist on staff that is well versed in lake modeling or HABs. DEQ has typically had a variety of modelers developing TMDLs to address aquatic growth issues and has used a great deal of consulting expertise for developing TMDLs on lakes. Consultants have been hired by agencies that manage reservoirs and lakes as well. This is not necessarily a problem but, given the likelihood that DEQ will need to be spending more time on developing HAB related TMDLs, it is worthwhile to consider having a staff position with specialized lake and HAB expertise within the TMDL section who can look at the broader issues, be a resource for other TMDL modeling and implementation staff and can work with other agencies and consultants who are doing HAB related studies.

- There may be some efficiency in addressing lakes in groupings rather than individually on lake by lake basis to gain some economies when addressing similar types of problems. This can be done by focusing on groups of lakes in a common ecoregion or area of the state (e.g. coastal, high cascades, southwest Oregon), basin/lake type (e.g. Willamette reservoirs) and/or where there may be common problems or approaches for management (e.g. fish stocking, reservoir management, shallow lake/pond management) as pointed out in the Characterization Section (Chapter 3.6). Additionally, use of technologies, such as using remote sensing, can help in identifying lakes that may be experiencing similar problems (Turner, 2010).

- Applying lessons learned within a similar group of lakes can accelerate implementation and potentially prevent problems. There is a need to examine causes, potential solutions and extend what has been learned over a broader area as appropriate to prevent or address other similar situations. Examples include: examining the role of fish stocking and introduced species in high Cascade Lakes, drawing from the Diamond Lake study; impact of sedimentation and septic tanks, drawing from the Tenmile Lakes study; facilitating the exchange of information regarding lake management techniques among lake managers, e.g. aeration and alum use experience (Lake Oswego), pond restoration (Laurelhurst Pond), etc. DEQ should explore the use of the Category 4B approach (use of other pollution controls) as it may be more appropriate means of addressing potential issues such as fish stocking, pond management, etc.

- The Department has committed to the development of Implementation Ready TMDLs in the Coastal Zone. These should provide a more detailed goal or target under which management agencies can address sources of nutrients and sedimentation when a TMDL is developed. Implementation Ready TMDLs will likely be done on a watershed and sub-watershed scale, as opposed to a basin or sub-basin scale starting with basins in the Coastal Zone Management Area. Implementation Ready TMDLs would be appropriate for lake TMDLs.

6.3.3 Recommendations Related to Current HAB Related TMDL Approaches

- Continue to Address Aquatic Growth under the TMDL Program. In recent years, a number of studies and control strategies have been developed for lakes that experience HABs under the TMDL program including: Diamond, Klamath and Tenmile Lakes. This effort should continue and a number of options should be explored that may accelerate these studies by drawing on what has been learned in earlier studies:

    - Lake/HABs Specialist: Dedicate a portion of a modeler in the Watershed Management Section to be the lead on lakes and HABs issues. This position would require: being knowledgeable about HABs, lake/reservoir modeling and lake/reservoir management techniques; working with staff , other agencies and consultants to address HABs and lake related issues; and to begin to either take on or work with other staff to begin to address broader issues related to HABs (e.g. developing an Oregon HABs surveillance program, investigating the role of fish with HABs in High Cascade Lakes, reservoir management, etc) that would include working with other resource management agencies.

    - Lake Groupings: The Department should explore various ways of addressing waters that experience HABs as various subgroups, rather than individually. Some of these have been indentified in Section 3.6. While this approach needs to be tempered by the fact that each water body is unique, potential subgroups can be developed as the Department completes more studies on waters with HABs. These groupings could be done geographically (e.g. ecoregion), lake type (reservoirs, shallow lakes/ponds), common lake issues (e.g. fish stocking in formerly fishless Cascade Lakes), etc. Several subgroups seem to be apparent at this time that could be investigated further:

        - High Cascade Lakes and the role of fisheries on HABs (building off the technical work from the Diamond Lake TMDL and studies on Odell Lake, see section 3.6);
        - Coastal Lakes and the role of septic tanks and sediments with HABs (building off the technical work from the Tenmile Lakes TMDL);
        - Willamette River Reservoir Management working with the USACE and others (e.g. utilities such as Portland General Electric; Drinking Water Supplies such as those in the Clackamas and the Cities of Cottage Grove, Eugene, Lowell, Salem, Springfield, etc);
        - Ecoregional and/or geographic opportunities such as Jackson County Lakes and Reservoirs;
        - Urban, heavily managed lakes (Blue, Fairview).

      This approach could result in addressing a larger number of lakes and potentially preventing HABs in lakes that have similar issues with the potential of doing it in a shorter time period and using fewer resources.

- Consider 4B and 4C alternatives to TMDLs, as appropriate: The Clean Water Act allows for other options, than a TMDL, to address a water quality limited waterbody including: 4B - other pollution control requirements are expected to address all pollutants and will attain water quality standards; and 4C – impairment is not caused by a pollutant (e.g., lack of flow is not considered a pollutant). Techniques, such as the development and implementation of a management plan for Laurelhurst Pond, were considered adequate to address the HABs listing and were suggested as 4B on the 2010 Integrated Report. Similarly, if a High Cascade Lakes fishery management plan were deemed appropriate to address HABs listings for selected lakes in the Cascades, it could be deemed appropriate under Category 4B or 4C (see section 6.2 for discussion of the categories).

- Implementation Ready TMDLs: The Department has committed to the development of Implementation Ready TMDLs in the Coastal Zone. These should provide a more detailed goal or target under which management agencies can address sources of nutrients and sedimentation when a TMDL is developed. Implementation Ready TMDLs will likely be done on a watershed and sub-watershed scale, as opposed to a basin or sub-basin scale starting with basins in the Coastal Zone Management Area. These TMDLs would be appropriate for lake TMDLs.

- Prioritization of Water Quality Problems: DEQ is using a Watershed Approach for assessing water quality problems within a basin and to prioritize problems and the actions necessary to address the problems (this can include TMDLs or other work). HABs have been identified as moderate and high priority problems in the Deschutes and Rogue reports, respectively. It is unclear at this time how this will translate to the TMDL priorities which are to be submitted to EPA every two years. Further work is needed to clarify the meshing of watershed priorities with the overall TMDL priorities.

- Utilize authority under Section 303(d)(3) for Protection: Where Section 303(d)(1) requires States to develop TMDLs for pollutants that cause waters not to meet water quality standards, Section 303(d)(3) encourages States ("for the purpose of developing information") to estimate TMDLs for other waters to their assure their protection. These estimated TMDLs could provide management targets, especially for lakes and reservoirs at risk of experiencing HABs, for various agencies and watershed groups that are involved in management and protection of those lakes.

6.4 Drinking Water Source Water Protection (SWP)

Primary concerns related to HABs are the threat to and protection of drinking water supplies. Oregon implements a joint program through a partnership between DEQ and OHA for drinking water *protection*. The Safe Drinking Water Act does not have authority to prevent contaminants entering the water systems. The Clean Water Act is the implementing authority for preventing contamination in the source streams and groundwater. The DEQ drinking water protection program staff provide data, GIS information, and technical assistance for preventing contamination of drinking water sources. As part of this program, DEQ and OHA completed source water assessment reports for over 1100 public water systems in Oregon. The assessments include a GIS delineation of the geographic source area that supplies the public water system, and provides data and information on the potential contamination risks (natural and man-made).

Oregon's SWP activities for both DEQ and OHA include:

- Assisting individual Public Water Systems;
- Statewide and Regional Projects;
- Land use planning assistance;
- Coordinating with State and Federal agencies;
- State Revolving Fund Grants;
- Source Water Assessment data availability and distribution;
- Assistance to smaller non-community water systems (schools and work sites);
- Coordination with National Rural Water Association Rural Communities Action Corp.

The following discussion describes current approaches that DEQ use for source water protection and makes recommendations for further consideration. As this effort is a close partnership with OHA, some of OHA's actions are decribed as well.

6.4.1 Current HAB Related Source Water Protection Approaches

When an algal bloom has the potential to affect a public water system, OHA responds through a consistent protocol for communication and technical assistance. This procedure focuses on providing technical assistance to water treatment plant operators to minimize the chance for cyanotoxins to enter the public drinking water supply from an algal bloom. If an algae bloom is reported near a Public Water System (PWS), OHA advises the PWS to test initially for algae identification/enumeration if no other test has been performed on the particular water body of concern. This is to determine if the algae is present in concentrations sufficient to produce toxins (WHO suggests a drinking water guideline of 20,000 cells/ml). OHA provides the PWS with a list of algae labs.

If a public health advisory has been issued by OHA for recreational purposes on a water body where a PWS has an intake, OHA advises the PWS to test water for the potential toxins associated with the type of cyanobacteria present. Testing raw and finished water for toxins would provide the most relevant data, however if cost is a limiting factor testing only finished water is recommended. Weekly toxin testing is advised. If a bloom on a water body is affecting a downstream PWS or a PWS has a well near the blooming water body (within 500 ft.), OHA advises the PWS to use an alternate source of water if possible and consider advising PWS to take a toxin test on a case-by-case basis. The likelihood of toxins entering the public water supply in these situations is very rare. Factors that are considered in the downstream scenario include the distance from the PWS intake to the outfall of dam or reservoir, the dilution factor, and the degradation rate by UV light and rapidly moving water. For groundwater wells, the scenario factors to consider include the soil type/geology according to the well log, the bloom intensity, and the well pumping demand and capacity. For the most up-to-date information regarding HABs and PWS, see the OHA website[92].

Algal toxins are on the EPA Contaminant Candidate List for consideration of future regulation, but there are no current drinking water standards. Algae are present in all surface waters and in some cases can increase filter head loss and decrease filter run times thereby increasing maintenance costs in treatment plants. The World Health Organization (WHO) has established a health-based drinking water guideline of 1.0 ppb for one algal toxin, Microcystin-LR. The Australian standard is 1.3 ppb for total microcystins, while Health Canada has proposed a similar standard of 1.5 ppb for total microcystins. If results of toxin testing in treated drinking water indicate microcystin is above 1.0 ug/L, OHA advises the water system to post an immediate public notice indicating toxin levels have exceeded the World Health Organization guideline value of 1 ug/L, and drinking this water is not advised. OHA provides assistance to PWSs for alternative sources and supplies during these types of emergencies. Potential solutions include relocating the intake and using powdered activated carbon (PAC), granular activated carbon (GAC), or ozone in the water treatment plant. Both PAC and GAC are capable of removing algal toxins from the water, while ozone is a more powerful and effective oxidant than chlorine. Effectiveness of these processes depends on the type of toxin and other parameters.

Both agencies offer more to PWS, in addition to response to HABs. DEQ's drinking water protection staff has identified and mapped the "potential sources of contamination (PCS)" that pose the greatest risk to the source waters for each system. The Source Water Assessment reports for community public water systems contain lists of PCSs identified within drinking water source areas. Over 18,000 PCSs are in DEQ's database for drinking water source areas, including all 5^{th}-field watersheds for the entire western slope of the Cascade Mountain range. These are all municipal watersheds for communities in the Willamette and Rogue Valleys. These data are readily available to this and other programs seeking to address HABs or prevent HAB-related contaminant loadings. Examples of the types of PCSs[93] in DEQ's database include:

- Agricultural-related activities including: CAFOs, grazing animals, irrigated and non-irrigated crops
- Forest management activities including harvests, chemical application areas, and roads
- Wastewater treatment plant discharges and high density areas of septic systems
- Transportation-related activities including: stream crossings, high use roadways and corridors, railroads, and runoff from parking lots
- Stormwater detention ponds and outfalls from urban residential, commercial and industrial sources
- Mining, industrial and manufacturing activities
- Dump sites and landfills

For preventative work within watersheds, DEQ uses the database to prioritize potential sources of contamination in areas that are more susceptible to the contamination. These activities or facilities are prioritized for grants and technical assistance from DEQ and other partners such as the OSU Extension Service. In some watersheds, potential sources of contamination to surface water may also include areas of groundwater contamination discharging to surface water.

As an example of grant support, four community water systems using coastal lakes (Clear, Eel, Siltcoos and Woahink Lakes) as their water source partnered to apply for a Safe Drinking Water Protection grant to build local capacity related to HABs. The project is starting its second monitoring season in 2011 and has trained a number of interested parties and volunteers, including local PWS staff and watershed council staff. These stakeholders have identified two HAB events at their lakes and were key links in the identification and sampling chain.

DEQ drinking water staff provides Source Water Assessment data and GIS layers to many other programs. Maps and downloadable statewide GIS shapefiles of drinking water source area coverages and identified potential sources of contamination are available on DEQ's Drinking water source protection website. Drinking water source areas can now also be identified (and selected as a search criteria) for both DEQ's Facility Profiler (a location based system showing DEQ permit holders and cleanup sites) and DEQ's LASAR (Laboratory Analytical Storage and Recovery for air and water quality monitoring data). The source water assessment data are also available from other Oregon websites, including the OSU Institute for Natural Resources and the Oregon Geospatial Data Clearinghouse.

DEQ developed a "Public Water System Locator Web Tool" to allow agency staff, permittees, and the public to easily identify and obtain contact information for downstream public water system intakes[94]. This was initially designed to assist NPDES permittees as they develop and implement Emergency Notification and Response Plans but is also useful for other applications as well.

6.4.2 Recommendations related to Current HAB Related Drinking Water Protection Approaches

- Collect and assess more data to characterize the vulnerability of public water supply source waters. In particular, more data would help assess whether source water is being negatively impacted by a variety of activity including harmful algal blooms, pesticide applications, biosolids applications, high density septic systems, and forest management practices, etc. Algal toxins should be considered when screening source water for toxins. More data will increase the likelihood that DEQ is correctly targeting the pollutants and sources that pose the greatest risks to human health and drinking water in Oregon. This can be done by DEQ and/or the water supply.

- Continue analyzing existing data to determine potential risk to public health. For source testing data, continue strong partnership between toxicologists at OHA RES and DEQ DWP staff to ensure consistency in evaluation and interpretation of data for public water systems.

- Continue technical analysis and reports. Reports such as the Turbidity Report[95] and Nitrate Report (in development) can be useful for affecting changes in policy/rules, where needed, and for prioritizing funding and technical assistance. This work can be useful for addressing sedimentation and nutrients, which can contribute to HABs.

- Actively minimize input from known sources of pollutants where possible. Utilize data from source testing to prioritize DWP staff technical assistance, BMP implementation and project development. Use characterization of potential sources (with data) to develop pollutant reduction priorities for statewide policy work and to work with PWS to develop and implement protection plans. In some cases, such as with Dunes City which relies on the surface waters of Woahink and Siltcoos Lakes for their potable water, local ordinances have been developed to address sources of phosphorus which contribute to HABs in Siltcoos Lake.[96]

- Leverage resources, update/share data and GIS information/analysis, and assist in implementation of other programs when directly related to drinking water sources. Develop and implement a joint DEQ/OHA strategy to identify water supplies at risk for HABs and provide technical assistance to those sources for testing, treatment alternatives and protection.

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[96] Dunes City septic tank maintenance ordinance
Dunes City phosphorus reduction ordinance - Dunes City Building Moratorium on certain type of development

6.5 Nonpoint Sources

Oregon's Nonpoint Source (NPS) program is implemented by land use in order to address water quality issues on agricultural lands; state, private, or federal forest lands; or in urban areas (Table 6-3).

Table 6-3 Oregon Nonpoint Source Implementation Strategies by Land Use

Land Use	Implementation Strategies[97]
Agricultural Land	Oregon Department of Agriculture's (ODA) is responsible for developing and implementing agricultural pollution prevention and control programs to meet water quality standards, Total Maximum Daily Load (TMDL) allocations, and to implement Groundwater Management Area (GWMA) action plans affected by agricultural lands. These are done through the development and implementation of Agricultural Water Quality Management Plans (AgWQMP) which have been developed at the basin or sub-basin level. DEQ's Pesticides Stewardship Partnership uses a voluntary, collaborative approach to identify problems and improve water quality associated with pesticide use.
State and Private Forest Land	Oregon Department of Forestry (ODF) is the Designated Management Agency by statute for regulation of water quality due to nonpoint source discharges or pollutants resulting from forest operations on forestlands and oversees the Forest Practices Act (FPA). DEQ and ODF periodically do a sufficiency analysis of Best Management Practices to determine if they are sufficient to meet standards. The 2002 ODF/DEQ Sufficiency Analysis: A Statewide Evaluation of FPA Effectiveness in Protecting Water Quality identified 12 recommendations that included improvements to the implementing rules or guidance of the FPA and other recommendations under the Oregon Plan for Salmon and Watersheds. ODA, Oregon Division of State Lands (DSL), Oregon Department of Land Conservation and Development (DLCD), Oregon Department of Fish and Wildlife (ODFW), Oregon Parks and Recreation Department (OPRD), and DEQ have common interests and responsibilities in protecting waters of the state and other natural resources during the conversion of forestland to non-forest uses.
Federal Forest Land	DEQ has a Memorandum of Agreement (MOA) with the Bureau of Land Management and a Memorandum of Understanding (MOU) with the US Forest Service to ensure water quality standards, TMDLs, and drinking water rules and regulations are met. This includes periodic assessments through 5-year progress reports and updates to the agreements.
Urban and Rural Residential, transportation	DEQ, in cooperation with the Oregon Department of Land Conservation and Development's (DLCD) Oregon Coastal Management Program, has developed Oregon's Coastal Nonpoint Pollution Control Program (CNPCP) designed to restore and protect coastal waters from nonpoint source pollution. Coastal states are also required to implement a set of management measures based on guidance published by EPA. Water Quality Model Code and Guidebook - The goal of the guidebook is to provide local communities, both small cities and counties, with a practical guide to protecting and enhancing water quality through improved land use regulations. The guidebook includes model development code ordinances and comprehensive plan policies that are ready for implementation. Stormwater is being managed under permit for cities over 100,000 and smaller cities within their urban areas. Other cities under TMDLs often need to address the same requirements that under the Phase II Storm Water Permit in their TMDL management plan.

An assessment of the current Nonpoint Source Program was not made as part of this HABs strategy development. The following recommendations were made based on the review of the HABs in Oregon (Chapter 3) including the Characterization of HABs Problems in Oregon and Implementation for their Management (Chapter 3.6) as well as from review of other state programs. Many of the recommendations draw from lessons learned from lakes that had more detailed studies done and were actively implementing plans to control HABs (Appendix C).

6.5.1 Recommendations related to Current Nonpoint Source Activities

- Continue to address nutrient, sediment and other HAB related load allocations to lakes through Forest Practices Act, Agricultural Area-Wide Water Management Plans, and Designated Management Agency Management Plans**.** DEQ is currently developing a Total Maximum Daily Loads Internal Management Directive (ODEQ, draft 2011) that describes in detail how the Department will develop TMDLs, develop Water Quality Management Plans (which is a broad strategy for implementing TMDLs) and evaluate the adequacy of DMA Implementation Plans. This includes evaluating the adequacy of Agricultural Water Quality Management Area Plans and Forest Practice Act which are the means that the Oregon Department of Agriculture and Department of Forestry use to meet load allocations and water quality standards. While this Directive was still in draft at the time this report was developed, this Directive should provide a consistent framework for developing and implementing TMDLs and will document how DEQ will make decisions related to TMDLs within its regulatory authority. Consideration, such communicating or addressing the potential risks to farm workers and to crops from using waters that have HABs for irrigation, should be given in the development and review of the Agricultural Area-Wide Water Management Plan.

- Expand use of Interagency Agreements to address HABs. DEQ has developed Interagency Agreements with the U.S. Forest Service and Bureau of Land Management[98] and review/updates these on a five-year basis. The purpose is to provide a framework for how point and nonpoint sources will be managed on their lands. These agreements could include more about their role in the HAB surveillance program partnership and for investigating and addressing causes of HABs under their control. A good model to examine is the 2010 USFS policy memo for addressing HABs on USFS lands for the 2010 field season. Additionally, DEQ may want to develop agreements with other federal and state agencies such as USACE, U.S. Bureau of Reclamation and Oregon Department of Fish and Wildlife that would address HABs and other point and nonpoint source activities. Some of this could be addressed through a HABs MOA mentioned in Section 6.1.4 as a tool for coordinating HAB surveillance.

- Reduce Sources of Phosphorus – Lawn Maintenance Fertilizers. There are several sources of phosphorus that are relatively easy to control by way of product substitution and can reduce concentrations of phosphorus that may get to waters of the state through wastewater or runoff. For example, Oregon is one of a number of states[99] that restrict the level of phosphorus in laundry and dishwater detergents to less than 0.5% phosphorus. There are alternative detergents that are readily available and this restriction eliminated a source of phosphorus that would otherwise need to be removed through treatment processes where there are phosphorus load limits for point sources (e.g. Tualatin, Yamhill, Umpqua, etc). Clean Water Services attributed a 22% reduction of the phosphorus load to the Durham Treatment Plant to the state-wide phosphate detergent ban.[100]

98

99 States that restrict phosphorus in laundry and dishwasher detergents include: Illinois, Indiana, Maryland, Massachusetts, Michigan, Minnesota, Montana, New Hampshire, Ohio, Oregon, Pennsylvania, Utah, Vermont, Virginia, Washington and Wisconsin.

100

Lawn maintenance fertilizers may be a similar product where substitution or use of 0-phosphorus fertilizer can achieve green lawns without the potential for increased phosphorus loads to the watershed. A number of states[101] and a number of municipalities have restricted the use of phosphorus in lawn maintenance fertilizers. These states have waters (which include the Great Lakes) that are phosphorus limited. They have found that soils in those states typically have sufficient phosphorus to meet the requirements for established lawns. The restrictions often allow use of phosphorus fertilizers for establishing new lawns or, if needed, based on soil testing. In general, turf fertilizers are often developed for national distribution, and they all contain the three macronutrients required for plant growth: nitrogen, phosphorus, and potassium. Where phosphorus is in excess, it can contribute to the excess loading of waters through runoff. EPA estimates that only 35 percent of lawn fertilizers ever reach the grass plant; the remainder is volatized into the air or seeps into groundwater[102].

An initial study (Lehman et al, 2009) suggests that a 25% reduction in total phosphorus occurred after implementation of a lawn fertilizer ordinance in Ann Arbor. While the reduction cannot fully be attributed to the ordinance (there were other efforts being implemented including education regarding yard waste discharge to storm drains and use of buffer strips) and more data are being collected, it suggests that control of this source of phosphorus can have a significant effect on phosphorus loading.

A study done in Lake Oswego (Lundt, 2001) suggested that soils in the area were high in phosphorus where they did not need supplements to support turf grass. At that time, an effort was made to have available a 0-P brand of fertilizer available and to encourage homeowners to use it. The City committed to use it in parks and other areas where it uses fertilizer. Since that time, 0-P fertilizers have become more available partly due to cost of adding P to fertilizers and partially in response to the global demand for fertilizers which has raised the costs of phosphorus along with the fact that phosphorus may not be needed in many applications and have been restricted in a number of states.

Scotts Miracle Gro Company, a major producer of lawn fertilizer sold in retail stores, announced that it was removing phosphorus from most of its lawn maintenance fertilizers by 2012[103]. DEQ should track the shift to 0-P fertilizers to determine if the voluntary approach to shifting to 0-P fertilizers is effective in addressing this source of phosphorus or if additional measures are needed (this could be done through the NPS program). Appendix F contains additional background related lawn maintenance fertilizers that was assembled by an EPA intern as part of this strategy. Based on limited research, it appears that there is a shift toward 0-P fertilizer in retail stores in Oregon. However, this trend is not apparent for fertilizers used by lawn care services (this could be a priority for further follow-up under a 319 grant).

Given the number of areas where DEQ has established phosphorus TMDLs (figure 6-1), DEQ should explore the need for phosphorus lawn maintenance fertilizers in these areas. Initial work could focus on areas with large urban populations (such as the Portland Metropolitan area which includes the Tualatin Basin and Columbia Slough Watershed where phosphorus TMDLs have been established) where lawn fertilizers would likely be used more but it could be broadened out regionally to include the Willamette Valley, Western Oregon or statewide based on soil information, etc. Both the need for phosphorus (based on further information related to phosphorus in soils) and use of lawn maintenance fertilizers would need to be addressed. If additional control of this source of phosphorus is needed, it could be address in a variety of ways

[101] States that restrict phosphorus in lawn fertilizer include: Illinois, Maine, Michigan, Minnesota, New York, Wisconsin

such as: through more active educational programs; action under MS-4 storm water permits; or local, regional or statewide bans. The Dunes City Ordinance that restricts the use of phosphorus containing fertilizers is a local example (Dunes City, 2007).

- Explore the role of introduced fisheries in Lake Eutrophication. Cyanobacterial blooms in wilderness and other mountain lakes have posed a dilemma to resources managers. Anthropogenic sources of nutrients appear to be absent, yet blooms continue in lakes that theoretically should not exhibit signs of water quality degradation. Research over the last several decades has revealed that lakes are affected by both external and internal sources of nutrient loading and that fish populations can factor heavily into contributing to internal loading. Fisheries management appears to offer a viable explanation for the cyanobacterial blooms in mountain lakes.

  Fisheries (both illegal introductions of fish and fish stocking) appear to play a role in the eutrophication of lakes. Research supporting the effects of fish on water quality have been available for decades and Diamond Lake is one the first lakes to use the TMDL process to address fish eradication and achieve water quality goals (Eilers, In Press May 2011). As a result of the Diamond Lake TMDL, objectives of fish management plan (OAR 635-500-0703(2) now include:

  > "(b) Conduct ecologically based fishery monitoring and evaluations necessary to maintain ecologically based fisher objectives and healthy lake ecology; and
  > (c) Provide for the prevention and control of illegally introduced fish species."

  As described in Section 5.1, it is very likely that a number of other lakes, particularly but not limited to the High Cascades, are being affected by their fishery. The Department should work cooperatively with ODFW, USF&WS, USFS, USBOR, USACE, EPA and others to begin to address the role of fisheries in lake eutrophication, particularly in the Cascade Lakes, rather than addressing it on a lake by lake basis. A small grant proposal was developed by DEQ during this grant period but was not funded by EPA. DEQ should continue to explore means for funding and undertaking this work.

- Consider having a nutrient reduction strategist to look at ways to protect and reduce nutrient pollution to surface and groundwater. This can be done to both protect drinking water supplies from nitrate contamination as well as to reduce or prevent HABs. This could also be a way to continue the conversation with EPA on how best to procede to achieve near- and long-term reductions of nitrogen and phosphorus in Oregon's waters.

6.6 Waste Water Permiting, On-Site System and 401 Certifications

DEQ can regulate a variety of activities under its permitting authorities. Several of these control activities that related to HABs – such as control of nutrient sources (point source, on-site systems); regulating use of pesticides or potentially other substances, such as alum, which may be used in HAB control program; or management of reservoirs that generate power under the Section 401 Hydropower Certification program.

An assessment of the current Waste Water Permiting, On-Site System and 401 Certification Programs was not made as part of this HABs strategy development. The following recommendations were made based on the review of the HABs in Oregon (Chapter 3) including the Characterization of HABs Problems in Oregon and Implementation for their Management (Chapter 3.6) as well as from review of other state programs. Many of the recommendations draw from lessons learned from lakes that had more detailed studies done and were actively implementing plans to control HABs (Appendix C).

6.6.1 On-Site Disposal Systems

More than 30 percent of Oregonians dispose of wastewater from their homes through the use of on-site disposal systems (i.e. septic systems). DEQ or contract counties regulate the siting, design, installation and on-going operation and maintenance of septic systems.

Septic systems can account for a large amount of the nutrient loading to a lake. For example, in the Tenmile Lake system, septic inputs represented about 20% of the total watershed phosphorus loading; however, during the summer when tributary loads are small, the relative contribution of septic inputs increases to about 50% constituting an important component of the load (Eilers et al, 2002). DEQ estimates that 10 to 20 percent of all septic systems are failing or improperly performing at any given time, which increases the risk of contamination of waterways and potential public health risks. Staff in the On-site Wastewater Management Program are fee supported with most of the funding and work focused on the siting of new or replacement systems and little funding or resources available to evaluate if old septic systems are properly functioning or for following up to complaints or potential concerns.

Several proposals were introduced for the 2011 legislative session which would improve septic tank management and have good potential for reducing their nutrient contribution which are discussed immediately below.

Time of Transfer Evaluations

The Coastal Zone Management Act and associated Coastal Zone Act Reauthorization Amendments require, among other things, that coastal states have enforceable policies and mechanisms to control nonpoint source pollution. One of DEQ's requirements is to track inspections of all septic systems at the time of transfer of a property in the coastal zone. Oregon's coastal zone covers the entire Rogue and Umpqua basins, and north of Douglas County from approximately the peak ridgeline of the Coast Range westward to the ocean. These inspections will allow DEQ to identify failing or improperly performing septic systems. A report by the Barry-Eaton District Health Department in Michigan that evaluated the first three years of their time of sale or transfer program found that approximately 26% of the systems that were evaluated had sewage failure conditions (602 of 2297 stites)[104].

DEQ proposed to create a time of transfer evaluation reporting fee and a septic tank pumping event reporting fee in its 2011-2013 Budget Requests (Policy Option Package 120). Both fees were passed by the legislature. DEQ proposes to require time of transfer evaluations and reporting of all septic tank pumping events in the coastal zone in order to verify proper management and disposal of septage. DEQ proposes to create a time of transfer evaluation reporting fee and a septic tank pumping event reporting fee, both of which will range between $25 and $75 depending on the reporting method (via Internet or paper reports).

The revenue from reporting fees for time of transfer evaluation reports and septic tank pumping event reports will be used to fund compliance and enforcement and to ensure proper handling, transport and disposal of septage, which is necessary to protect public health and the environment from raw sewage. The inspection results and pumping events reported will be available online in a searchable format.

DEQ will be initiating rule making in late 2011 to set up the fee structure, etc and then will be initiating this work. Department should evaluate if time of sale transfers are effective at addressing concerns due to on-site systems to determine if the inspections should be expanded statewide or if it should be required periodically for all systems in sensitive areas, such as along lake shores.

Requirements for on-site system evaluations have been made using local authority for Siltcoos/Woahink and are being explored at Devils Lakes. In 2006, Dunes City, Oregon adopted a Septic System

Maintenance ordinance that required an evaluation at least once every five years and adopted an ordinance imposing a moratorium on land development based on concerns about nutrients from septic systems (Dunes City, 2006).

Devils Lake has also proposed a septic tank revitalization program[105]. As it is currently proposed, it would require an inspection of existing properties abutting Devils Lake, or its tributaries, that receive municipal water within a five year period. Continued water service would be contingent on property owners obtaining the one-time inspection within the five year period. Water service would not be terminated for properties that had inadequately functioning systems. In those cases, they would be addressed under current law through the Lincoln County, which operates the onsite program on behalf of the State of Oregon. This proposal may not be enacted given authorization for the Time of Transfer Inspections in the Coastal Zone.

Use of existing local authorities should continue to be supported for septic tank inspection programs outside of the coastal zone, where needed.

Onsite Sewage Disposal System Funds (SB 83, 2011)

Oregon's onsite wastewater management program receives multiple requests for assistance from many communities in Oregon with known pollution problems from septic systems. Currently all revenue comes from application fees for permits, reports and licenses and the program does not have the funding or capacity to engage in these activities, including outreach and education, training, and coordination with communities.

In addition, DEQ estimates that ten to twenty percent of existing septic systems around Oregon are in need of repair or replacement to protect human health and the environment. Replacing septic systems can be very expensive (generally starting at $3,000 and can go up to over $20,000) and there are many property owners in Oregon that cannot afford to replace/upgrade the failing systems.

SB 83, which was not passed by the 2011 Oregon Legislature, would have authorized the Environmental Quality Commission, DEQ's rulemaking and policy board, to adopt rules for DEQ to make grants or loans available for the repair, replacement or decommissioning of septic systems. SB 83 would have established a fund (the Subsurface Sewage Disposal System Improvement Fund) that would be used to assist communities in addressing health or water quality problems associated with individual septic systems. Civil penalties collected from onsite septic system fines would have gone into the fund, as well as any gifts or grants. The funds could have also be used for the development of community-based solutions for sewage disposal problems provided those solutions comply with applicable land use regulations. The grants or loans would be based on hardship and would be used to protect public health by helping to fund the repair, replacement or decommission of failing septic systems. A portion of the fund must be dedicated to training programs related to installation, operation, maintenance and technical assistance on individual septic systems.

Local units of governments (such as the Devils Lake Water Improvement District) have interest and have sought out the ability to provide financial support for septic system repairs, including seeking State Revolving Loan Funds (SRF) to help support such a program. Eugene Water & Electric Board has set up a septic system zero interest loan program[106] which will provide up to $7,000 for septic repairs to homeowners and provide limited grant funds to low-income homeowners located in the McKenzie River Watershed upstream of their drinking water intake. Efforts both at the state and local level should continue to help address the issue of funding septic tank repairs.

DEQ should continue to work with local units of government to find creative ways to support funding for repair and replacement of septic tanks, based on need.

6.6.2 NPDES Permits

DEQ's wastewater management program regulates and minimizes adverse impacts of pollution of Oregon's waters from point sources of pollution. The term "point source" generally refers to wastewater discharged into water or onto land through a pipe or a discernable channel. Point sources operate under the terms of a federal National Pollutant Discharge Elimination System (NPDES) or a state Water Pollution Control Facilities (WPCF) wastewater discharge permit issued by DEQ.

Point Source discharge of nutrients can be of concern related to HABs. Nutrients that are discharged from a point source can be responsible for a majority of the nutrient loading to a water body. Fortunately, Oregon does not allow point sources to discharge to lakes or reservoirs and, therefore, these are not a significant source to lake or reservoir (see discussion below) but may be significant in rivers that experience HABs and would be addressed under a TMDL.

NPDES permits can be also used to regulate or control aquatic pesticides. The State of Washington controls the application of pesticides to the waters of the state under a NPDES permit[107].

No Discharge of Wastes to Lakes or Reservoirs

In Oregon, no point source discharge of wastes to lakes or reservoirs is allowed. A Statewide Narrative Criteria (OAR 340-041-0007 (4)) states: "No discharges of wastes to lakes or reservoirs may be allowed except as provided in section OAR 340-041-0004(9).[108]"

This rule has been of great benefit for preventing point source discharge of nutrients directly to these water and should be and should be continued. The benefits of diverting wastewater, including secondary treated domestic wastewater and dairy wastewater, have been well documented in studies of numerous lakes including nearby Lake Washington and Lake Sammamish in Washington (Cooke et al, 2005).

There still may some potential concerns where a discharge may have existed prior to this rule (estimated as 1976) or where the discharge is upstream of a reservoir or a river system that acts like a reservoir (e.g. the lower Tualatin River) would not be addressed by this rule. These situations can be addressed through TMDLs where alternatives can be explored for determining what is best for the system (e.g. whether it is better to have no discharge to the system, require a high level of treatment such as required in the Tualatin TMDL or other alternative). For example, one of the earliest TMDLs developed in Oregon (approved by EPA in 1988) was for phosphorus in Garrison Lake. The TMDL required the Port Orford Wastewater Treatment Plant, which had a discharge (that was in place prior to the rule) to a tributary of Garrison Lake, to relocate its discharge from a tributary that entered Garrison Lake. The discharge was moved outside of the Garrison Lake watershed.

Pesticide Permit

On January 7, 2009, the 6th Circuit Court ruled that National Pollutant Discharge Elimination System (NPDES) Permits are required for all biological pesticide applications and chemical pesticide applications that leave a residue or excess pesticide in water when the applications are made in or over waters of the U.S by April 9, 2011. The Court ruling affected DEQ because DEQ is authorized by EPA to issue NPDES permits and conduct the compliance and monitoring for these permits. At the time of this report, DEQ had released a draft permit for public comment that would address a variety of pesticide applications, such as for the control of invasive or other nuisance weeds, algae and pathogens, such as fungi and bacteria, in water and at the water's edge.

[107]

[108] Section OAR 340-041-0004(9) identifies procedures need to be met to allow such a discharge.

However, legislation passed the U.S. House of Representatives in March 2011 and a bill was introduced in the Senate (S.718) on April 4, 2011 that would prevent implementation of the court order requiring pesticide applications to be covered by NPDES permits under the Clean Water Act. At the same time, the Sixth Circuit granted EPA's request for an additional six months. This means that, without further action by Congress, the new deadline for spraying activities to be covered by NPDES permits is Oct. 31, 2011. Pending outcome of the legislation, pesticide application to waters of the nation would either be covered by permit or under FIFRA. Hopefully, by October 31, 2011, this authority for use pesticides for addressing nuisance aquatic weeds will be clarified so that DEQ can take appropriate action.

Typically, pesticides are not recommended for addressing HABs during a bloom as they can cause cells to break down (lyse) and release toxins. They have been used, however, to control algae before the development of a bloom but can have a number of negative impacts (see Table 4-1).

Alum and Other Product Additions

There are a number of other products that are used in algal control such as alum and colorants. DEQ does not require any permits for alum applications to lakes, based in part on the agency's determination that alum is neither a "waste" nor a regulated pesticide. Alum has not been widely used in Oregon but usage could increase to address blooms as more lake management plans are developed. In lakes where alum has been used, DEQ has asked for a management or application plan that addresses alum application to ensure that there are no waste products that would degrade water quality. It has been used successfully as part of an overall lake management plan for Lake Oswego (see Appendix C for more detail on Lake Oswego's Program).

The State of Washington addresses the use of Alum under their aquatic pesticide general permits although they are not considered pesticides[109]. The use of Alum is more extensive in Washington than in Oregon[110]. DEQ should clarify under what conditions a permit is or is not required for Alum or for other lake treatments such as colorants, etc (described in Table 4-3).

Consider Phosphorus Removal as Secondary Treatment

The Tualatin Basin phosphorus TMDL, adopted in 1989, required the Clean Water Services (CWS) Durham facility to seasonally treat phosphorus to a limit of 0.1mg/l. While at the time this was considered an unattainable level, CWS responded and met that level within five years. Over time, the treatment processes have been modified and refined. Currently, CWS and Ostara Nutrient Recovery Technologies has formed a partnership to construct a full-scale facility at the Durham facility that directly removes phosphorus and ammonia from wastewater and converts them into a slow-release fertilizer that can be used on golf courses, commercial nurseries and specialty agricultural markets. This facility has been in operation since May 2009 and, according to CWS, the facility is projected to remove more than 90% of the phosphorus in the recycle stream. The state-wide phosphate detergent ban reduced the phosphorus load to the Durham Treatment Plant by 22% and the Ostara system reduces it an additional 24% percent. The initial investment in the technology is expected to be paid back within five years (depending on the direct cost savings and revenue generated by selling the fertilizer product). A number of other benefits have also been identified[111].

Secondary treatment standards are established by EPA for publicly owned treatment works (POTWs) and reflect the performance of secondary wastewater treatment plants. These technology-based regulations apply to all municipal wastewater treatment plants and represent the minimum level of effluent quality attainable by secondary treatment, as reflected in terms of 5-day biochemical oxygen demand (BOD5) and total suspended solids (TSS) removal. Nutrient removal is considered as tertiary treatment and is required as needed such as through a TMDL process. EPA should consider nutrient removal under the technology-based regulations that could apply to all or some (e.g. major) municipal wastewater treatment plants given the increasing concerns about nutrients and EPA's commitment to partner with states and collaborate with stakeholders to make greater progress in accelerating the reduction of nitrogen and phosphorus loading to the nation's waters (EPA, 2011), the potential for increases in HAB due to climate change and the advancement in nutrient removal technology.

6.6.3 401 Hydro Relicensing

Section 401 of the federal Clean Water Act requires that any federal license or permit to conduct an activity that may result in a discharge to waters of the United States must first receive a water quality certification from the state in which the activity will occur. This section of the Clean Water Act directly authorizes states ensure that federally approved activities will meet water quality standards and policies established by the state under the Clean Water Act. In Oregon, DEQ is the agency responsible for reviewing proposed projects under this requirement. By ensuring a project does not degrade water quality, Oregon's waters remain safe for a wide range of uses, such as drinking water, recreation, fish habitat, aquatic life, and irrigation.

In the case of hydroelectric projects, the Federal Energy Regulatory Commission (FERC) administers the federal licensing process and DEQ issues the 401 certification. The water quality certification typically includes operating conditions designed to ensure that project operations will not violate water quality standards.

A number of reservoirs that experience HABs, including Lemolo, North Fork have been recertified under Section 401 and have conditions that require the operator to monitor and, if appropriate, identify and implement measures to address HABs and other nuisance conditions. An example of conditions can be found in the certification of the Portland General Electric Clackamas Hydro-electric Project.[112]

6.7 Funding

The issue of funding for a wide variety of work related to the control of HABs was raised throughout the course of the DEQ HABs strategy development. A list of potential sources of funding was kept and is shown below (but is very loosely organized). This list is, by no means, a complete or exhaustive list of funding sources. It is meant to be a listing of potential funding sources that can be considered if DEQ or other partners wish to persue funding to enhance portions of the HAB strategy.

Federal Sources:

- **Harmful Algal Blooms and Hypoxia Research and Control Amendments Act of 20**11 **-** The 2010 bill to reauthorize HABHRCA contained an EPA mandate, a modest funding authorization, and direction for the Agency to use those funds to support research and control projects for freshwater HABs by becoming a partner with NOAA in the several existing NOAA grant programs. That bill passed in the House with bipartisan support, but did not come up for a vote in the Senate. At the time of this report, hearings are taking place on the HABHRCA Amendments of 2011.
- **Section 314 Funding:** Bring back EPA LWQA funds to support HABs surveillance/volunteer monitoring; or potentially expand Beach Environmental Assessment Communication and Health (BEACH) Program or develop HABs legislation nationally;

- **Section 319 Funds:** EPA has not requested funds for the Clean Lakes Program in recent years, but rather has encouraged states in its December 1999 Supplemental Guidance for the Award of Section 319 Nonpoint Source Grants in FY 2000 (and previous guidance) to use section 319 funds to fund eligible activities that might have been funded in previous years under section 314. This guidance has a section on Clean Lakes that includes a suggestion that each state use at least 5 percent of its section 319 funds for Clean Lake activities to address the restoration and protection needs of priority lakes, ponds and reservoirs. The guidance also suggests that states give priority to funding the following Clean Lake activities: Lake Water Quality Assessment (LWQA) projects; Phase 1 Diagnostic/Feasibility Studies; Phase 2 Restoration/Implementation Projects; and Phase 3 Post-Restoration Monitoring Studies. In addition, the guidance added new data elements for Clean Lake activities to the Grants Reporting and Tracking System (GRTS) to enable EPA and the states to track progress in the use of section 319 to support Clean Lake activities.
  DEQ has not set any fixed targeted number to support lake projects or any other types of projects for its 319 funding. It has used a portion of the 319 funding (base grant) to fund staff to address non point source issues within Oregon. The remaining portion of the 319 funding (incremental) has been made available to support projects that address nonpoint source issues which would include Clean Lake activities (monitoring and assessment, management planning, implementation).
  Table 6-4 shows the number of lake related projects funded using Section 319 "pass-through" grants from FY 2001 – 2010 and the percentage of the project and total 319 funds. As shown, an average of 8.0% of the "pass-through" or project funds and 4.2% of the total grant funds have been spent on lake related work. The number has varied significantly from year to year with a range of 0 – 21.6% of the project funding and 0 – 13.8% of the total 319 funding supporting lake work.
  Funds have been spent to support projects on the following lakes (% of the total 319 funds spent from FY 2001 – 2010 are shown in parenthesis):

  - Lakes that have had HABs advisories (91%): Blue Lk (1%); Devils Lk (1%); Diamond Lk (22%); Klamath Lk (6%); Lava Lk (3%); Siltcoos Lk (6%); and Tenmile Lks (51%);
  - Other lakes (9%): Laurance Lk (1%); North Coast Regional Lakes (8%).

  Based on the FY 2001 – 2010 year history of use of the incremental funding, while an annual set aside has not been done, it appears that it is not needed as 319 funds are available and are being spent on lake and HAB related issues in a manner that meets the spirit of the EPA guidance.

Grants/Loans available in Oregon:

- Focus/priority of various funding programs to address a portion of the issue – Drinking Water (protection of Watershed), State Revolving Fund (SRF), Section 319, OWEB, Agriculture Fertilizer Fee
- Crater Lake license plate – this mechanism is in place to support work at Crater Lake. Further investigation could occur to see if the use of the funds could be expanded to cover other lake work (e.g. monitoring and surveillance, restoration, etc)[113];
- Marine Board – boat registration fees for HABs in addition to invasive species control/prevention

Table 6-4 Federal Section 319 Grant Funding for Lake Projects in Oregon (FY 2001 – 2010)

Year	# of Lake Projects Funded	Total Funded	Incremental 319 Funds (Available for Projects)	% Incremental 319 Funding	Total 319 Funds	% Total 319 Funding
2001	1	$77,486	$2,054,555	3.8%	$3,217,500	2.4%
2002	3	$444,596	$2,054,555	21.6%	$3,217,500	13.8%
2003	1	$18,500	$1,387,400	1.3%	$3,224,900	0.6%
2004	0	$0	$1,387,400	0.0%	$3,192,300	0.0%
2005	4	$267,621	$1,387,400	19.3%	$2,779,300	9.6%
2006	1	$67,240	$1,387,400	4.8%	$2,738,400	2.5%
2007	0	$0	$1,387,400	0.0%	$2,667,000	0.0%
2008	2	$195,678	$1,387,400	14.1%	$2,675,700	7.3%
2009	2	$50,500	$1,387,400	3.6%	$2,675,700	1.9%
2010	3	$83,784	$1,387,400	6.0%	$2,675,700	3.1%
Total:	17	$1,220,404	$15,208,310	8.0%	$29,064,000	4.2%

Other States:

- Washington State uses a portion of the vessel registration fee, approximately $500,000 per biennium: $50,000/ year for sampling and lab analysis, $150,000 in grants to assist communities and the remainder for staff.

- Nebraska and New Hampshire have programs tied to their Beach Environmental Assessment Communication and Health (BEACH) program.

- Minnesota funds it programs (including HAB related work) through their Clean Water Legacy Program

- Wisconsin - indicated that did not have a special fund for HABs but did have a source of funding for lake and river management (among other activities) based on a portion of the gas tax – that amount that was paid for by boats, e.g. In 1998-99, for example $9,466,700 is transferred to the water resources account under this formula (532,437 motorboats x 50 gallons per motorboat x 25.4¢ per gallon x 1.4)[114].

7. Synthesis

The actions recommended, primarily in Section 6 but may come from other sections, have been organized by DEQ subprograms and by a level of effort it may take to implement the various actions including: those that DEQ already does, those that would take minor operational adjustments, those that should be considered as staff time is available, those that require additional funding and those that would require EPA or legislative action. These are summarized in Table 7-1.

7.1 Suggested Priorities

The author suggests that DEQ consider the following as priorities for improving the strategy.

- Surveillance (monitoring, advisory, education): Maintain current surveillance program while seeking funding to enhance it and make it sustainable for the near-future. The number of waters experiencing HABs is larger than currently shown and will likely get larger with climate change. Exploring and seeking additional funding needs to be done in conjunction with key partners, particularly OHA who has increased their staffing for their HABs program based on a 5-year CDC grant that will end in 2013.

  Develop a DEQ core HAB group to improve DEQ's ability to respond to HAB related incidents such as the dog deaths in the Umpqua Basin in 2009 and 2010 and HAB related concerns in the Tualatin in 2008. This group would be a good team to review and update this strategy in the future.

- Enhance Department focus for identifying and addressing causes of HABs in listed waters: Dedicate a portion of a TMDL modeler to be a lead on lakes/HABs issues, including being knowledgeable about HABs, lake modeling and lake management techniques and who can work with partners such as the USFS, USACE, USBR, USGS, ODFW as well as local groups and agencies, especially those that are doing or planning to do lake studies, and can look for efficiencies in doing TMDLs or their equivalent;

- Role of introduced fisheries in lake eutrophication: Expand effort to collectively explore the impact of introduced fisheries in lake eutrophication and HABs, particular focusing on lakes in the high Cascades (many of which were formerly fishless) building off of studies in Diamond and Odell Lakes. In Diamond Lake, the fish management plan was modified to include objectives such as "ecologically based fishery objectives and healthy lake ecology" and "provide for the prevention and control of illegally introduced fish species". Additional funding to support additional resource to pull together the literature, information on the impacts collected in Oregon and nearby states, work with a multi-agency technical group and collect some additional key data (e.g. sediment core) could strengthen this effort. Explore the impact of shift to warm water fisheries in the coastal lakes and need for updating those ODFW management plans as well.

- Enhance Department focus on Nutrients: Explore way to better address and reduce nutrient loading at their source both for reducing/preventing HABs and for protecting drinking water supplies. Dedicating a portion of a staff position to focus on identifying and addressing key elements of a nutrient reduction strategy and working with EPA on the nutrient reduction partnership could be a good steps for developing a more cohesive nutrient reduction strategy. Some key elements (some of which are underway) include: developing and implementing time of transfer on-site system inspections; better tracking and improving effectiveness of implementation plans (e.g. ODA, ODF, urban); track and encourage shift to 0-Phosphorus lawn maintenance fertilizers; development of implementation-readyTMDLs; development of a NPS IMD for anti-degradation.

Table 7-1 A list of actions that DEQ Subprograms should continue, make adjustments or consider in order to better address HABs in Oregon.

Activity or Subprogram	**Action** (high priority actions marked in bold)	**Current Action**	**Minor Operational Adjustments**	**As Staff Time is Available**	**Additional Funding**	**Legislative or EPA Support**
Surveillance:	Following actions discussed in Section 6.1:					
Surveillance	• Continue active participation in current HAB surveillance program with OHA and other partners	X				
Surveillance	• Continue working with partners to review and refine monitoring procedures and Health Advisory Criteria (annual meeting, etc)	X				
Surveillance	• DEQ as a co-chair for the annual meeting to review and discussion of implementation-related activities.		X			
Surveillance	• **Have a DEQ HAB response group – lab, regions and HQ for responding to HAB events such as those that occurred in the Umpqua**		**X**			
Surveillance	• Develop a DEQ HABs website to provide access to the HAB strategy, Satellite analysis, other DEQ HAB related info, links, and other available information;		X			
Surveillance	• Develop a MOA among partners to better define roles and responsibilities			X		
Surveillance	• **Work with partners to develop/fund a more active surveillance program similar to WA, either through grants or a policy option package**				**X**	X
Surveillance	• Incorporate genetics, satellite and numeric modeling work as appropriate				X	
Surveillance	• Consider forming an Oregon HABs Task Group (state, federal, local agencies, academia, etc) to discuss, plan, develop and coordinate actions in Oregon to improve multi-agency response to HABs and ultimately prevent and control HABs building on the Oregon Partnership.					X

Activity or Subprogram	**Action** (high priority actions marked in bold)	Current Action	Minor Operational Adjustments	As Staff Time is Available	Additional Funding	Legislative or EPA Support
Standards & Assessment	Following actions discussed in Section 6.2:					
Standards & Assessment	• Continue to list waters with HABs Health Advisory as category 5 (or other appropriate category based on management activities) based on narrative standard	X				
Standards & Assessment	• List other waters based on data showing the Health Advisory criteria were exceeded but a Health Advisory was not issued (e.g. data not shared with OHA, etc)		X			
Standards & Assessment	• Use potential concern (3B) to identify waters where HABs may be of concern (based on past data, satellite, other info) for monitoring		X			
Standards & Assessment	• Develop nutrient issue paper as part of next Triennial Standards Review (~2012)			X		
Standards & Assessment	• **DEQ should develop an IMD for Antidegradation Policy Implementation for nonpoint sources**			**X**		
Standards & Assessment	• Develop Water Quality Criteria for Cyanotoxins (EPA)					X
Watershed Management/ Watershed Approach	Following actions discussed in Section 6.3					
Watershed Management/ Watershed Approach	• Continue development of TMDLs or their equivalents for HAB listed waters	X				
Watershed Management/ Watershed Approach	• Refine the prioritization process for HABs (and other water quality parameters) through the Watershed Approach		X			
Watershed Management/ Watershed Approach	• **Dedicate a portion of modeling staff as a HAB/lake specialist in the WMS to develop/share HAB/lake expertise with staff and DMAs; especially related to monitoring, modeling and lake restoration actions**		**X**	**x**	**x**	
Watershed Management/ Watershed Approach	• Where possible, address HAB in groupings – e.g. fish, reservoirs, ecoregion (e.g. coast), shallow lk, etc		X			

Activity or Subprogram	**Action** (high priority actions marked in bold)	Current Action	Minor Operational Adjustments	As Staff Time is Available	Additional Funding	Legislative or EPA Support
Watershed Management/ Watershed Approach	• Consider alternatives to TMDLs (e.g. 4B and 4C approaches), as appropriate		X			
Watershed Management/ Watershed Approach	• Develop implementation-ready TMDLs for HABs, esp. in coastal zone, to better address sources of nutrients and sedimentation		X			
Watershed Management/ Watershed Approach	• Develop load targets (303(d)(3)) to prevent HABs in lakes that may be at risk, where appropriate		X	x	x	
Watershed Management/ Drinking Water	Following actions discussed in Section 6.4:					
Watershed Management/ Drinking Water	• Continue to characterize PWS and their vulnerability to risk such as HABs	X				
Watershed Management/ Drinking Water	• Continue TA and grant support	X				
Watershed Management/ Drinking Water	• Fully assess PWS vulnerability to HABs using tools and information such as GIS, databases, landuses, etc		X			
Watershed Management/ Drinking Water	• For PWS that are vulnerable to HABs, provide assistance to develop protection plans			X		
Watershed Management/ Drinking Water	• **Consider having a nutrient reduction strategist to look at ways to protect and reduce nutrient pollution to surface and groundwater. Work with EPA on nutrient framework.**			**X**		
Watershed Management/ Drinking Water	• Implement pollution reduction strategies in PWS protection plans				X	
Watershed Management/ Drinking Water	• If needed, consider potential restriction on HAB-related sources in Drinking Water Source Areas (using local authority)					X
	•					
Watershed Management/ Nonpoint Source	Following actions discussed in Section 6.5:					

Activity or Subprogram	Action (high priority actions marked in bold)	Current Action	Minor Operational Adjustments	As Staff Time is Available	Additional Funding	Legislative or EPA Support
Watershed Management/ Nonpoint Source	• Continue laundry and dish washer phosphorus detergent ban (no action needed to continue it).	X				
Watershed Management/ Nonpoint Source	• Continue to address LA through DMA management plans, SB1010 plan, FPA	X				
Watershed Management/ Nonpoint Source	• **Evaluate effectiveness of DMA management plans, SB1010 plan, FPA in meeting LA**		**X**			
Watershed Management/ Nonpoint Source	• Consider adding HABs-related work to Interagency Agreements to get other agencies to develop HAB policies (e.g. similar to USFS) for surveillance and follow up			X		
Watershed Management/ Nonpoint Source	• **Explore role of introduced fisheries (stocked and illegally introduced) in lake eutrophication/ HABs, especially in High Cascade Lakes, working with ODFW and others**			**X**	**x**	
Watershed Management/ Nonpoint Source	• **Track shift to zero-P lawn maintenance fertilizer to determine if addition info/action is needed to address this source**			**X**	**x**	
Watershed Management/ Nonpoint Source	• Consider a lawn maintenance fertilizer phosphorus ban pending information relative to the need in soils and success of industry phase out in Oregon (could be done at a variety of levels - City, Country, Regional Govt or Oregon Legislature)					X
On-Site	Following actions discussed in Section 6.6.1:					
On-Site	• Continue and promote use of local authorities to require on-site system evaluations, where needed		X			
On-Site	• **Initiate process for doing Time of Transfer on-site inspections in the Coastal Zone; track effectiveness of inspection process**		**X**			
On-Site	• Explore ways to provide SRF or other funding to assist with repair/replacement of on-site systems, if requested		X			
On-Site	• Work with local units of government to utilize their authorities to require and implement on-site system evaluations for waters		X			

Activity or Subprogram	Action (high priority actions marked in bold)	Current Action	Minor Operational Adjustments	As Staff Time is Available	Additional Funding	Legislative or EPA Support
	experiencing HABs in which on-site systems are of concern					
On-Site	• Consider seeking authority for doing Time of Transfer on-site inspections Statewide or consider requiring period inspections (vs at Time of Transfer) (Oregon Legislature)					X
Permits	Following actions discussed in Section 6.6.2:					
Permits	• Continue no discharge of waste water to lakes/reservoir rule	X				
Permits	• Continue to incorporate WLA into permits as appropriate	X				
Permits	• Continue to clarify ability to use pesticides – either through conformance with FIFRA labeling or through permit	X				
Permits	• Explore whether clarification or a permit needed for using Alum and other chemicals for lake/pond mgmt		X	X		
Permits	• **Consider addressing 0-P lawn maintenance fertilizer through storm water permits in P-TMDL areas**		**X**			
Permits	• EPA should consider defining nutrient removal as standard secondary treatment (at least for major dischargers) based on Clean Water Services nutrient recovery system that reduces phosphorus load ~24%, converts the phosphorus and other nutrients into a slow release fertilizer and pays back initial investment in 5 years (Could be done through Oregon Administrative Rule)					X
401 - Hydro	Following actions discussed in Section 6.6.3:					
401 - Hydro	• Continue to address HABs through the 401 process including certification conditions	X				
401 - Hydro	• Include hydro and HABs issues in the Kaizen process to streamline the 401 program		X			
Funding	Following actions discussed in Section 6.7:					

Activity or Subprogram	**Action** (high priority actions marked in bold)	Current Action	Minor Operational Adjustments	As Staff Time is Available	Additional Funding	Legislative or EPA Support
Funding	• Continue to use 319 funding to address HABs/lakes and continue to exceed EPA guidance of at least a 5% for lake work (10 yr average of 8.0% of competitive 319 grant funding)	X				
Funding	• Seek out state funding for HABs program – either grants, general fund or explore fee options (e.g. Boat registrations; Shift or share Crater Lake license plate funds to support HAB surveillance…) (Oregon Legislature to establish fees or use of GF)			X		X
Funding	• Pass and fund federal legislation under HAB and Hypoxia Research and Control Amend. Act of 2011(Congress)					X
Funding	• Fund the LWQA Section of Section 314 of CWA to support HAB surveillance (EPA with Congress approval)					X

7.2 Future Updates

Cyanobacteria have been one of the earliest forms of life on earth so coping with problems due to their blooms is not new and many techniques for controlling or managing the blooms are well known. However, there is still a great deal of emerging science and technology (such as genetic monitoring and remote sensing techniques) and research being done on HABs – particularly related to their toxins and human/ecological risk assessment. Additionally, given the increasing awareness and occurance of HABs, the response infrastructure, that includes federal, state and local agencies, universities, public water systems, lake associations, etc, will be improving in their ability to plan, coordinate, communicate and use resources over time.

This is the initial attempt for identifying and making recommendations for improving DEQ's overall HAB strategy. It is not perfect and will need to be reviewed and modified over time. It will only get better with future updates. It is recommended that this occur on an annual or biennial basis and be timed with the annual review of the Oregon HAB surveillance program that is coordinated through the OHA.

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