Attachment 11

MEMORANDUM

TO: Bob Ellis, PhD
FROM: Ken Vigil, John Vlastelicia
DATE: August 10, 2006

SUBJECT: Preliminary Water Quality Review
Proposed Drift Creek Reservoir (East Valley Irrigation District)

INTRODUCTION

The purpose of this technical memorandum is to summarize our preliminary review of water quality issues (primarily temperature) associated with the East Valley Water District's (EVWD's) proposed irrigation reservoir on Drift Creek. The EVWD's proposal to construct an impoundment on Drift Creek provides both challenges and opportunities related to water quality. This initial water quality review focuses on temperature, since it appears to be the parameter of greatest interest/concern for the proposed project.

The tables and figures referenced in this memorandum are all included at the back of the document (along with the appendix materials) for convenience.

REGULATORY ISSUES/STATUS

The federal Clean Water Act requires that states adopt water quality standards to protect the integrity of surface waters of the U.S. In Oregon, the Oregon Department of Environmental Quality (DEQ), with review and approval by the U.S. Environmental Protection Agency (EPA), develops water quality standards. DEQ and EPA utilize the standards as regulatory tools to prevent pollution of surface waters, and to assess whether the quality of Oregon's rivers and lakes are adequate for aquatic life, recreation, drinking, agriculture, industry, and other uses.

Oregon water quality standards for temperature are aimed at protecting temperature-sensitive beneficial uses in waters of the State, including specific salmonid life cycle stages. As such, temperature criteria may vary between streams, and between different reaches of any given stream, based on the beneficial uses that stream or reach provides.

The State identifies Drift Creek as being used for salmon and trout rearing and migration (OAR 340-41-340, Figure 340A). Additionally, Drift Creek is classified by State regulations as salmon and steelhead spawning habitat from October 15 to May 15 (OAR 340-41-340, Figure 340B). Based on the temperature criteria outlined in OAR 340-41-0028, the seven-day average maximum temperature of a stream identified for salmon and trout rearing and migration use may not exceed 18.0˚C (64.4˚F). For stream reaches identified as having salmon and steelhead spawning use, the seven-day average

maximum temperature may not exceed 13.0˚C (55.4˚F) during the designated spawning periods.

Drift Creek is identified on DEQ's 303(d) list as being water quality limited for temperature in the summer because it exceeds temperature criteria for salmon and trout rearing and migration (River Mile 0 to 9.5). Drift Creek is not identified on the 303(d) list for parameters other than temperature.

The Pudding River, into which Drift Creek flows, also appears on DEQ's 303(d) list for summer temperature due to exceedances of the 18.0˚C criteria for salmon and trout rearing and migration. The section of the Pudding River into which Drift Creek flows is also identified on the 303(d) list as water quality limited for bacteria (fecal coliform and E. coli) (Fall/Winter/Spring) and DDT (year-around).

EXISTING CONDITIONS

General

The Pudding River watershed (5th field HUC# 17090009) comprises approximately 528 square miles of land in Marion and Clackamas counties, much of which is used for agriculture, timber harvesting, manufacturing, and recreation. Several large streams flow to the north and west from the Cascade Mountains into the Pudding River, which drains to the Molalla River, a Willamette River tributary. The Drift Creek subbasin (6th field HUC# 170900090106) comprises an area of approximately 25 square miles (4.8% of total basin area) in the upper portion of the Pudding River watershed (Figure 1).

Hydrology/Temperature

Preliminary streamflow estimates used for this review were obtained from summer field measurements (base flows) and an Oregon Water Resources Department (OWRD) peak discharge estimation tool (http://map.wrd.state.or.us/apps/wr/wr_mapping/), which estimates peak discharges for selected stream locations based on prediction equations.

Preliminary estimates of water temperature used in this review were based on field measurements and DEQ temperature data from five locations on Drift Creek and the Pudding River, as summarized below:

- Drift Creek at Victor Point Road (Station #32054) – Data from Summer 2004
- Drift Creek at Hibbard Road (Station #32057) – Data from Summer 2004
- Drift Creek at RM 2.5 (Station #s 23864 and 25385) – Data from Summers 2000 and 2001
- Pudding River at Sunnyview Road (Station #32056) – Data from Summer 2004
- Pudding River below Drift Creek (Station #31878) – Data from Summer 2004

Graphs for the temperature data collected at these DEQ stations are presented in the appendix. The project researchers have installed automatic temperature recorders on Drift Creek and are in the process of collecting more detailed temperature data.

The approximate base and peak flows for Drift Creek immediately upstream of its confluence with the Pudding River are outlined below.

Drift Creek Flow Rate Estimates

Base Flow	5 to 10 cubic feet per second (CFS)
2-Year Peak	873 CFS
10-Year Peak	1,570 CFS
100-Year Peak	2,500 CFS

Summer water temperatures in Drift Creek typically range from approximately 10˚C to 20˚C, with maximum temperatures often approaching 25˚C in portions of the creek in July and August. Water temperatures in the vicinity of the proposed dam site are generally cooler than water temperatures lower in the system. Summer 2004 data from the DEQ gage on Drift Creek at Victor Point Road (Station #32054) indicate water temperatures generally ranging between 15˚C and 20˚C between about mid-June and mid-September, with temperatures exceeding 20˚C on a few occasions in July and August (temperatures peaking at about 21˚C). DEQ data collected during the same period from the gage at Hibbard Road (Station #32057) downstream of the proposed dam site indicate temperatures in excess of 20˚C as early as mid-June and as late as early September, with temperatures between 20˚C and 25˚C common from mid-July through mid-August (temperatures peaking at about 25˚C).

The portion of the Upper Pudding River subbasin above the Drift Creek confluence comprises an area of approximately 34 square miles. The base and peak flows for the Pudding River just above its confluence with Drift Creek are outlined below.

Upper Pudding River Flow Rate Estimates

Base Flow	5 to 10 CFS
2-Year Peak	756 CFS
10-Year Peak	1,400 CFS
100-Year Peak	2,280 CFS

Available data indicate that summer water temperatures in the Pudding River generally range between 10˚C and 25˚C from June through October, with maximum temperatures exceeding 25˚C. The data indicate that water temperatures above the Drift Creek confluence (DEQ gage at Sunnyview Road, Station #32056) are generally above 15˚C between about late June and mid-September and are frequently between 20˚C and 25˚C in July and August. Maximum temperatures for the gage at Sunnyview Road often exceeded 25˚C in 2004, with peaks as high as 28˚C. (note: The 2004 data for gage #32056 are being viewed cautiously. The extremely high temperatures recorded, and the marked difference between daily highs and lows, could indicate that the temperature recorder was exposed to the air during low water periods and that certain data are indicating air temperatures rather than water temperatures.) Pudding River water temperatures below the Drift Creek confluence in 2004 (Station #31878) were generally above 15˚C between approximately mid-June and mid-September and often exceeded

20˚C in July and August. Peak temperatures below the Drift Creek confluence approached but did not exceed 25˚C in 2004.

Based on these preliminary reviews of basin areas, flow rates, and water temperatures, it is clear that that the quantity and quality of water from Drift Creek greatly influences the quantity and quality of water in the upper Pudding River. The Drift Creek subbasin (25 square miles) is similar in size to the portion of the Upper Pudding River subbasin above the Drift Creek confluence (34 square miles). Therefore, future changes in either the flow rate or the temperature of Drift Creek would be expected to significantly influence the corresponding conditions on the upper Pudding River.

IMPOUNDMENT TEMPERATURE COMPARISONS

Water temperature characteristics of surface impoundments (lakes, reservoirs, etc) are influenced by several factors, including the availability and intensity of sunlight, the depth of the water body, and the water body's exposure to wind. Shallow water bodies are generally more evenly heated and thoroughly mixed, and thus temperatures throughout the water column are typically relatively uniform in these types of impoundments. Deeper impoundments, on the other hand, have a tendency to stratify at certain times of the year due to density differences that develop from uneven heating and inadequate mixing. In such water bodies, a marked transition zone (metalimnion) will develop, separating a warmer layer of surface water (the epilimnion) from a colder bottom stratum (hypolimnion).

Vigil-Agrimis, Inc. (VAI) obtained and reviewed temperature data and information for a number of lakes and reservoirs in Oregon and Washington. Sources of information included the Portland State University Center for Lakes and Reservoirs, the Washington Department of Ecology, and the comprehensive lake survey entitled *Atlas of Oregon Lakes*, a joint publication by authors affiliated with Portland State University and DEQ.

The vast majority of these lakes exhibited thermal stratification during the summer. As would be expected, the tendency of deeper lakes to stratify was stronger than that of shallow water bodies, although temperature stratification was documented in lakes with maximum depths as little as 13 feet. For lakes with maximum depths between 30 and 60 feet (comparable to the proposed reservoir, which will have a projected maximum depth of 50 feet), the depth of the thermocline (plane of maximum temperature change) ranged from approximately 3 feet to 20 feet. The average depth of the thermocline measured in these lakes was approximately 12 feet.

Table 1 is a summary of this temperature stratification review on Oregon and Washington lakes and reservoirs. The appendix also includes examples of lake water quality and temperature stratification data for lakes and reservoirs in Oregon and Washington with similar characteristics to the proposed irrigation reservoir.

Based on VAI's review of the data, which focused on impoundments with characteristics (e.g. climate, depth) similar to the proposed reservoir, it appears that temperature stratification will likely develop in the proposed Drift Creek reservoir during the summer, when high stream temperatures are generally of greatest concern. This stratification phenomenon has the potential of reducing stream temperatures by providing cooler discharge water (from the lower depths of the reservoir) during these periods.

GENERAL WATER QUALITY CONSIDERATIONS

Water from the deepest, bottom part of the reservoir would provide cooler water during the summer, but not necessarily water with the best overall water quality. The deepest parts of reservoirs tend to be deficient in dissolved oxygen in the summer, which is an undesirable condition. The deepest parts of lakes and reservoirs can also have higher sediment concentrations, which could be undesirable. The shallowest parts of reservoirs or lakes typically have undesirable water quality conditions too, including high temperatures and high algal concentrations. The mid depths of lakes and reservoirs typically have the best overall water quality conditions during the summer. Figure 2 provides a simple graphical representation of these concepts.

Several examples are included at the end of this memorandum in the appendix to document these depth and water quality relationships on existing impoundments. The purpose of these examples is to show general trends in impoundment water quality and present typical references. These examples have some similarities with the proposed Drift Creek reservoir as outlined in the above section. However, every water body is unique. The project team needs to develop detailed bathymetric data on the proposed reservoir to move forward on the water quality/temperature evaluation.

To manage water quality and temperatures, the designers of the proposed reservoir will have to provide an outlet control structure that allows water to be discharged from multiple depths. This type of outlet structure would offer the most discharge flexibility and allow the dam operators to optimize their management of the impoundment to provide irrigation benefit, while protecting natural resources.

RESERVOIR STORAGE

Based on work done by others (Stuntzner, 2005) and recent discussions, we understand that the proposed Drift Creek Reservoir may have a storage capacity of approximately 9,000 acre-feet with a dam height of 50 feet.

The District will likely be required to discharge some of this stored water during the summer months to keep appropriate base flows in Drift Creek downstream of the dam. Because of the probability of thermal stratification (as outlined above), the District could design the reservoir so that the discharge water is drawn from the middle depths of the reservoir. This approach would tend to provide higher quality discharge water: water with lower temperatures and other more favorable water quality conditions.

The water quality reviewers performed some simple flow balancing to estimate the amount (volume) of water that could be discharged to meet required base flow conditions

during the summer months. We assumed that the base flow discharge needs (based on preliminary flow measurements) would be on the order of 5 to 10 cubic feet per second (CFS). Furthermore, we assumed that this discharge rate may need to be maintained for approximately 120 days (June through September). To meet these discharge needs, then, approximately 2,000 acre-feet of stored water may need to be reserved for base flow discharges during the summer months.

Based on the proposed storage volume of approximately 9,000 acre-feet, it would appear that the proposed reservoir would have sufficient capacity to store the appropriate volume of higher quality water for this purpose.

The reservoir storage capacity and discharge needs will need to be evaluated in greater detail as the project moves forward and additional information becomes available. For example, a detailed bathymetric map of the proposed reservoir is not yet available, but will need to be completed to further define storage capacity. Moreover, the base flow discharge requirements will need to be defined more clearly through discussions with regulatory agencies.

TEMPERATURE MANAGEMENT

Releasing cooler, base flow water to Drift Creek from the proposed reservoir would provide the opportunity of improving water quality conditions in Drift Creek below the reservoir and also in the Pudding River.

The researchers completed some simple mass balance modeling to evaluate the potential effect on water temperatures of these discharges. By considering the flowrate and temperature of the upstream Pudding and the flowrate and temperature of the Drift Creek discharge, we estimated the resultant temperature of the Pudding River downstream of its confluence with Drift Creek.

Table 2 provides a summary of this analysis based on the limited existing conditions information summarized earlier in this memorandum.

Based on this simple review, it would appear that discharging cooler water from the proposed Drift Creek reservoir could result in a temperature decrease in the Pudding River (downstream of the confluence with Drift Creek) of approximately 2˚C or more

Furthermore, since summer temperatures on Drift Creek are typically in the range of 20 to 25˚C, the discharges of cooler water from the proposed reservoir could cool the waters in Drift Creek below the dam by 5˚C, or more.

WATER RIGHTS

It is beyond the scope of this memorandum to evaluate water rights on Drift Creek. However, it is important to note as this project moves forward that water rights issues may play an important role in determining the required summertime stream flows in Drift Creek below the proposed reservoir. These instream flow requirements will likely dictate the summertime water releases from the reservoir.

For example, water releases from the dam may be required for water rights related to summertime irrigation of downstream farms and for fish and other aquatic organisms and their habitat.

CONCLUSIONS

The investigators draw the following conclusions based on this preliminary review of water quality:

1. The existing temperature conditions on Drift Creek in the project area appear to violate state water quality standards.

2. The existing temperature conditions on the Pudding River downstream from its confluence with Drift Creek appear to violate water quality standards.

3. Both of these streams are identified on DEQ's 303(d) list as being water quality limited for temperature in the summer.

4. The proposed impoundment would be expected to stratify during the summer months, providing the opportunity to discharge cooler water collected below the surface of the reservoir.

5. Water from the middle depths of the reservoir would likely have the best water quality during the summer with respect to temperature, dissolved oxygen, and other water quality parameters.

6. Water from the middle depths of the reservoir could be 5˚C, or more, cooler than the surface water during the summer months.

7. Discharging this cooler water during the summer could reduce the temperature of Drift Creek below the proposed reservoir by 5˚C, or more, during the summer months.

8. Discharging this cooler water during the summer could also result in reductions in the temperature of the Pudding River (below its confluence with Drift Creek) by approximately 2˚C, or more during the summer months.

RECOMMENDATIONS

The investigators have the following recommendations based on this preliminary review:

1. Complete a detailed topographic survey and bathymetric analysis of the proposed reservoir site to clearly define depth/area/volume relationships and storage capacity.

2. Review instream water rights and summertime base flow discharge needs with appropriate agencies to determine the rate and quantity of water that would need to be discharged from the reservoir.

3. Review and summarize the instream temperature data that is currently being collected on Drift Creek and the Pudding River.

4. Set up a meeting with DEQ to review the proposed project as it relates to water quality and learn what opportunities and constraints may exist for the project in this regard, from their point of view.

5. Submit this preliminary water quality review memorandum to DEQ prior to the meeting to inform them of some of the issues associated with this project.

PRELIMNARY WATER QUALITY REVIEW FOR PROPOSED DRIFT CREEK RESERVOIR

FIGURES
&
TABLES

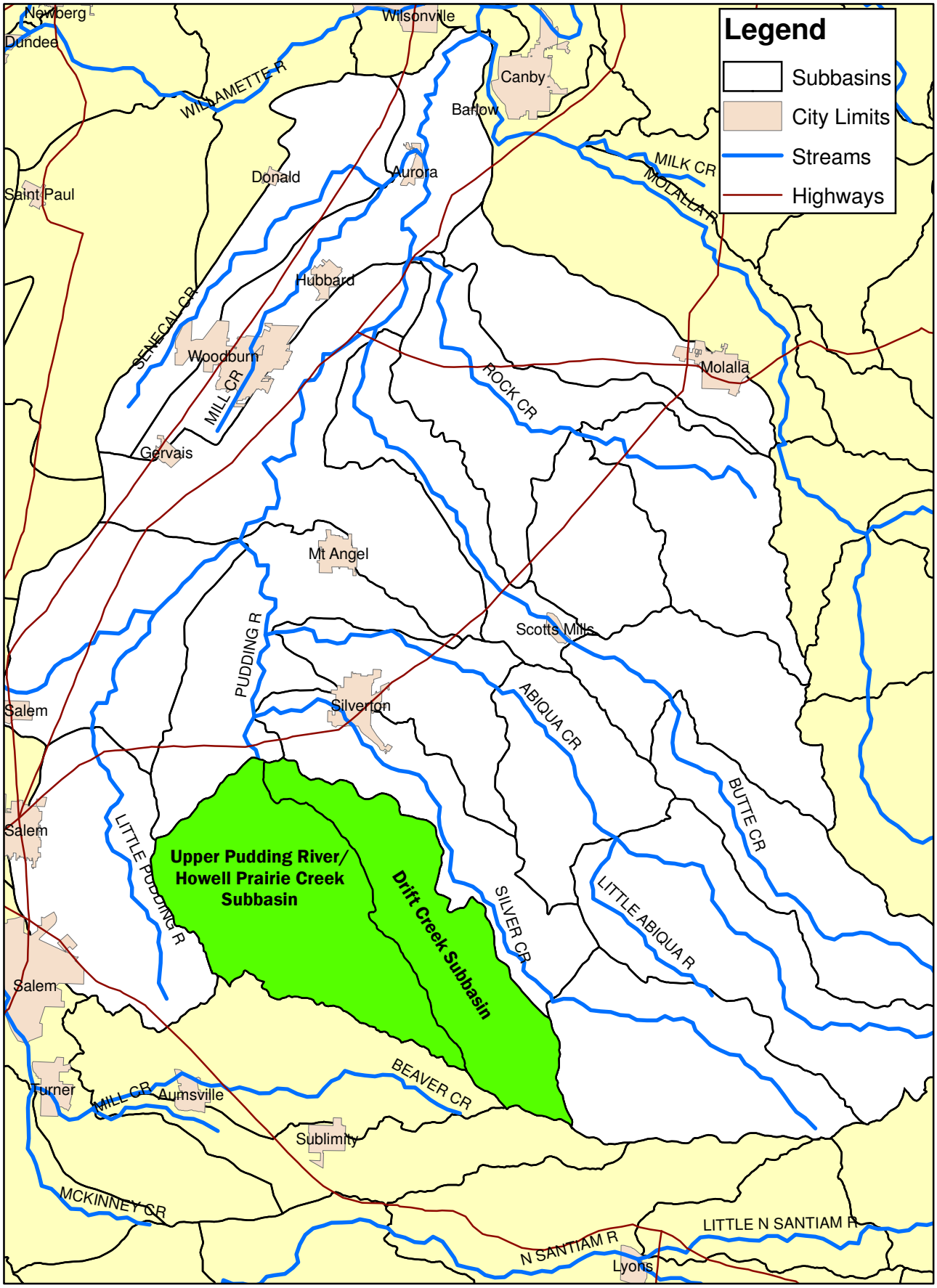

Figure 1. Pudding River Basin

EVWD Drift Creek Reservoir Project

N

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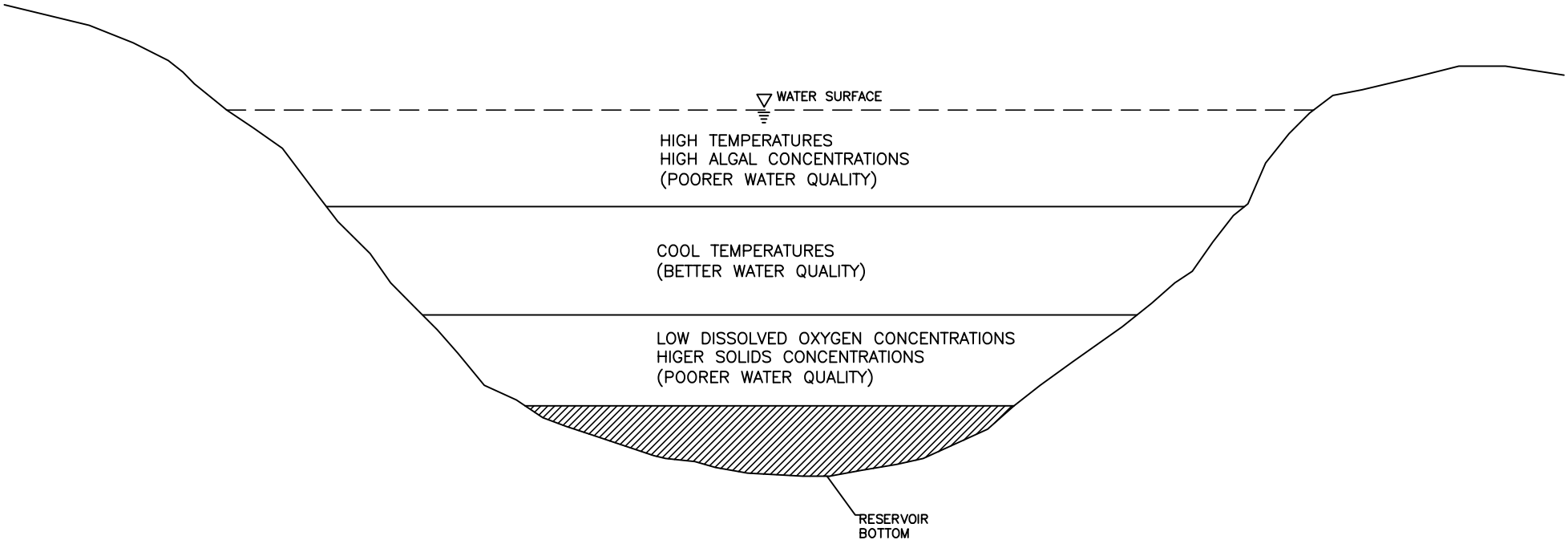


FIGURE 2. RESERVOIR WATER QUALITY SECTION

*Figure 340A: Fish Use Designations**
Willamette Basin, Oregon

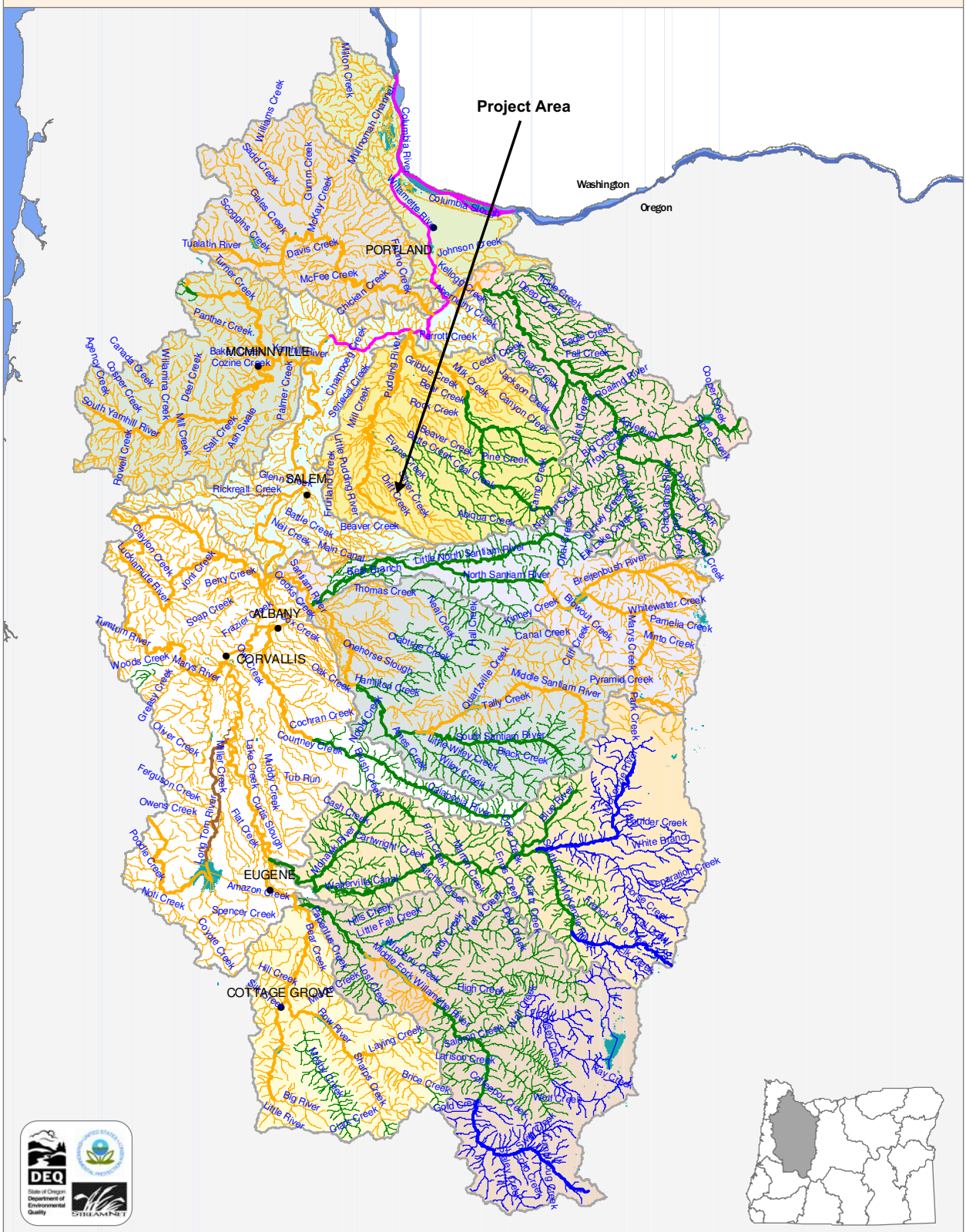

Project Area
Washington
Oregon
PORTLAND
MCMINNVILLE
SALEM
ALBANY
CORVALLIS
EUGENE
COTTAGE GROVE
Columbia River
Willamette River
Columbia Slough
Tualatin River
Johnson Creek
Pudding River
Molalla River
Clackamas River
Santiam River
North Santiam River
South Santiam River
Middle Santiam River
Calapooia River
Luckiamute River
Marys River
Long Tom River
Coast Fork Willamette River
Middle Fork Willamette River
McKenzie River
Mohawk River
Little Fall Creek
Amazon Creek
Spencer Creek
Coyote Creek
Fall Creek
Lake Creek
Muddy Creek
Tub Run
Cottage Grove Reservoir
Dorena Reservoir
Fern Ridge Reservoir
Cougar Reservoir
Blue River Reservoir
Detroit Reservoir
Big Cliff Reservoir
Green Peter Reservoir
Foster Reservoir
Lost Creek Reservoir
Hills Creek Reservoir
Fall Creek Reservoir
Dexter Reservoir
Lookout Point Reservoir
Cougar Reservoir
Blue River Reservoir
Leaburg Reservoir
Walterville Canal
Big River
Little River
Bear Creek
Beaver Creek
Mill Creek
Salem Ditch
Main Canal
Thomas Creek
Hamilton Creek
Cochran Creek
Courtney Creek
Oak Creek
Calapooia River
Tally Creek
Pyramid Creek
Canal Creek
Mill Creek
Little North Santiam River
Breitenbush River
Whitewater Creek
Pamelia Creek
Minto Creek
Marion Creek
White Branch
Sweet Creek
Lake Creek
Fall Creek
Little Fall Creek
Hill Creek
Laying Creek
Brice Creek
Gold Creek
Larson Creek
Salmon Creek
Hills Creek
Lost Creek
Bear Creek
Bow River
Mill Creek
Muddy Creek
Shotgun Creek
Big River
Little River
Fall Creek
Lake Creek
Muddy Creek
Tub Run
Flat Creek
Cole Slough
Long Tom River
Ferguson Creek
Owens Creek
Pogue Creek
Noti Creek
Coyote Creek
Spencer Creek
Amazon Creek
Little Fall Creek
Hills Creek
Middle Fork Willamette River
Hill Creek
Bear Creek
Lost Creek
Mohawk River
Wildcat Creek
Gilkey Creek
Oliver Creek
Ferguson Creek
Owens Creek
Pogue Creek
Noti Creek
Coyote Creek
Tumtum River
Woods Creek
Marys River
Luckiamute River
Clayton Creek
Soap Creek
Berry Creek
Joint Creek
Frazier Creek
Calapooia River
Oak Creek
Cochran Creek
Courtney

*Figure 340B: Salmon and Steelhead Spawning Use Designations**
Willamette Basin, Oregon

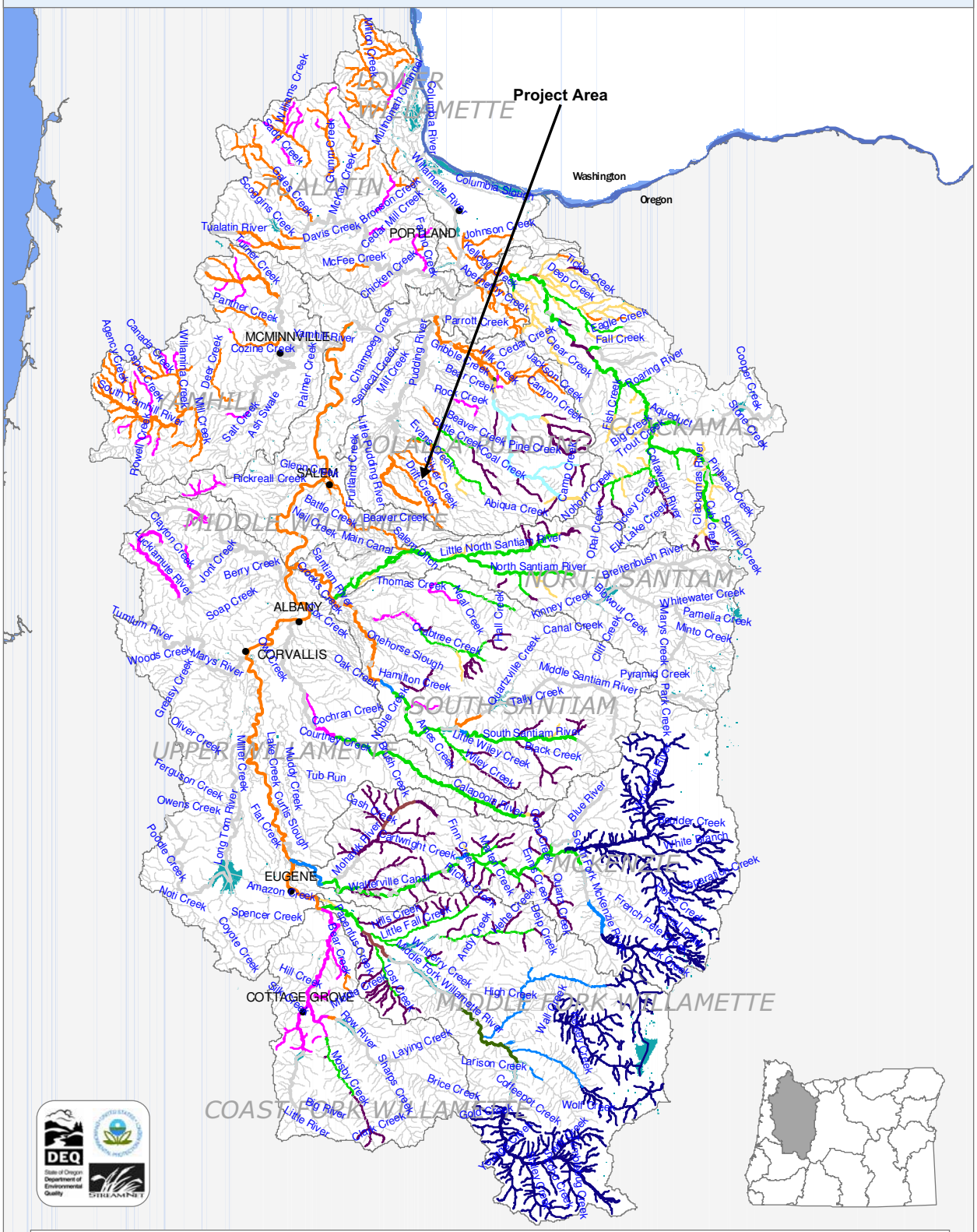

Project Area
Washington
Oregon
PORTLAND
MCMINNVILLE
SALEM
ALBANY
CORVALLIS
EUGENE
COTTAGE GROVE
LOWER WILLAMETTE
TUALATIN
PAL
MIDDLE WILLAMETTE
CLACKAMAS
NORTH SANTIAM
SOUTH SANTIAM
UPPER WILLAMETTE
MIDDLE FORK WILLAMETTE
COAST FORK WILLAMETTE
Columbia River
Willamette River
Columbia Slough
Tualatin River
Yamhill River
Pudding River
Molalla River
Clackamas River
Santiam River
Little North Santiam River
North Santiam River
Little South Santiam River
South Santiam River
Middle Santiam River
Calapooia River
Marys River
Luckiamute River
Long Tom River
Mohawk River
Blue River
Lake Creek
Curtis Slough
Muddy Creek
Tub Run
Amazon Creek
Spencer Creek
Coast Fork Willamette River
Row River
Little River
Big River
Middle Fork Willamette River
Waterville Canal
Main Canal
Salem Ditch
Thomas Creek
Onehorse Slough
Hamilton Creek
Cochran Creek
Courtney Creek
Oak Creek
Calapooia River
Little Wiley Creek
Wiley Creek
Black Creek
Tally Creek
Quartzville Creek
Canal Creek
Pyramid Creek
Minto Creek
Pamelia Creek
Whitewater Creek
Breitenbush River
Abiqua Creek
Pine Creek
Coal Creek
Beaver Creek
Butte Creek
Drift Creek
Rickreall Creek
Glenn Creek
Fudlaint Creek
Mill Creek
Champoeg Creek
Palmer Creek
Ash Swale
Salt Creek
Deer Creek
Mill Creek
Willamina Creek
Agency Creek
Coyote Creek
Canada Creek
South Yamhill River
Rowell Creek
Panther Creek
Tualatin River
Dairy Creek
Scoggins Creek
Gales Creek
Rock Creek
Chicken Creek
McFee Creek
Cedar Mill Creek
Johnson Creek
Kellogg Creek
Deep Creek
Trolle Creek
Eagle Creek
Fall Creek
Clear Creek
Jackson Creek
Canyon Creek
Fish Creek
Roaring River
Aqueduct
Big Creek
Trout Creek
Cooper Creek
Stone Creek
Callawash River
Elk Lake Creek
Dickey Creek
Opal Creek
Camp Creek
Nohorn Creek
Squirrel Creek
Pinhead Creek
Clear Creek
Kinney Creek
Blowout Creek
Cliff Creek
Marys Creek
Park Creek
Calapooia River
Hall Creek
Quartzville Creek
Cedar Creek
Deep Creek
Elm Creek
Olam Creek
Mill Creek
Wall Creek
Larison Creek
Brice Creek
Coffeepot Creek
Wolf Creek
Gold Creek
Laying Creek
Shanks Creek
Mosby Creek
Deer Creek
Hill Creek
Little Fall Creek
Mills Creek
Wingville Creek
Andy Creek
High Creek
Finn Creek
Earthwright Creek
Mohawk River
Fall Creek
Flat Creek
Poodle Creek
Noti Creek
Corde Creek
Ferguson Creek
Owens Creek
Greasy Creek
Oliver Creek
Woods Creek
Tumtum River
Soap Creek
Berry Creek
Jory Creek
Cloven Creek
Pamelia Creek
Minto Creek
Pyramid Creek
Middle Santiam River
Tally Creek
Blue River
Gander Creek
White Branch
French Pete Creek
Lost Creek
Little Fall Creek
Mills Creek
Hill Creek
Deer Creek
Row River
Little River
Big River
Mosby Creek
Shanks Creek
Laying Creek
Brice Creek
Coffeepot Creek
Larison Creek
Wolf Creek
Gold Creek
Wall Creek
Olam Creek
Elm Creek
Deep Creek
Mill Creek
Andy Creek
Wingville Creek
Middle Fork Willamette River
Finn Creek
Earthwright Creek
Mohawk River
Waterville Canal
Amazon Creek
Spencer Creek
Noti Creek
Poodle Creek
Long Tom River
Ferguson Creek
Owens Creek
Greasy Creek
Oliver Creek
Woods Creek
Tumtum River
Soap Creek
Berry Creek
Jory Creek
Cloven Creek
Luckiamute River
Pamelia Creek
Minto Creek
Pyramid Creek
Middle Santiam River
Tally Creek
Quartzville Creek
Canal Creek
Hamilton Creek
Onehorse Slough
Thomas Creek
Cochran Creek
Courtney Creek
Oak Creek
Calapooia River
Little Wiley Creek
Wiley Creek
Black Creek
Tub Run
Muddy Creek
Curtis Slough
Lake Creek
Flat Creek
Marys River
Luckiamute River
Long Tom River
Mohawk River

Table 1

Lake Stratification Review Summary

Lake Name	Volume (acre-feet)	Surface Area (acres)	Max. Depth (feet)	Avg. Depth (feet)	Depth of Thermocline (feet)
Oregon Lakes					
Munsel Lake	3,521	104	96.1	33.8	19.7
Woahink Lake	27,715	739	74.8	37.4	44.0
Eel Lake	14,237	348	68.6	41.0	22.3
Bradley Lake	532	23	33.5	23.3	6.2
Clear Lake	6,291	153	83.6	41.0	28.9
Clear Lake 2	13	316	119.1	54.1	38.4
Garrison Lake	1,482	131	31.5	11.8	12.1
Henry Hagg Lake	59,000	1,153	109.9	51.2	?
East Sutton Lake	1,147	62	33.5	20.3	9.8
West Sutton Lake	27,715	52	33.1	17.1	16.1
Oswego Lake	10,100	395	55.1	25.6	23.0
Collard Lake	876	42	56.7	21.0	16.1
Blue River Lake	85,000	935	248.0	90.9	19.7
Cottage Grove Lake	33,500	1,139	73.1	29.5	19.7
Cooper Creek Reservoir	3,800	166	69.9	23.3	13.1
Dexter Lake	27,500	1,025	56.1	26.9	3.3
Fall Creek Lake	125,000	1,860	161.0	67.2	19.7
Washington Lakes					
Crocker Lake	663	76	13.0	9.0	3.3
Horseshoe Lake	9,002	141	150.0	64.0	6.6
Island Lake	2,246	108	31.0	21.0	NA
Leland Lake	1,415	107	20.0	13.0	6.6
Liberty Lake	16,000	710	30.0	23.0	19.7
Limerick Lake	1,210	129	24.0	9.0	?
Long Lake (reservoir)	2,180	339	12.0	6.0	NA
Mason Lake	49,000	1,000	90.0	48.0	16.4
Medical Lake	5,000	160	60.0	32.0	13.1
West Medical Lake	4,900	220	35.0	22.0	13.1
Moses Lake	131,000	6,800	38.0	19.0	NA
Offutt Lake	2,900	200	25.0	15.0	8.2
Phillips Lake	1,800	110	25.0	16.0	NA
Potholes Lake	500,000	28,000	142.0	18.0	19.7
Spanaway Lake	4,600	280	28.0	16.0	6.6
Sutherland Lake	20,800	369	86.0	57.0	13.1
Ward Lake	2,100	65	67.0	33.0	13.1
Wildcat Lake	2,200	120	33.0	18.0	9.8
William Symington Lake	422	60	23.0	7.0	?
Big Lake	7,470	520	23.0	14.0	13.1
Browns Lake	1,085	84	23.0	13.0	6.6
Campbell Lake	2,770	367	16.0	8.0	NA
Curlew Lake	39,519	921	130.0	43.0	6.6
Deer Lake	57,000	1,110	75.0	52.0	16.4
Desire Lake	933	71	21.0	13.0	8.2

Table 1 (continued)

Lake Name	Volume (acre-feet)	Surface Area (acres)	Max. Depth (feet)	Avg. Depth (feet)	Depth of Thermocline (feet)
Washington Lakes (cont'd)					
Duck Lake	3,000	278	30.0	11.0	6.6
Erie Lake	711	113	12.0	6.0	NA
Gillette Lake	1,600	47	85.0	34.0	3.3
Harts Lake	3,100	120	50.0	26.0	3.3
Loomis Lake	825	165	9.0	5.0	NA
Martha Lake	2,034	62	70.0	33.0	6.6
McMurray Lake	4,500	160	52.0	29.0	13.1
Lake Sacajawea	353	61	21.0	6.0	?
Starvation Lake	233	30	14.0	8.0	3.3
Terrell Lake	2,950	435	10.0	7.0	NA

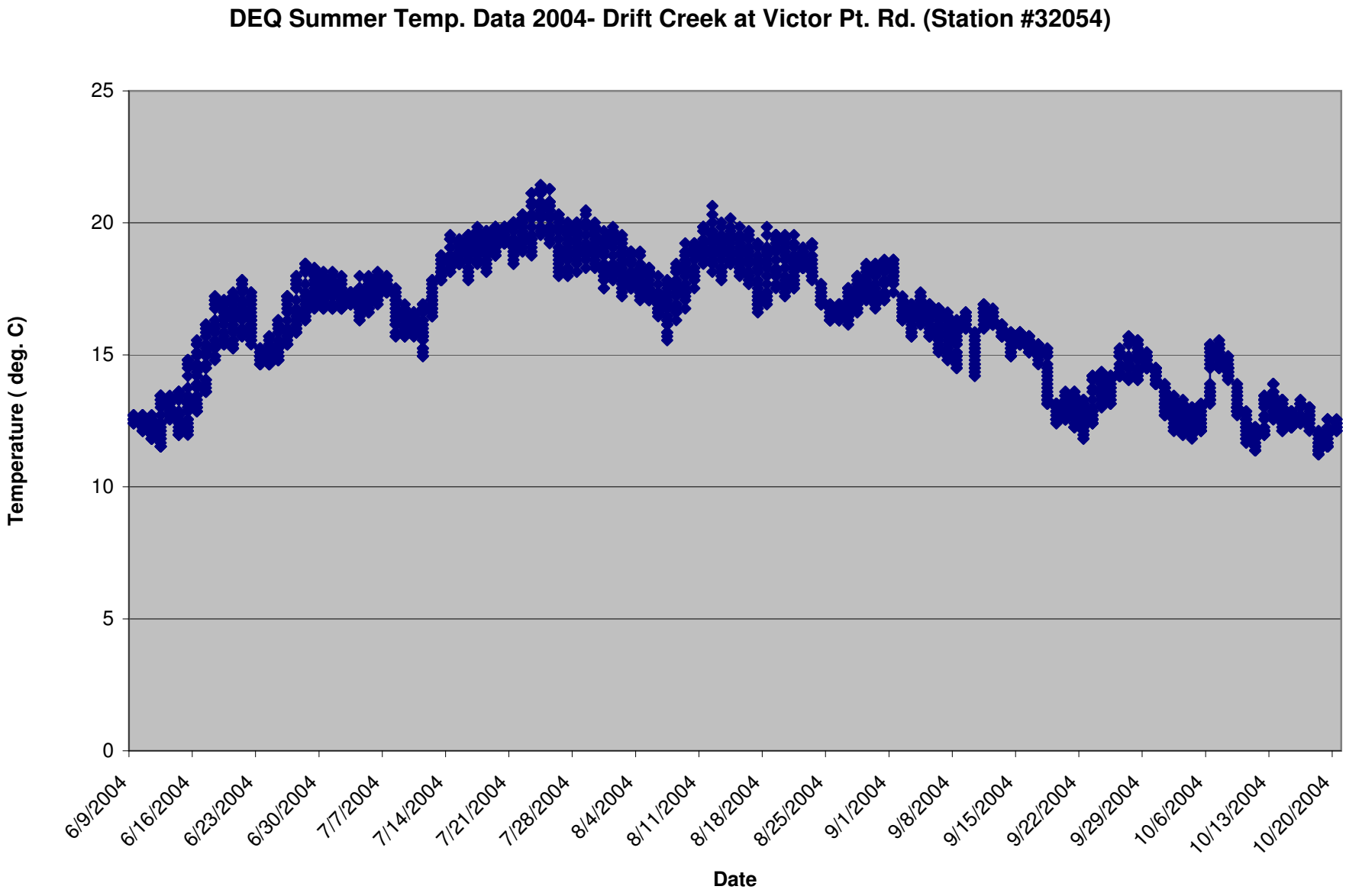
TABLE 2

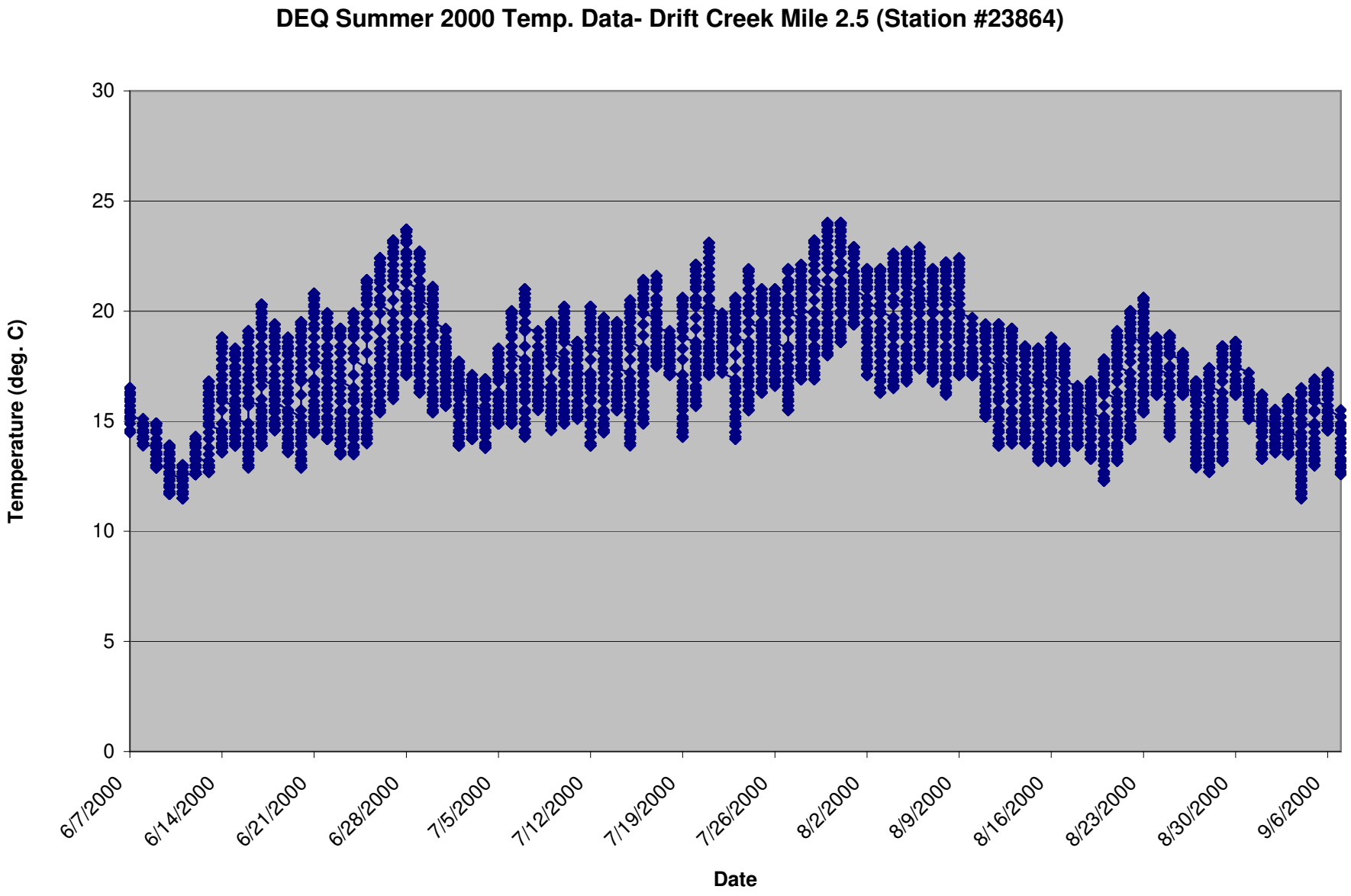
RESULTANT PUDDING RIVER TEMPERATURE
WITH SUMMER BASE FLOW RELEASES FROM DRIFT CREEK
BASED ON TEMPERATURE (MASS) BALANCE APPROACH

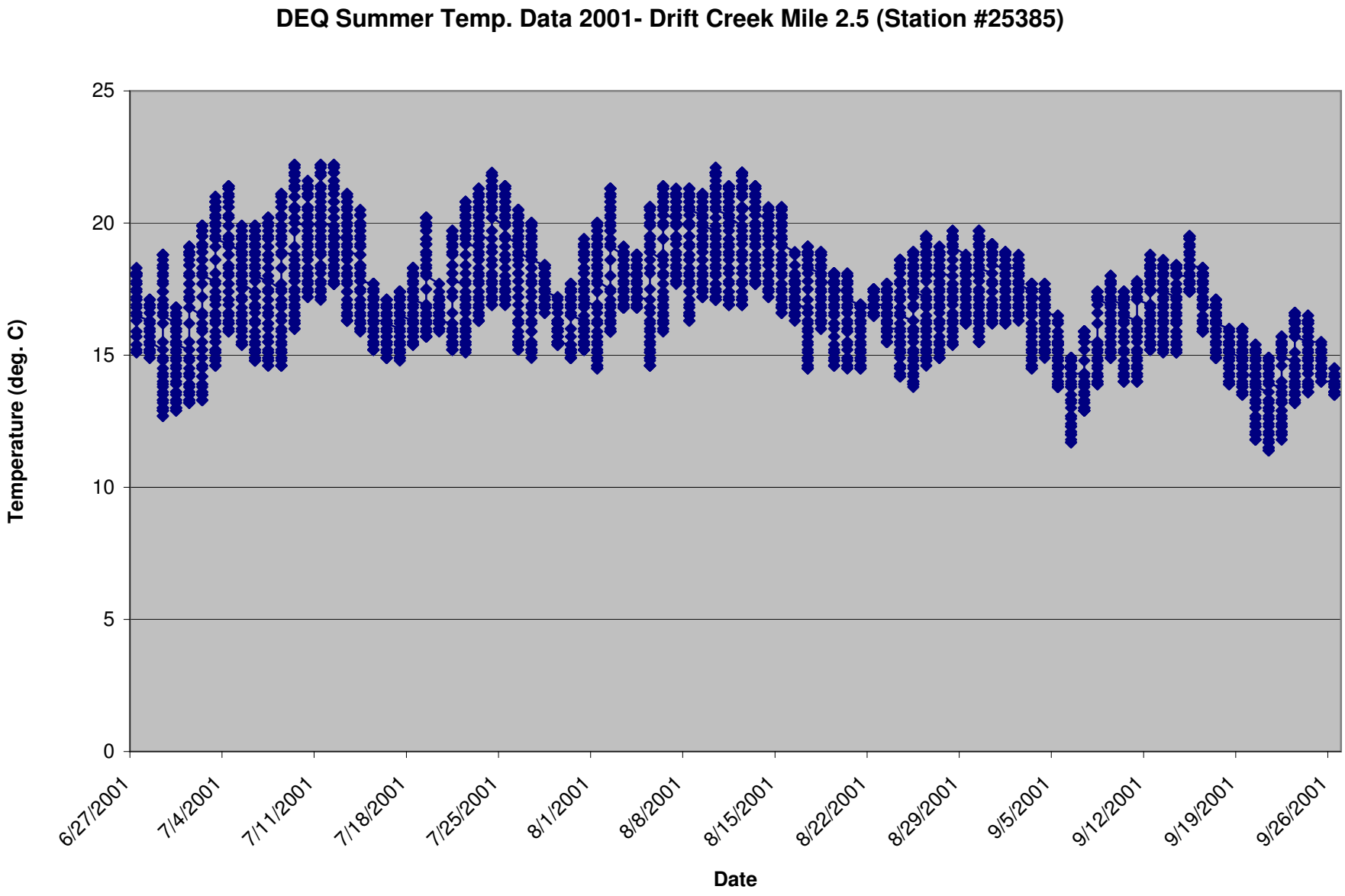
Upstream Pudding R. Flowrate (CFS)	Upstream Pudding R. Temperature ºC	Reservoir Discharge Drift Ck. Flowrate (CFS)	Reservoir Discharge Drift Ck. Temperature ºC	Combined D/S Pudding R. Flowrate (CFS)	Combined D/S Pudding R. Temperature ºC	Reduction in D/S Pudding R. Temperature ºC
5	19	5	15	10	17.0	2.0
5	19	5	15	10	17.0	2.0
5	19	5	15	10	17.0	2.0
5	19	5	15	10	17.0	2.0
5	19	5	15	10	17.0	2.0
5	19	5	15	10	17.0	2.0
5	19	5	15	10	17.0	2.0
5	19	5	15	10	17.0	2.0
5	19	5	15	10	17.0	2.0
10	20	10	15	20	17.5	2.5
10	20	10	15	20	17.5	2.5
10	20	10	15	20	17.5	2.5
10	20	10	15	20	17.5	2.5
10	20	10	15	20	17.5	2.5
10	20	10	15	20	17.5	2.5
10	20	10	15	20	17.5	2.5
10	20	10	15	20	17.5	2.5
10	20	10	15	20	17.5	2.5

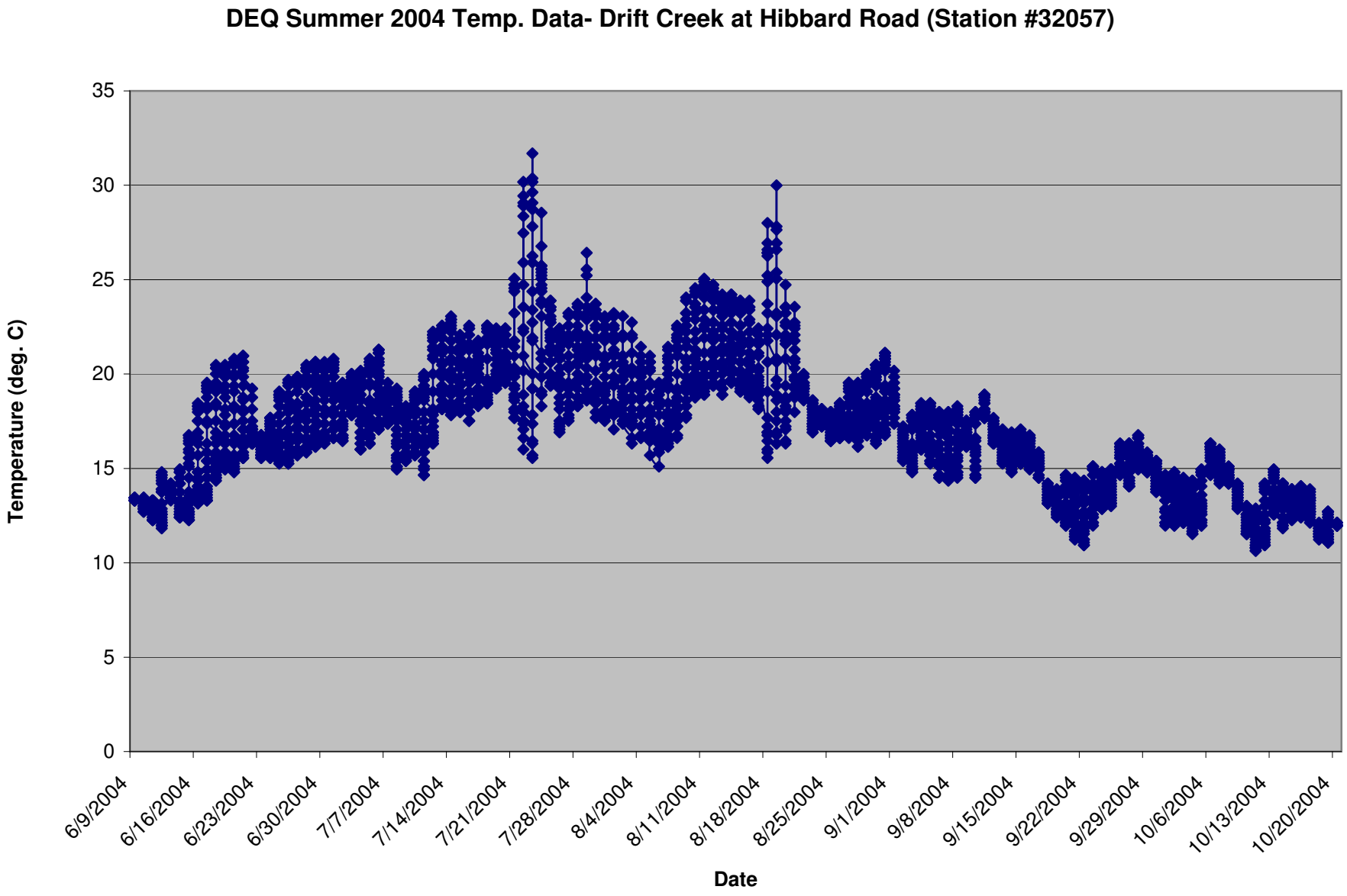
PRELIMINARY WATER QUALITY REVIEW FOR PROPOSED DRIFT CREEK RESERVOIR

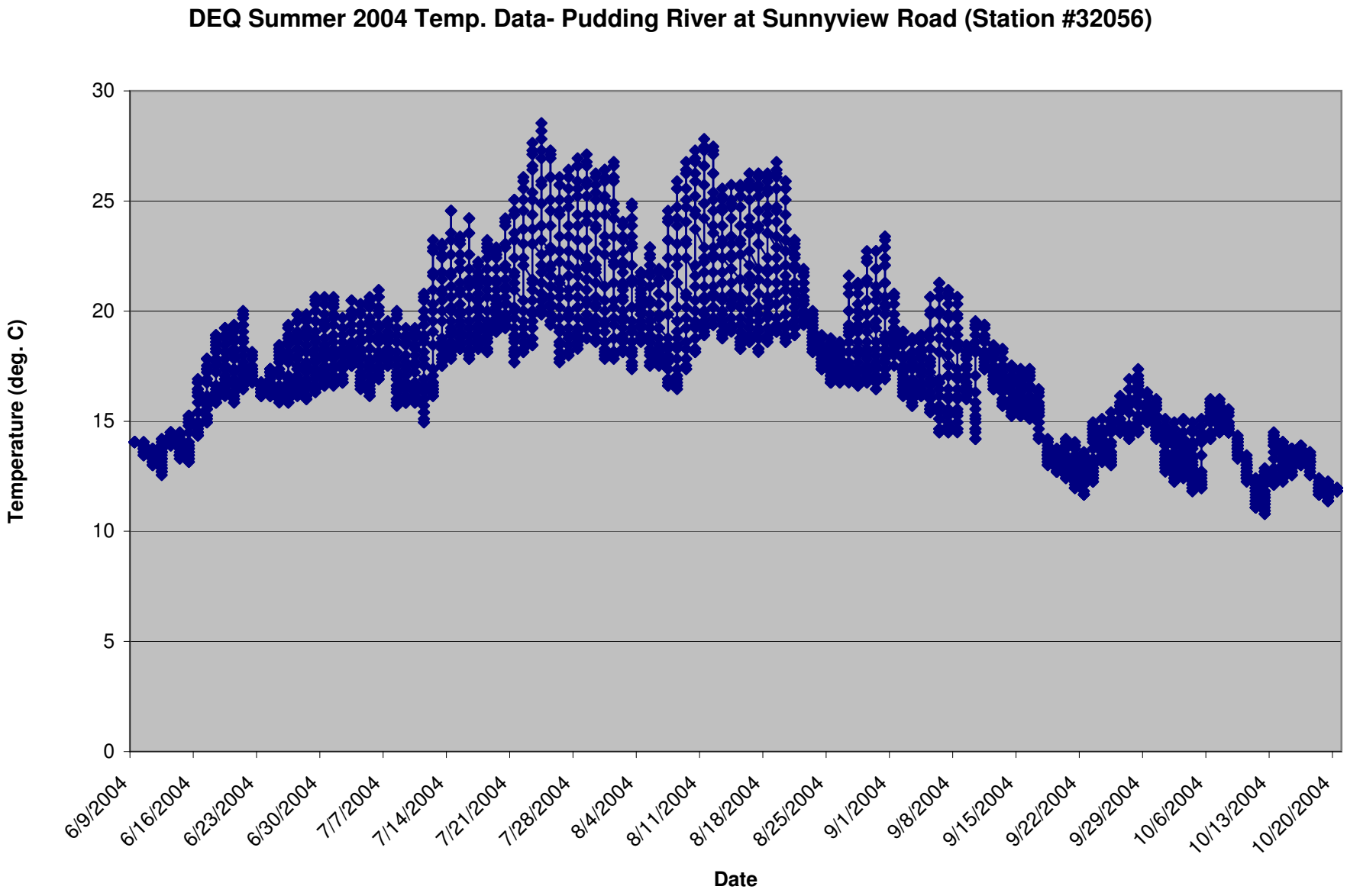
APPENDIX

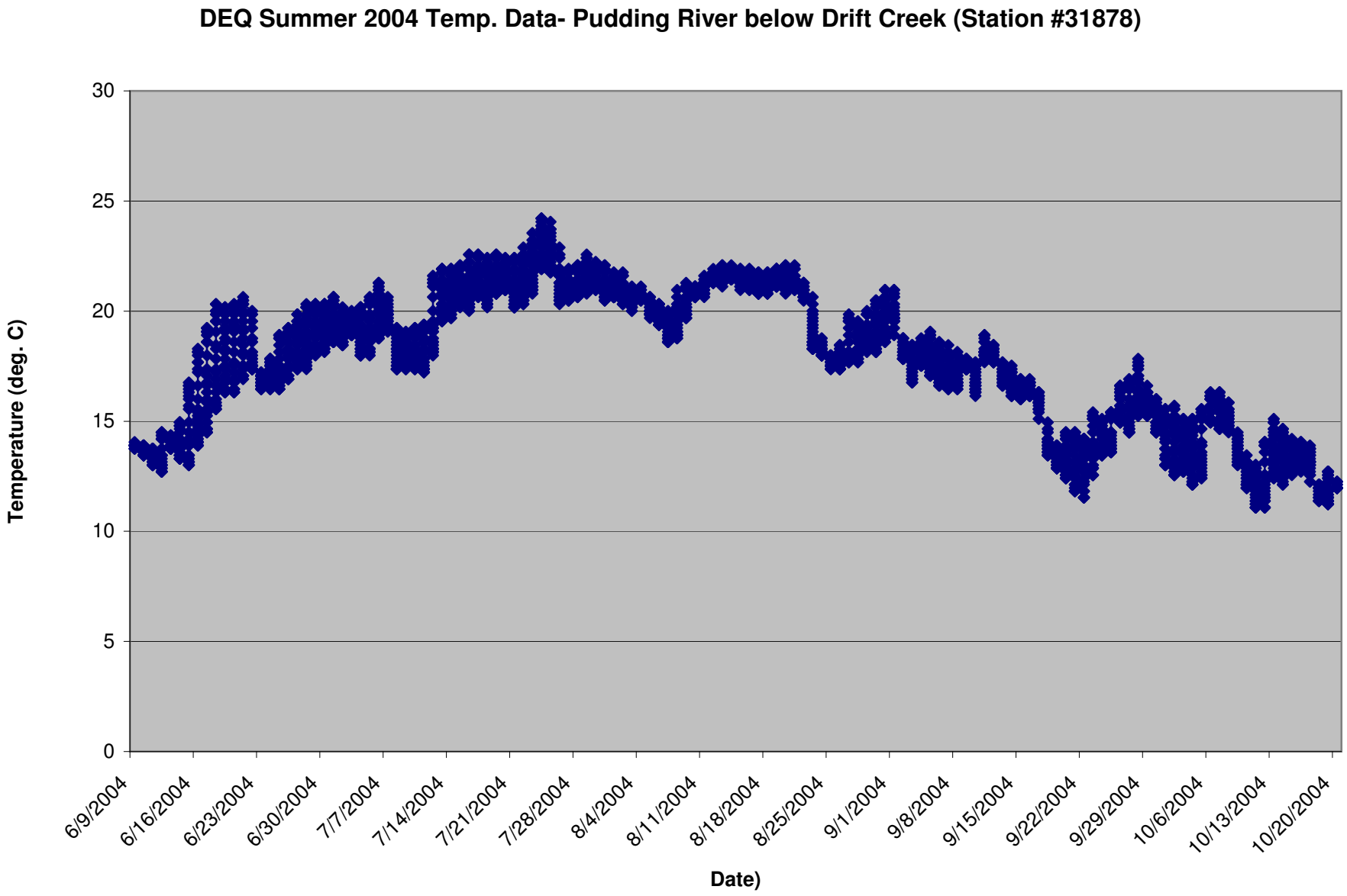

DEQ Summer Temp. Data 2004- Drift Creek at Victor Pt. Rd. (Station #32054)
Temperature (deg. C)
25
20
15
10
5
0
6/9/2004
6/16/2004
6/23/2004
6/30/2004
7/7/2004
7/14/2004
7/21/2004
7/28/2004
8/4/2004
8/11/2004
8/18/2004
8/25/2004
9/1/2004
9/8/2004
9/15/2004
9/22/2004
9/29/2004
10/6/2004
10/13/2004
10/20/2004
Date


DEQ Summer 2000 Temp. Data- Drift Creek Mile 2.5 (Station #23864)
Temperature (deg. C)
30
25
20
15
10
5
0
6/7/2000
6/14/2000
6/21/2000
6/28/2000
7/5/2000
7/12/2000
7/19/2000
7/26/2000
8/2/2000
8/9/2000
8/16/2000
8/23/2000
8/30/2000
9/6/2000
Date


DEQ Summer Temp. Data 2001- Drift Creek Mile 2.5 (Station #25385)
Temperature (deg. C)
25
20
15
10
5
0
6/27/2001
7/4/2001
7/11/2001
7/18/2001
7/25/2001
8/1/2001
8/8/2001
8/15/2001
8/22/2001
8/29/2001
9/5/2001
9/12/2001
9/19/2001
9/26/2001
Date


DEQ Summer 2004 Temp. Data- Drift Creek at Hibbard Road (Station #32057)
Temperature (deg. C)
35
30
25
20
15
10
5
0
6/9/2004
6/16/2004
6/23/2004
6/30/2004
7/7/2004
7/14/2004
7/21/2004
7/28/2004
8/4/2004
8/11/2004
8/18/2004
8/25/2004
9/1/2004
9/8/2004
9/15/2004
9/22/2004
9/29/2004
10/6/2004
10/13/2004
10/20/2004
Date


DEQ Summer 2004 Temp. Data- Pudding River at Sunnyview Road (Station #32056)
Temperature (deg. C)
30
25
20
15
10
5
0
6/9/2004
6/16/2004
6/23/2004
6/30/2004
7/7/2004
7/14/2004
7/21/2004
7/28/2004
8/4/2004
8/11/2004
8/18/2004
8/25/2004
9/1/2004
9/8/2004
9/15/2004
9/22/2004
9/29/2004
10/6/2004
10/13/2004
10/20/2004
Date


DEQ Summer 2004 Temp. Data- Pudding River below Drift Creek (Station #31878)
Temperature (deg. C)
30
25
20
15
10
5
0
6/9/2004
6/16/2004
6/23/2004
6/30/2004
7/7/2004
7/14/2004
7/21/2004
7/28/2004
8/4/2004
8/11/2004
8/18/2004
8/25/2004
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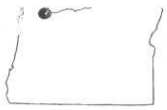
10/6/2004
10/13/2004
10/20/2004
Date)



OSWEGO LAKE

Clackamas County

Willamette/Sandy Basin

LOCATION

Area 395 acres (159.9 hect) **Elevation** 99 feet (30.2 meters)
Type natural lake with dam **Use** recreation (privately owned)
Location within Lake Oswego city boundary, 8 mi. S of Portland
Access private
USGS Quad. Lake Oswego (7.5 min.)
Coordinates 45 deg, 24 min, 38 sec N; 122 deg, 40 min, 00 sec W
USPLSS township 2S, range 1E, section 44

Lake Oswego, located in the heart of the city of the same name, is a well-known but difficult-to-see lake in the Portland metropolitan area. The entire shoreline is private land and rimmed with residential neighborhoods, and the lake is visible only in glimpses from the roads surrounding it. The lakebed is owned and maintained by the Lake Oswego Shorefront Committee, a corporation whose members have lake frontage or access rights to the water and recreational facilities through property agreements. Even with this restricted access, Lake Oswego receives very heavy recreational use. According to Frenkel (1975), it is the seventh busiest body of water in Oregon, and perhaps the busiest for use by waterskiers.

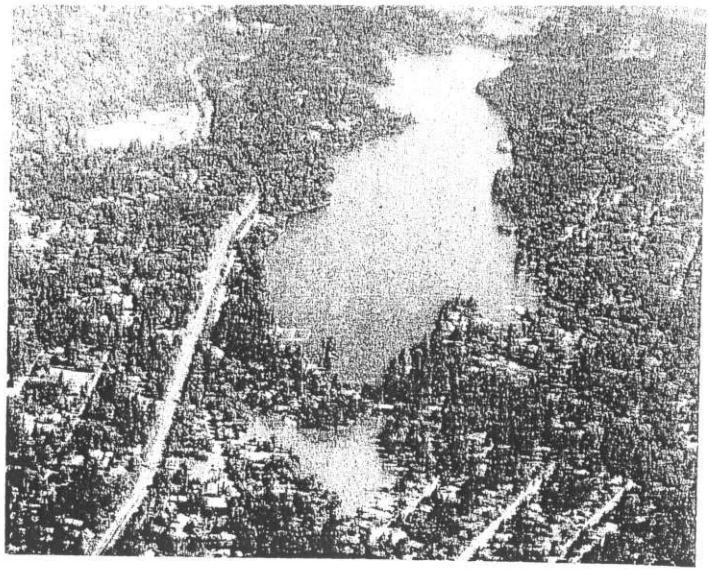
Lake Oswego has an interesting geologic history. It occupies a former channel of the Tualatin River, carved in Columbia River basalt. Downcutting and excavation eventually captured the main channel of the Tualatin River, leaving the old Lake Oswego route abandoned. About 13,000 years ago flood waters from glacial Lake Missoula raced down the Columbia River, backed up the Willamette River, and poured through the Lake Oswego gap, deeply scouring and enlarging the channel.

The cultural history of the lake is equally as interesting. It was called Waluga ("Wild Swan") by the Indians, while early settlers gave it the less appealing name of Sucker Lake. Discovery of iron ore beds brought the first iron furnace west of the Rockies, built just below the lake in 1805 at the point where Oswego Creek pours into the Willamette River. Although the area did not live up to initial predictions that it would become the "Pittsburgh of the West", numerous summer cottages and then permanent homes were built on attractive lake front property. In 1913 the name of the lake was changed to Lake Oswego for the community that had grown up on its shores, in turn named for pioneer Walter Durham's hometown of Oswego, New York. Early in the century a canal connected with the Tualatin River and a small dam on the outlet increased the water level of the lake by several feet. The purpose of the canal was to provide a commercial route for flat-bottomed wheat freighters and rafts of logs. Through neglect, the canal filled with grass and willows, impeding its use. In 1939 a project to clear and widen the canal begun, but work was interrupted by World War II; it was completed in 1948. In February, 1941, the Oregon Iron and Steel Corporation gave the lake bed to the Lake Oswego Shorefront Committee, but has retained control of the dam and power plant. Once a year the lake is lowered about six feet for a three week period so that owners may repair their seawalls and docks.

The water quality in Lake Oswego is poor and by all indications it is a hypereutrophic lake. When sampled on 9/21/82, the hypolimnion was anoxic (oxygen-depleted) below 22 feet (7 meters), the transparency was low (Secchi disk depth = 4.6 feet; 1.4 meters), and the concentrations of total phosphorus and phytoplankton were very high, as were nitrogen values. Conductivity, major ion concentrations, and pH were also quite high (although calcium was relatively low). These are all characteristics of a hypereutrophic lake. Nutrient sources into the water include the Tualatin River (the major inflow), activities by homeowners (lawn fertilizers, insect sprays, etc.), non-point sources from within the extensively developed drainage basin, and from waterfowl on the lake. Also, the anoxic sediments probably release phosphorus.

Macrophytes are not a problem. In fact, very few macrophytes can be found in the littoral areas of the lake, probably a result of the annual lake draw-down. Phytoplankton blooms are common, and the City of Lake Oswego treats these blooms with copper sulfate as they start to develop. However, several residents and lake users have indicated that these algal blooms are not bothersome. The phytoplankton density observed on 9/21/82 (3696 algae per ml.) was among the highest from any Oregon lake. More unusual, however, is the species composition of the phytoplankton. With the exception of Rhodomonas minuta which is widespread, the dominant algae were not found in any other lake sampled in this state-wide inventory, even at low densities. It may be that the annual addditions of copper have a significant effect upon the phytoplankton species, with only copper tolerant species able to survive.

There is very little existing biological and chemical data on Lake Oswego, partially because it is a private lake without public access. Future studies on Lake Oswego could be mutually beneficial for the scientific community as well as for city residents. The present management of the lake includes two treatments that would be of interest to limnologists: lake draw-down, and copper additions to the water. Monitoring lake conditions before, during, and after these treatments could provide insight into basic limnological interactions under actual field conditions, while the generated data would also benefit the City of Lake Oswego by providing information that may reduce the cost, or increase the efficiency, of present management practices.



Source: Oregon National Guard, 1981-82. View looking northeast.

DRAINAGE BASIN CHARACTERISTICS

Area 7 sq mi (16 sq km) **Relief** steep **Precip.** 40 in (102 cm)

Land use by type (%)	Forest	Range	Water	Irr. Ag.	Non Irr. Ag.	Urban	Other
	12.6	.	9.7	0.2	5.4	72.1	.

Notes Data are for natural drainage basin only.

LAKE MORPHOMETRY

Area 395 acres (159.9 hect) **Depth** Maximum 55 ft (16.8 m) Average 26 ft (7.8 m)
Ave/Max Depth Ratio 0.46 **Volume** 10100 acre ft (12.4 cu hm)
Shoal Area 20% **Volume Factor** 1.39 **Shape Factor** 3.8
Length of Shoreline 10.6 mi (17.1 km) **Retention Time** 2 mo
Notes

WATER QUALITY DATA

Sample near surface except as noted in Appendix A.

Sample Date 10/29/75[1] **Temp.** 53.6 F (12 C) **pH** 7.8
Transparency 6.6 ft (2 m) **Phosp. (mg/l)** - **Chlorophyl a (ug/l)** -
Alkalinity (mg/l) 48 **Conductivity (umhos/cm)** - **Diss. Oxygen (mg/l)** 9.0

Major Ions (mg/l)	Na	K	Ca	Mg	Cl	SO4
	-	-	-	-	-	-

Sample Date 9/21/82 **Temp.** 64.9 F (18.3 C) **pH** 9.2
Transparency 4.6 ft (1.4 m) **Phosp. (mg/l)** 0.127 **Chlorophyl a (ug/l)** 2.3
Alkalinity (mg/l) 50 **Conductivity (umhos/cm)** 174 **Diss. Oxygen (mg/l)** 10.4

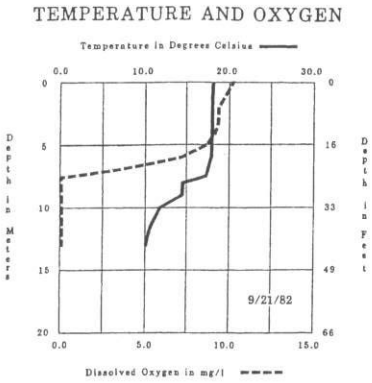
Major Ions (mg/l)	Na	K	Ca	Mg	Cl	SO4
	13.2	3.2	1.9	2.1	11.6	13.3

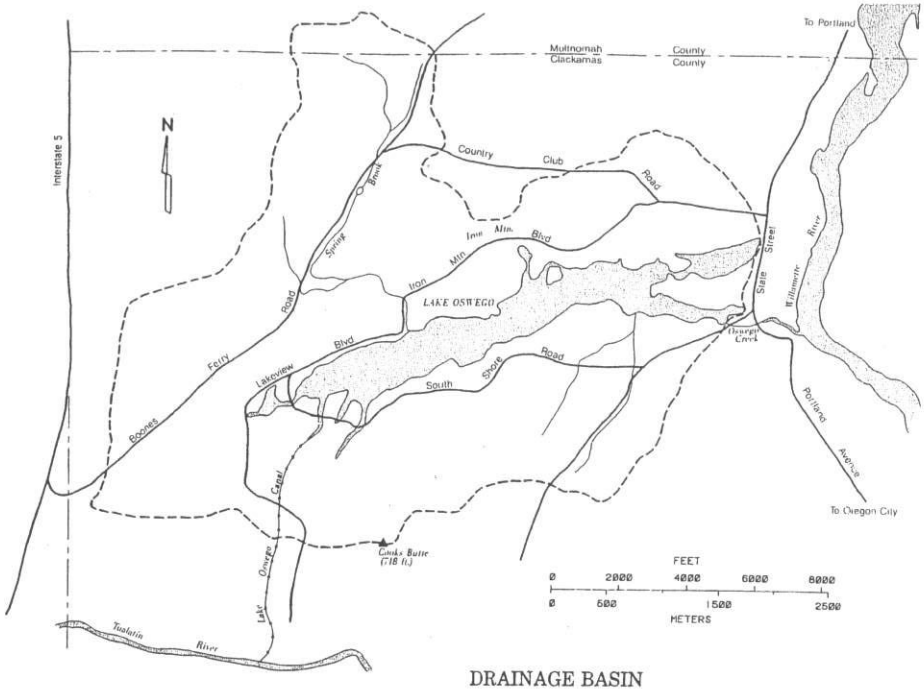
Trophic Status hypereutrophic - significant amount of nutrient input due to land use activity
Notes 1-all data from U.S.G.S.

Phytoplankton Surveys:

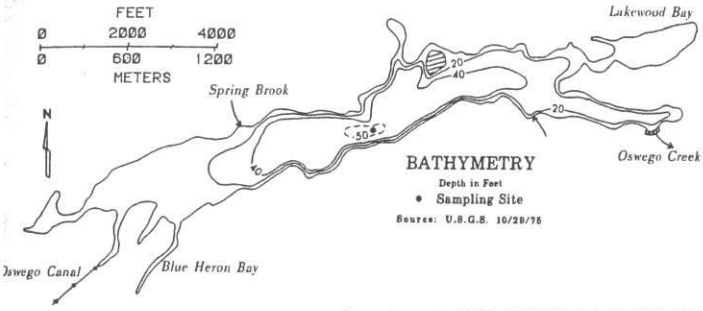
9/21/82

Alga	#/ml	%
Coelastrum microporum	2,703	73.1
Rhodomonas minuta	347	9.4
Pediastrum duplex	322	8.7
Nitzschia microcephala	124	3.4
others (7)	200	5.4
Total	3,696	100.0

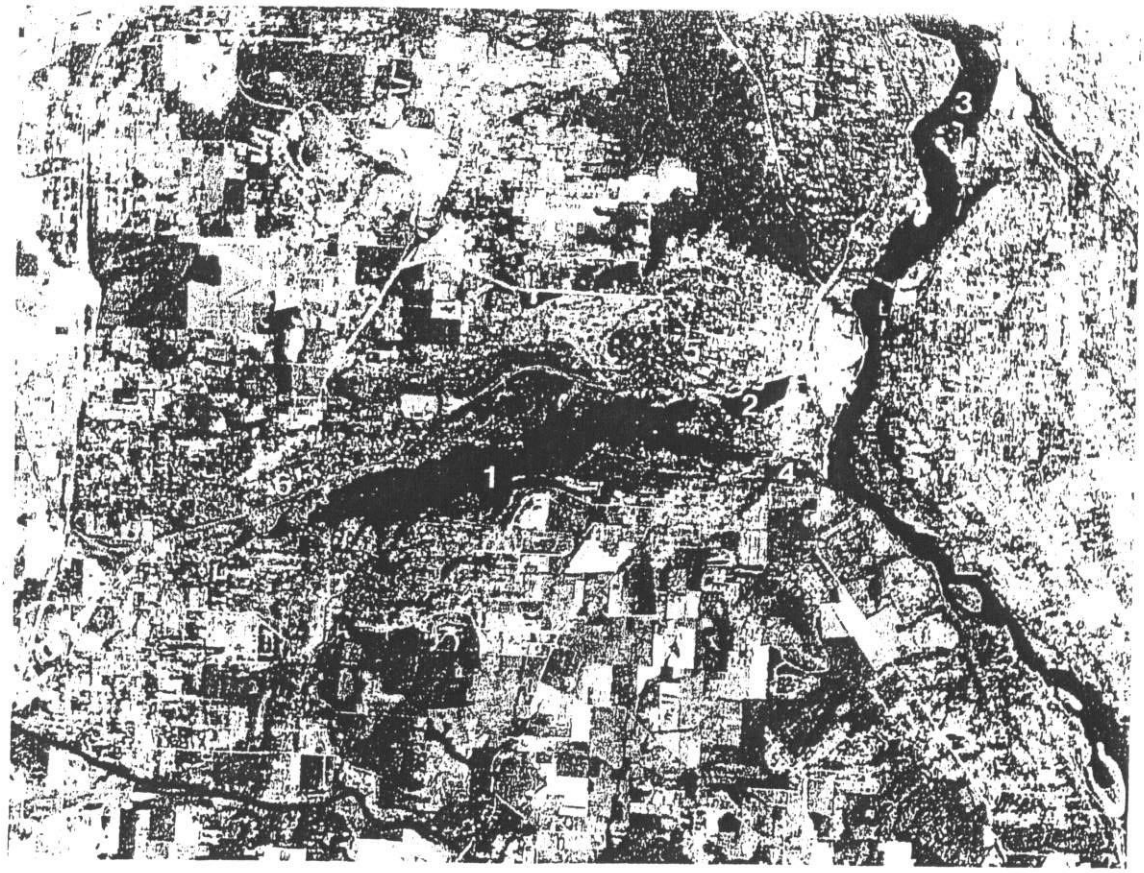




DRAINAGE BASIN
--- Basin Boundary



BATHYMETRY
Depth in Feet
• Sampling Site
Source: U.S.G.S. 10/29/75



oto Captions

Oswego Lake
Lakewood Bay
Willamette River
Sucker Creek
Lake Oswego (town)
Lake Grove (town)
Oak Grove (town)
Lake Oswego Country Club

Source: NASA, 1974. Vertical photograph.

COOPER CREEK RESERVOIR

Douglas County

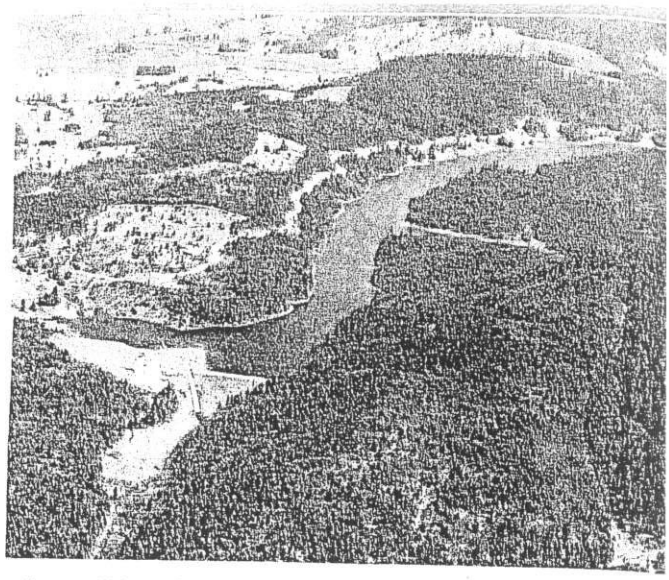
Umpqua River Basin

LOCATION

Area 166 acres (67.2 hect) **Elevation** 660 feet (201.2 meters)
Type reservoir (earth dam) **Use** municipal water supply, recreation
Location 11 miles north of Roseburg, 2 miles east of Sutherlin
Access from county roads 120 and 305
USGS Quad. Sutherlin (15 min.)
Coordinates 43 deg, 22 min, 48 sec N; 123 deg, 16 min, 54 sec W
USPLSS township 25S, range 5W, section 22(23;26)

Cooper Creek Reservoir is a long, narrow impoundment which stores the flow of Cooper Creek, a tributary of Sutherlin Creek. The dam is about eight miles upstream from the North Umpqua River. It was built in the late 1960s by the Soil Conservation Service as a multi-purpose water resource project, with primary uses for both municipal supplies and public recreation. The drainage basin is mostly private forest land; the shoreline is also mostly private land, although public access is available on all sides. Douglas County has some shoreline property and has built two picnic areas and two paved boat ramps. Quite a bit of water skiing is done on the reservoir, an activity that conflicts with fishing, although a five mile per hour speed limit is enforced in the fishing areas. Cooper Creek Reservoir is very popular with local anglers and is a good producer of rainbow trout, largemouth bass and crappies. Crappie angling is especially good in the arms of the lake during spring and early summer.

The reservoir is relatively shallow with a mean depth of 23 feet. It is deepest (70 feet) near the dam at the western end and becomes progressively shallower toward the southeast where Cooper Creek enters. Sodium and chloride concentrations are remarkably high, similar to nearby Plat I reservoir. Conductivity is also well above average for southern Oregon reservoirs and there is some evidence of even greater conductivity in water near the bottom of the reservoir (USGS, 1979). This suggests that the reservoir may be somewhat meromictic, or permanently stratified. During summer, the water is sometimes anoxic (depleted of oxygen) below 40 feet. Rooted macrophytes develop in shallow water areas.



Source: U.S. Geological Survey, 1978. View looking east.

DRAINAGE BASIN CHARACTERISTICS

Area 4.5 sq mi (11.1 sq km) **Relief** moderate **Precip.** 35 in (89 cm)

Land use by type (%)	Forest	Range	Water	Irr. Ag.	Non Irr. Ag.	Urban	Othe
	90.1	5.0	4.9	.	.	.	.

Notes

LAKE MORPHOMETRY

Area 166 acres (67.2 hect) **Depth** Maximum 70 ft (21.3 m) Average 23 ft (7.1 m)
Ave/Max Depth Ratio 0.33 **Volume** 3800 acre ft (4.73 cu hm)
Shoal Area 25% **Volume Factor** 0.97 **Shape Factor** 2.8
Length of Shoreline 5.1 mi (8.2 km) **Retention Time** 9 mo
Notes

WATER QUALITY DATA

Sample near surface except as noted in Appendix A.

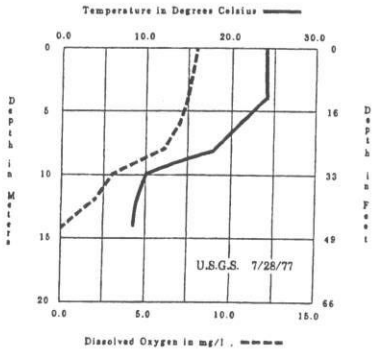
Sample Date 9/6/82 **Temp.** – **pH** 7.0
Transparency 12.5 ft (3.8 m) **Phosp. (mg/l)** – **Chlorophyl a (ug/l)** –
Alkalinity (mg/l) 35 **Conductivity (umhos/cm)** 182 **Diss. Oxygen (mg/l)** –

Major Ions (mg/l)	Na	K	Ca	Mg	Cl	SO4
	17.4	0.6	12.2	3.3	58.1	2.7

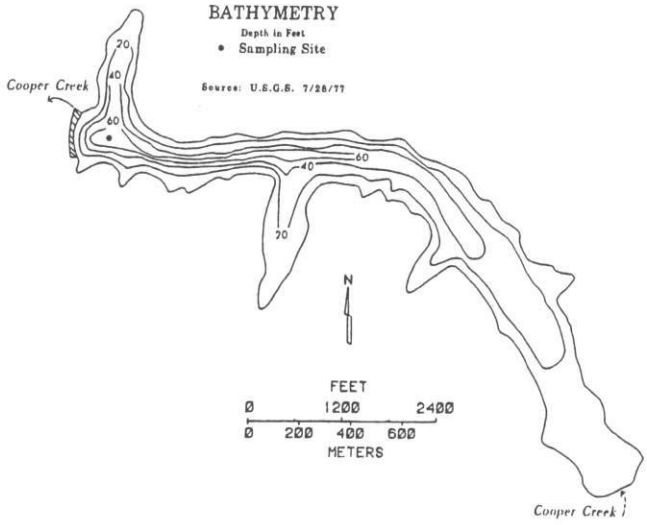
Trophic Status eutrophic

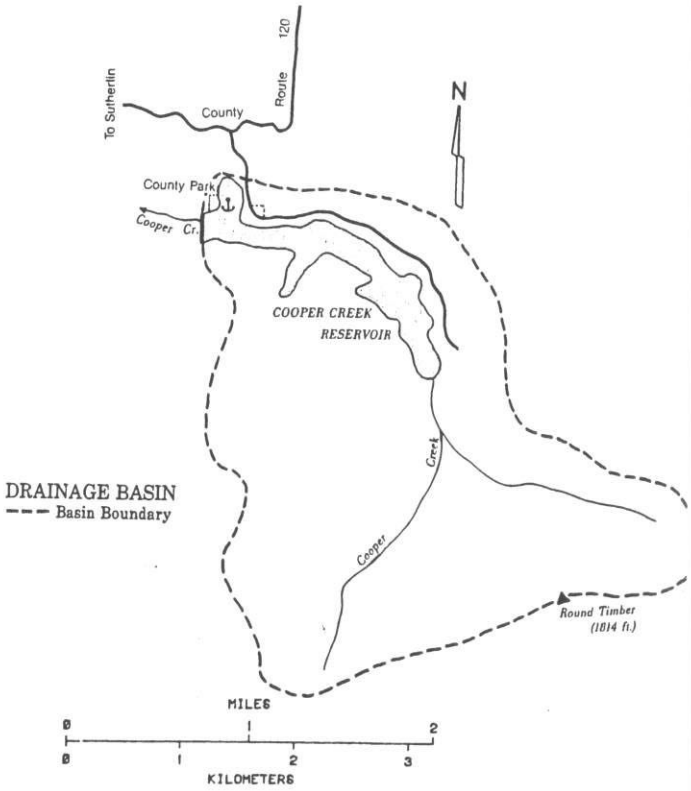
Notes pH and secchi from U.S.G.S. 7/28/77

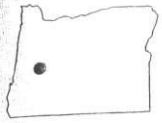
TEMPERATURE AND OXYGEN



BATHYMETRY







COTTAGE GROVE LAKE

Lane County

Willamette/Sandy Basin

LOCATION

Area 1139 acres (461 hect) **Elevation** 790 feet (240.8 meters)
Type reservoir **Use** multi-purpose
Location 6 miles south of Cottage Grove
Access 4 miles from US Hwy 5 on county road
USGS Quad. Anlauf (15 min.)
Coordinates 43 deg, 43 min, 00 sec N; 123 deg, 02 min, 58 sec W
USPLSS township 21S, range 3W, section 28

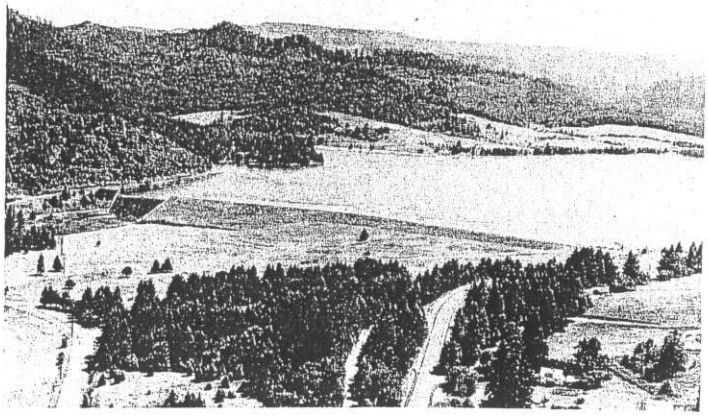
Cottage Grove Lake is a multi-purpose reservoir on the Coast Fork of the Willamette River. It is one of thirteen Corps of Engineers multi-purpose water projects in the Willamette Valley. The primary function of Cottage Grove Lake, in concert with nearby Dorena Lake, is to control flooding on the Coast Fork as well as to help reduce floodstages farther downstream on the mainstem of the Willamette. It was estimated in 1977 that the presence of Cottage Grove Lake had prevented over $64,000,000 in flood damages since its completion in 1942. The reservoir is maintained near full pool until after mid-summer. By August a gradual draw-down begins and by November it is at a minimum level to provide storage for potential flood waters.

This reservoir does not exhibit the typical branching pattern of so many impounded water bodies. The relatively flat topography of its valley is reflected in the regular shoreline, a fact that is most apparent after the fall draw-down when the surface area of the water is reduced to about 25 percent of its maximum. At this time extensive mudflats are exposed and access to the lake restricted. Although the shoreline of the lake is managed by the Corps of Engineers, about half of the forested drainage basin is private land and the rest is federal land managed by the Bureau of Land Management.

Cottage Grove Lake is very popular for all water-based recreation activities, especially boating. Trout are stocked by the state each year and the lake is also managed for warm-water game fish, primarily largemouth bass and black crappie. The Corps of Engineers has provided four parks for camping, picnicking and boat launching.

The Black Butte mine, two miles south of the lake and in its drainage basin, was once one of the largest producers of mercury in Oregon, and there has been a problem with natural deposits in the area yielding mercury to the lake. Analyses of fish tissue by the Department of Environmental Quality have shown that mercury levels in the fish are near levels at which the U.S. Food and Drug Administration would require action. Arsenic has also been reported in the area, primarily in the groundwater immediately downstream from the dam and upstream at London Springs.

A pronounced thermal stratification develops in Cottage Grove Lake during summer. Because the control outlet on the dam is near its base, cool hypolimnetic water is selectively withdrawn and only warmer epilimnetic water remains in the reservoir after it has been drawn down. Trophic indices, based on chlorophyl, phosphorus and water transparency indicate that the Cottage Lake is more oligotrophic than other reservoirs in the region. However, it develops a pronounced oxygen depletion in the hypolimnion and is reported to support a considerable production of fish. These factors imply that the lake is more eutrophic than suggested by the indices and it is therefore classified as mesotrophic.



Source: U.S. Army Corps of Engr., 1975. View looking south.

DRAINAGE BASIN CHARACTERISTICS

Area 104 sq mi (257 sq km) **Relief** moderate **Precip.** 48-62 in (122-157 cm)

Land use by	Forest	Range	Water	Irr. Ag.	Non Irr. Ag.	Urban	Other
type (%)	96.5	1.0	2.0	.	.	.	0.5[1]

Notes 1-rock outcrops

LAKE MORPHOMETRY

	Maximum	Average
Area 1139 acres (461 hect)	Depth 73 ft (22.3 m)	29 ft (9 m)

Ave/Max Depth Ratio 0.40 **Volume** 33500 acre ft (41.31 cu hm)
Shoal Area 17% **Volume Factor** 1.20 **Shape Factor** 2.1
Length of Shoreline 7.6 mi (12.2 km) **Retention Time** 2 mo
Notes Area, volume, and depth are from U.S. Corps of Engineers.

WATER QUALITY DATA

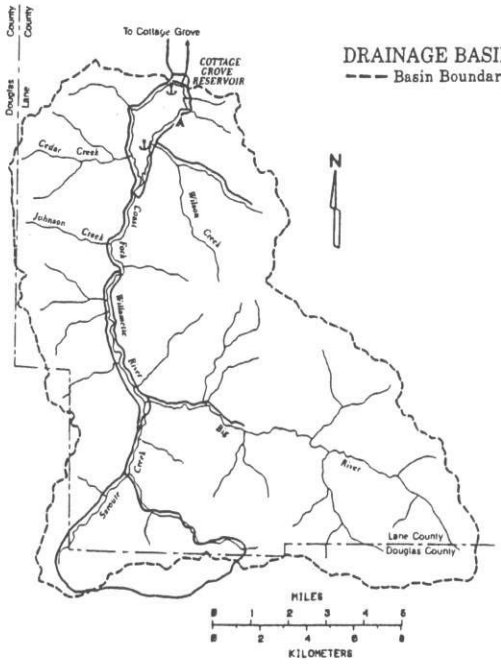
Sample near surface except as noted in Appendix A.

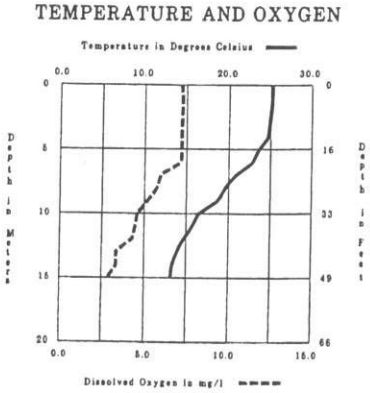
Sample Date 08/12/81 **Temp.** 77.4 F (25.2 C) **pH** 7.7
Transparency 19 ft (5.8 m) **Phosp.** (mg/l) 0.002 **Chlorophyl a** (ug/l) 0.8
Alkalinity (mg/l) 21 **Conductivity** (umhos/cm) 63 **Diss. Oxygen** (mg/l) 7.2

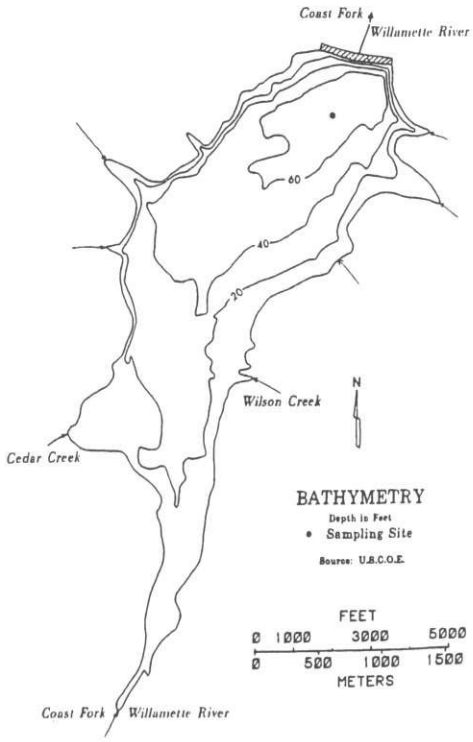
Major Ions	Na	K	Ca	Mg	Cl	SO4
(mg/l)	4.5	1.0	6.4	2.1	2.4	1.2

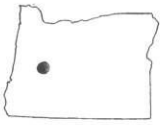
Trophic Status mesotrophic

Notes









DEXTER LAKE

Lane County

Willamette/Sandy Basin

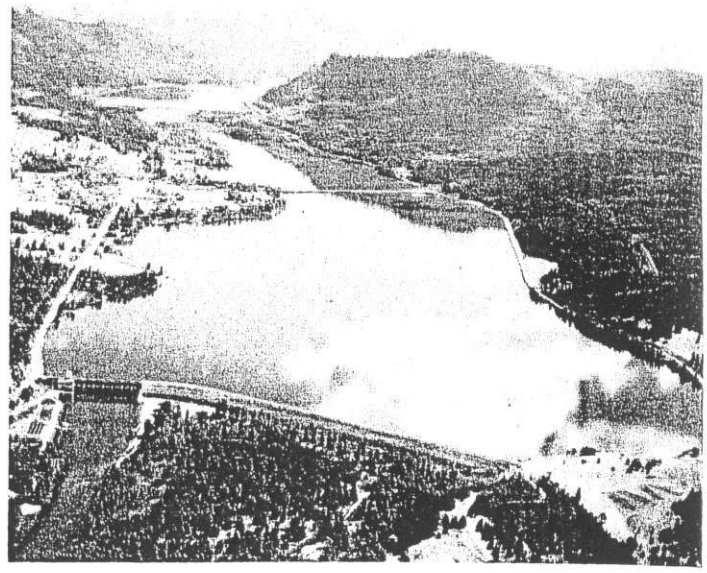
LOCATION

Area 1025 acres (414.8 hect) **Elevation** 695 feet (211.8 meters)
Type reservoir **Use** multi-purpose, reregulating dam
Location 20 miles southeast of Eugene
Access adjacent to Ore Hwy 58
USGS Quad. Lowell (15 min.)
Coordinates 43 deg, 55 min, 28 sec N; 122 deg, 48 min, 20 sec W
USPLSS township 19S, range 1W, section 16

Dexter Lake is a relatively small, shallow reservoir which functions as a reregulating basin for Lookout Point Lake immediately upstream. As such it is designed to contain, temporarily, surges of water released intermittently from Lookout Point Lake during hydroelectric power generation, thereby avoiding widely fluctuating flows downstream. Accordingly, the volume of water stored in Dexter Lake varies considerably throughout the year. It is one of 13 multi-purpose water projects built by the Corps of Engineers in the Willamette Valley. Dexter and Lookout Point Lakes were completed in 1954 with the construction of dams on the Middle Fork of the Willamette River and, in combination, have since prevented an estimated $200 million in damages from downstream flooding. A small amount of hydroelectric power is also generated from a powerhouse at Dexter Dam with one generating unit. In spite of fluctuations in surface water level, Dexter Lake is a very popular recreation site, used very heavily by waterskiers and sailboaters. Lane County parks on both the north and south shores provide full day-use facilities. Angling is also a popular activity and the lake is open for fishing all year, although there have been problems with infestation by rough fish in recent years.

The drainage basin for Dexter Lake is, of course, the same as for Lookout Point Lake; it is a forested area stretching to the crest of the Cascade Mountains. The lake itself lies in the transition zone between the mountains and the Willamette Valley, an area of gentle topography that consists of alluvial fill and old river terraces, surrounded by remnant buttes of basalt and diorite. The western hemlock and Douglas fir forests that dominate the drainage basin show great variety around the lake where there has been significant alteration of vegetation. About three-quarters of the drainage basin is managed by the Willamette National Forest. There are significant amounts of private holdings upstream around the town of Oakridge and adjacent to the lower half of Lookout Point Lake and around Dexter Lake.

The thermal properties of this reservoir are somewhat unusual because it is fed by cool water discharged from the bottom of Lookout Point Lake. This cool water tends to sink in Dexter Lake and maintains thermal stratification which would otherwise not develop in such a shallow reservoir. The major ion chemistry is typical of western Cascade reservoirs. There is extensive growth of rooted macrophytes and occasional algal blooms, including diatoms and cyanophytes. Chlorophyl and phosphorous concentrations and water transparency suggest that the lake is mesotrophic. However, because the lake shows some tendency to develop algal blooms and oxygen is sometimes depleted, it is classified as mesotrophic, a condition encouraged by the shallow depth.



Source: Oregon National Guard, 1981-82. View looking east.

DRAINAGE BASIN CHARACTERISTICS

Area 5 sq mi (12 sq km) **Relief** moderate **Precip.** 48-70 in (122-178 cm)

Land use by type (%)	Forest	Range	Water	Irr. Ag.	Non Irr. Ag.	Urban	Other
	96.3	.	2.4	1.2	.	0.1	.

Notes

LAKE MORPHOMETRY

Area 1025 acres (414.8 hect) **Maximum Depth** 56 ft (17.1 m) **Average** 27 ft (8.2 m)
Ave/Max Depth Ratio 0.48 **Volume** 27500 acre ft (33.91 cu hm)
Shoal Area 21% **Volume Factor** 1.27 **Shape Factor** 1.8
Length of Shoreline 7 mi (11.3 km) **Retention Time** <1 mo.
Notes Area, volume, and depth are from U.S. Corps of Engineers.

WATER QUALITY DATA

Sample near surface except as noted in Appendix A.

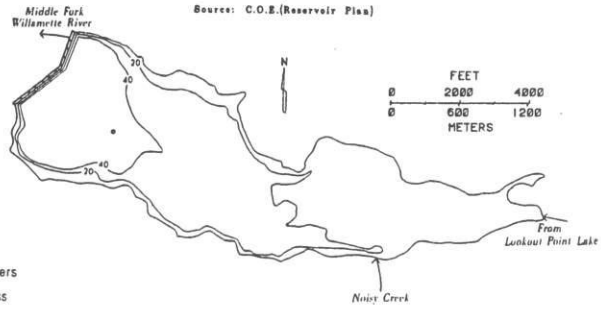
Sample Date 8/14/81 **Temp.** 68.4 F (20.2 C) **pH** 7.6
Transparency 13.5 ft (4.1 m) **Phosp. (mg/l)** 0.015 **Chlorophyl a (ug/l)** 0.9
Alkalinity (mg/l) 15 **Conductivity (umhos/cm)** 47 **Diss. Oxygen (mg/l)** 9.3

Major Ions (mg/l)	Na	K	Ca	Mg	Cl	SO4
	2.8	0.7	4.7	1.8	1.5	0.7

Trophic Status mesotrophic - algal blooms and extensive growth of macrophytes
Notes

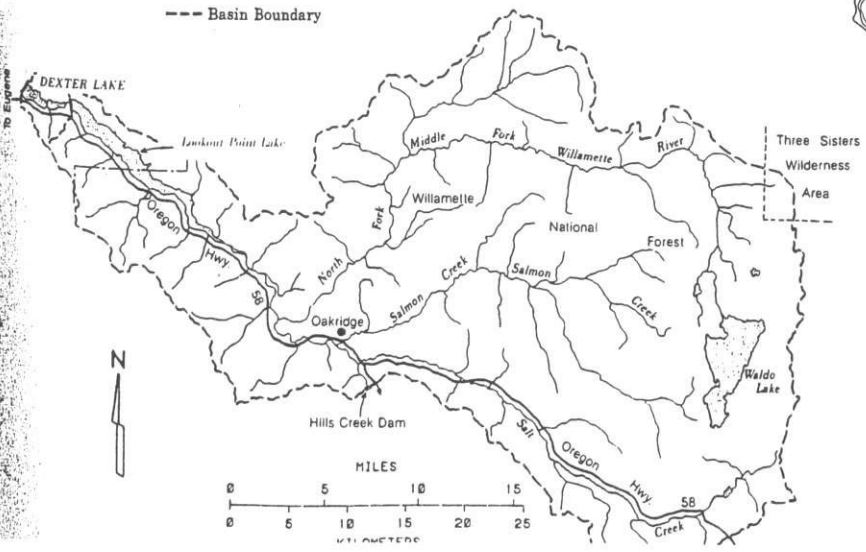
BATHYMETRY

Depth in Feet
• Sampling Site
Source: C.O.E.(Reservoir Plan)



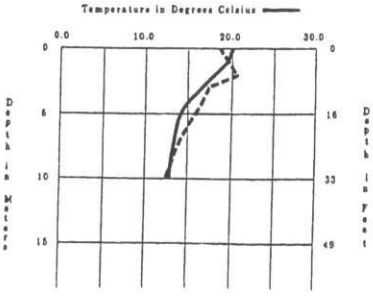
DRAINAGE BASIN

--- Basin Boundary



TEMPERATURE AND OXYGEN

Temperature in Degrees Celsius



Projects:
Ballast Water
Bathymetry
Clatsop Lakes
Columbia Surv.
CRANSI
Egeria Densa
Lake Inventory
Methods
Bradley
Clear N
Clear S
Collard
Eel
Garrison
Munsel
Sutton E
Sutton W
Woahink
LCRANS
Mitten Crab
Nutrient Criteria
Outreach OISC
PBWG
Zebra Mussel

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Tables and Figures
Click to Enlarge

Oregon Lake Inventory: Clear Lake, Douglas County, Oregon

Location:	43° 38' 02" N; 124° 10' 52" W
Surface elevation (m):	70
Watershed Area (ha):	536
Surface Area (ha):	128
Volume (m^3)	16,600
Maximum Depth (m)	36.3
Mean Depth (m)	16.5
Shoreline length (km)	14
Trophic State	Refer to water quality text

Introduction • Watershed • Morphometry • Water Quality • Resources

Introduction

Clear Lake is a large, deep natural lake located near the Oregon coast (figure 1). It serves as the primary municipal water supply for the City of Reedsport located five miles to the north. The city has restricted public access to the lake and watershed in an effort to protect this resource. The lake is well known, however, because of its location next to the heavily traveled Coast Highway. Clear Lake heads a chain of lakes that includes Lake Edna, Eel Lake and the Tenmile Lakes. The chain was formed during the Pleistocene epoch through subduction of coastal areas followed by ponding of streambeds by migrating sand dunes (Cooper 1958). Although this type of lake origin is common on the Oregon coast, the lake's elevation of near 70 meters is unusually high.

Clear Lake receives surface inflow from several intermittent streams. Outflow is south through the chain of lakes, Tenmile Creek and into the Pacific Ocean. The USGS reports that seepage occurs into unconsolidated sediments along the south and southwest margins of the lake (Rinella et al 1980).

Watershed Characteristics:

Fig. 1. Lake Watershed

Forests and water are the major components of Clear Lake's small watershed covering approximately 90% of the total area (table 1). Conifer forest comprises 66% of the total watershed area and the surface area of the lake 23 % of the watershed area. The remaining ten percent consists of sand dunes, non-forested vegetation, and roads. Road density is 22 meters per hectare, similar to other Coast Range watersheds. Some of the roads lead to a clear-cut logging area which occurred within the watershed during the winter and spring of 2001.

Average slope is 15% across the watershed. As noted earlier, the elevation of the lake is high when compared to other dune formed lakes on the Oregon coast. Elevations range from 70 meters at the outlet to 225 meters in the Coast Range. Mean elevation is 109 meters. The Coast Range and sand dune slopes in the watershed are steep, averaging 15%. The mean annual precipitation of 74 inches per year is typical of the rainy Oregon coast.

Table 1. Lake watershed characteristics

^-- Top

Morphometry:

Clear Lake has the characteristic dendritic shape of a dune formed lakes. Due to a limited boat use on Clear Lake and the windy nature of the area, an updated bathymetric map could not be completed. The U.S. Geological Survey did, however, complete a bathymetric map from data collected October 1977 (figure 2). The lake averages 16.5 meters deep and has a maximum depth of 36 meters. The shoreline drops very steeply with few exceptions. The tips of each of the arms and some bays have areas shallow enough to support limited rooted macrophyte growth.

Table 2. Water quality table

Water Quality

Several water quality parameters were measured in Clear Lake during the summer of 2001 (methods link). A summary is provided in table 2. The lake's trophic state based on Secchi disc depth, chlorophyll a concentration, and total phosphorus concentration ranged from index values of 28 to 71. This is an extremely wide range spanning oligotrophic to eutrophic values. The highest values were observed on April 18, 2001. Samples collected on that day were during the midst of an intense phytoplankton bloom. Chlorophyll a was 63 µg/l and Secchi disk depth was 3 meters, both values very poor for a drinking water supply lake. Trophic state values calculated from July and September data ranged from 28 to 37, all within the oligotrophic range. City of Reedsport water supply managers report that during the spring of 2001 Clear Lake's water quality was as poor as they had ever seen it. The poor water quality observed in April may reflect an input of nutrients from new clear-cut areas in the watershed. This assertion has not been verified, however. What is evident from the existing data is that Clear Lake's water quality is very sensitive to change.

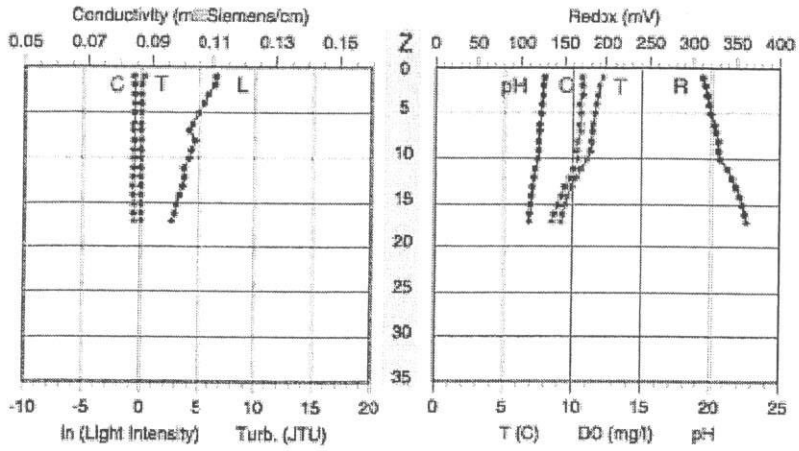
Thermal stratification was present during the July and September visits. The mixed depth was over ten meters during both visits (table 2). Oxygen was depleted in the lowest portions of the hypolimnion during the September visit. Vertical profiles of temperature, oxygen and other parameters are provided below.

The morphometry, water quality, and sediment quality of Clear Lake were not sufficient to support dense beds of macrophytes. The most common macrophyte encountered was a species of *Isoetes*. *Sparganium emersum*, *Vallisneria Americana*, and *Potomogetum spp.* were also present.

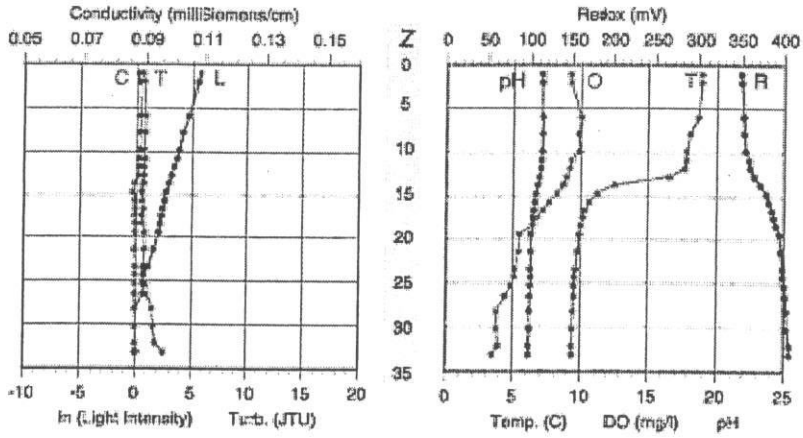
^-- To Top

Clear Lake South, 2001 Data:

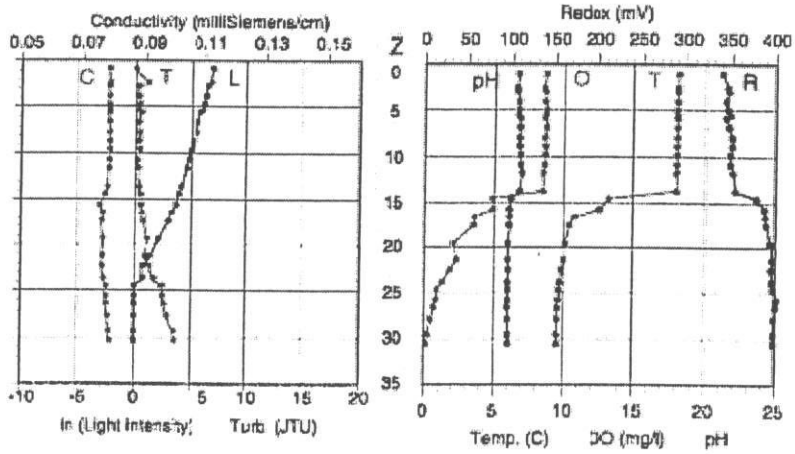
APRIL 19:



JULY 18



SEPT. 17



Resources:

Christensen, R., and B. Rosenthal. 1982. North Florence dunal aquifer study. Lane Council of Governments, Eugene, OR. 153 pp.

Cooper, W. S. 1958. Coastal Sand Dunes of Oregon and Washington. N.Y. Geol. Soc. Am. Memoir 72. New York, NY. 169 pp.}

LONG (RESERVOIR)

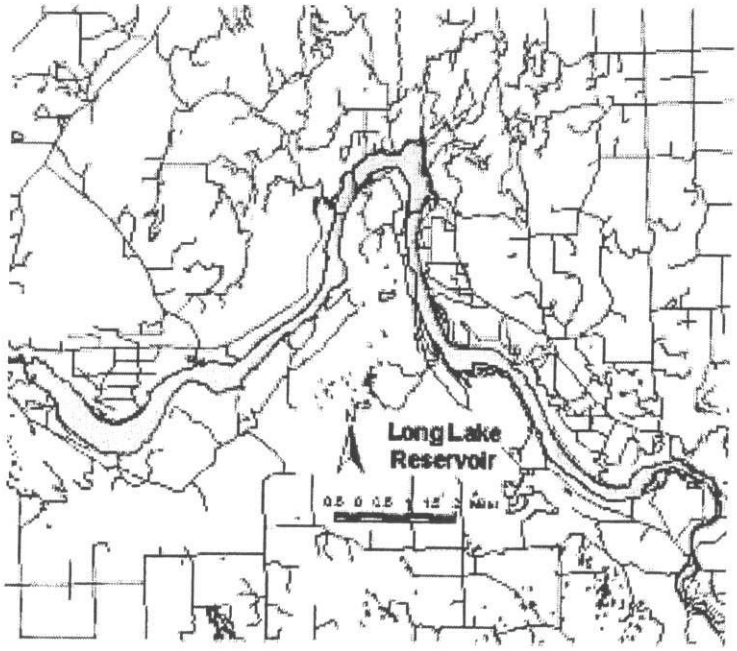
SPOKANE County

Lake ID: LONSP1

Ecoregion: 7

Long Lake is located three miles northwest of the City of Spokane. It is a reservoir of the Spokane River spanning more than twenty miles.

Area (acres)	*Maximum Depth (ft)*	*Mean Depth (ft)*	*Drainage (sq mi)*	
5020	180	49.5		
Volume (ac-ft)	***Shoreline (miles)***	***Altitude (ft abv msl)***	***Latitude***	***Longitude***
243341	53.8	1536	47 46 30.	117 32 30.



Station Information

LONSP1

Primary Station	Station # 1	latitude: 47 49 54.0	longitude: 117 45 46.0
	Description:	Directly across from the DNR Park/campground about four miles from the dam.	
Secondary Station	Station # 3	latitude: 47 51 37.0	longitude: 117 39 57.0
	Description:	About 1 1/2 miles upchannel from Willow Bay Resort, center channel across from an A-frame house.	
Secondary Station	Station # 5	latitude: 47 47 46.0	longitude: 117 34 19.0
	Description:	About 3 miles below Nine Mile Falls, across the channel from Nine Mile Resort.	

Trophic State Assessment for 1999

LONG (RESERVOIR)

Analyst: Sarah O'Neal

TSI_Secchi: [a]	36
TSI_Phos:	46
TSI_Chl:	51
Narrative TSI: [b]	M

Long Lake is a twenty-mile long reservoir of the Spokane River. Trophic state indices varied widely for the lake, each indicating a different trophic state. Water clarity was good, generating an oligotrophic Secchi index. Phosphorus levels were moderate. When the lake was stratified during the second half of the summer, hypolimnetic phosphorus levels were slightly elevated, indicating there may have been some internal nutrient loading. Fortunately, however, hypolimnetic dissolved oxygen levels remained stable during stratification, possibly due to hypolimnion flow through of the Spokane River. Chlorophyll levels were particularly high in Long Lake, consistent with an eutrophic state. However, algae was not reported as a particular problem, and plants were also not excessive. Two non-native, aggressive species were present in the lake: Eurasian watermilfoil (Myriophyllum spicatum) was introduced but not abundant; and a floating leaf plant, yellow floating heart (Nymphoides peltata), which is rare to Washington State, had established and proliferated in the lake. It grew densely wherever habitat was suitable.

While sampling, uses noted included swimming, skiing, and fishing. However, no questionnaires were distributed. WDFW reported a productive warmwater fishery in Long Lake which primarily consisted of large- and smallmouth bass. Other warmwater fish species in the lake included pumpkinseed, yellow perch, and black crappie. A few northern pike also entered the lake from Lake Coeur d' Alene. Long Lake was stocked with 5 - 10,000 brown trout annually. Some rainbow trout also migrated to the lake from the Spokane and Little Spokane Rivers, where they were planted.

The objective for monitoring Long Lake was to support work being conducted by others in 1999. Establishing a nutrient criterion was not an objective. In fact, Long

Lake is the only lake in Washington that has a phosphorus criterion in the Water Quality Standards. Lake Class water quality standards for Long Lake (Chapter 173-201-130 (107a) WAC) state that the average concentrations for total phosphorus in the euphotic zone shall not exceed 25 ug/L from June 1 to October 31. Phosphorus concentrations in 1999 were below this criterion.

Mean Secchi = 5.2m; Mean TP = 18.8 ug/L; Mean Chl = 7.8 ug/L

[a] TSI Qualifiers: B or W-Secchi Disk hit bottow or entered weeds; J-Estimate; N-Fewer than the required number of samples

[b] E=eutrophic, ME=mesoeutrophic, M=mesotrophic, OM=oligomesotrophic, O=oligotrophic

Chemistry Data

LONG (RESERVOIR)

Date	Time	Strata	Tot P (ug/L	Tot N (mg/L)	TN:TP	Chloro-phyll (ug/L)	Fecal Col. Bacteria (#/100mL)	Hardness (mg/L)	Calcium (ug/L)	Turbidity (NTU)
Station 1										
6/14/1999		E	21.5	.273	13	5.8		32.9	8360	2.3
7/12/1999	1415	E	21	.372	18	2.68				1.1
		H	20.1	.514	26					
8/9/1999		E	12.4	.519	42	1.9				.6
		H	23.2	1.16	50					
9/13/1999		E	19.1	.873	46	14.6				.8
		H	43.2	1.3	30					
Station 3										
6/14/1999		E	21.6	.298	14	3.9		33.7	8530	2.9
7/12/1999	1215	E	20	.726	36	5.71				2.3
8/9/1999		E	14	.577	41	6.7				1.5
		H	30.8	1.27	41					
9/13/1999		E	24.9	.77	31	4.5				1.5
		H	27.2	1.09	40					

Strata: L=lake surface, E=epilimnion, H=hypolimnion; Qualifier: J=Estimate, U=Less than, G=Greater than.

Aquatic Plant Data

LONG (RESERVOIR)

Sampler: Parsons, O'Neal

Survey Date: 8/31/1999

Max depth of growth (M): 6

Comments Cold, breeze. Alkalinity reading slightly off. Dense plant growth on sandbar across from

Nine Mile Resort, about 2 meters deep. Water clarity and depth of plant growth greater at lower (west) end. Eurasian milfoil found at lower end, none at upper end. Didn't inventory the middle part of the reservoir. Many Osprey.

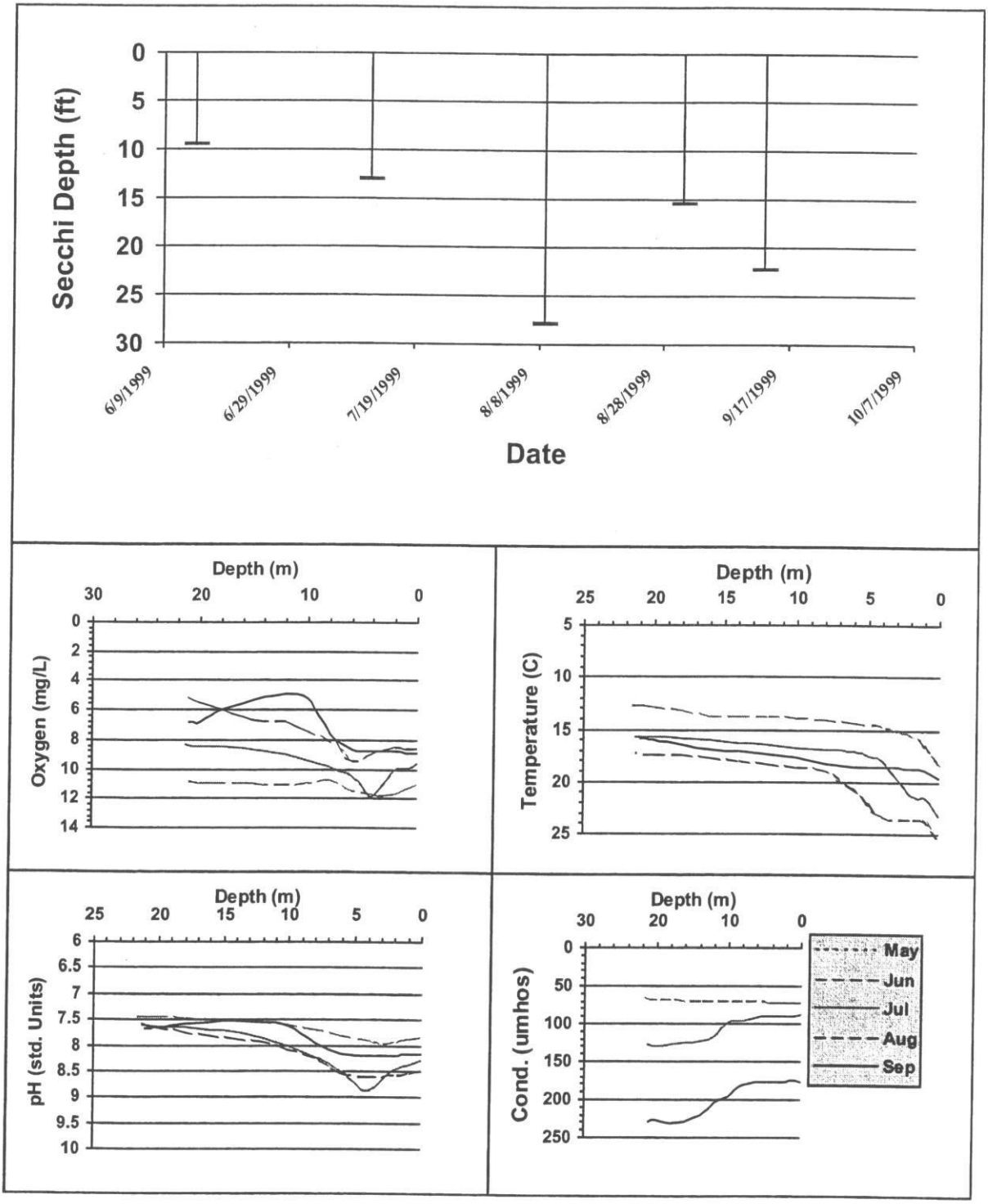
SPECIES LIST

Scientific Name	Common Name	Dist [a]	Comments
Ceratophyllum demersum	Coontail; hornwort	2	
Elodea canadensis	common elodea	3	
Iris pseudacorus	yellow flag	2	
Lythrum salicaria	purple loosestrife	2	at upper end
Myriophyllum spicatum	Eurasian water-milfoil	2	at lower end
Najas flexilis	common naiad	3	
Nitella sp.	stonewort	1	at lower end
Nymphoides peltata	water fringe	4	dominates in suitable habitat
Potamogeton crispus	curly leaf pondweed	2	
Potamogeton pectinatus	sago pondweed	2	
Potamogeton richardsonii	Richardson's pondweed	2	
Potamogeton sp (thin leaved)	thin leaved pondweed	3	
Potamogeton zosteriformis	eel-grass pondweed	1	
unknown plant	unknown	1	looked terrestrial
Vallisneria americana	water celery	2	at lower end

[a] 0 - value not recorded (plant may not be submersed)
1 - few plants in only 1 or a few locations
2 - few plants, but with a wide patchy distribution
3 - plants in large patches, codominant with other plants
4 - plants in nearly monospecific patches, dominant
5 - thick growth covering substrate to exclusion of other species

Secchi Depth and Profile Graphics

Station: 1 LONSP1



Secchi Data and Field Observations

LONG (RESERVOIR)

Date	Time	Temp-erature (F)	Secchi (ft)	Color (1-greens, 11-browns	Bright-ness (pct)	Wind (1-none, 5-gusty)	Rainfall (0-none, 5-heavy)	Aesthetics (1-bad, 5-good)	Swimming (1-poor, 5-good)	Geese (#)	Waterfowl (besides geese #)	Boats-Fishing (#)	Boats-Skiing (#)
Station 1													
6/14/1999			9.5	2	20	2	1	4	4	0	5	0	4
	Sampler: HALLOCK			Remarks:	Bottom: 21.4M. Site 1 is mid-channel directly out from DNR campground access. Lake not stratified. Dissolved oxygen measurement is qualified as an estimate due to calibration failing QA/QC requirements.								
7/12/1999			13.1	6	0	1	1	4	4	0		1	2
	Sampler: HALLOCK			Remarks:	Bottom: 21.3M. Lots of kids swimming at DNR park. Quite a bit of debris on surface. Dissolved oxygen measurement qualified as an estimate due to calibration failing QA/QC requirements.								
8/9/1999			27.9	1.5	10	1	1	5	5				
	Sampler: HALLOCK			Remarks:	Bottom: 21.3M. Dissolved oxygen measurement qualified as an estimate due to calibration failing QA/QC requirements.								
8/31/1999			15.42										
	Sampler: Parsons			Remarks:									
9/13/1999			22.3	2	10	1	1	4	4	0	0	0	0
	Sampler: HALLOCK			Remarks:	Bottom 21.0M. Lots of dead adult midges on surface.								
Station 3													
6/14/1999			8.2	2	20	2	1	4	4	0	0	0	2
	Sampler: HALLOCK			Remarks:	Bottom: 15.4M. Access is via launch at Willow Bay Resort. Go upstream about 1 mile to just before lake widens out (adjacent from an A-frame on N. bank). Lake not stratified. Dissolved oxygen measurement qualified as an estimate due to postcalibration failing QA/QC requirements.								
7/12/1999			12.1	6	0	1	1	4	4	5	1	0	0
	Sampler: HALLOCK			Remarks:	Bottom 14.8M. Debris on surface. All boats were in transit. "Other" waterfowl was an osprey. Not stratified. Dissolved oxygen measurement qualified as an estimate due to calibration failing QA/QC requirements.								
8/9/1999			18	6	10	2	1	5	5	0	8	1	1
	Sampler: HALLOCK			Remarks:	Bottom: 16.8M. Dissolved oxygen measurement qualified as an estimate due to calibration failing QA/QC requirements.								
9/13/1999			13.8	2	0	2	1	4	4	25	50	3	0
	Sampler: HALLOCK			Remarks:	Bottom: 16.8. Collected discrete TP OP and chl samples at 3M intervals for Jim Carroll at this station.								
Station 5													
8/9/1999			10.5	2	10	2	1						
	Sampler: HALLOCK			Remarks:	Bottom at 3.7M. Sampled here for Jim Carroll. Site is directly out from Nine Mile Resort near far bank, but just short of main channel. Abundant weeds in the area. Dissolved oxygen measurement qualified as an estimate due to calibration failing QA/QC requirements.								