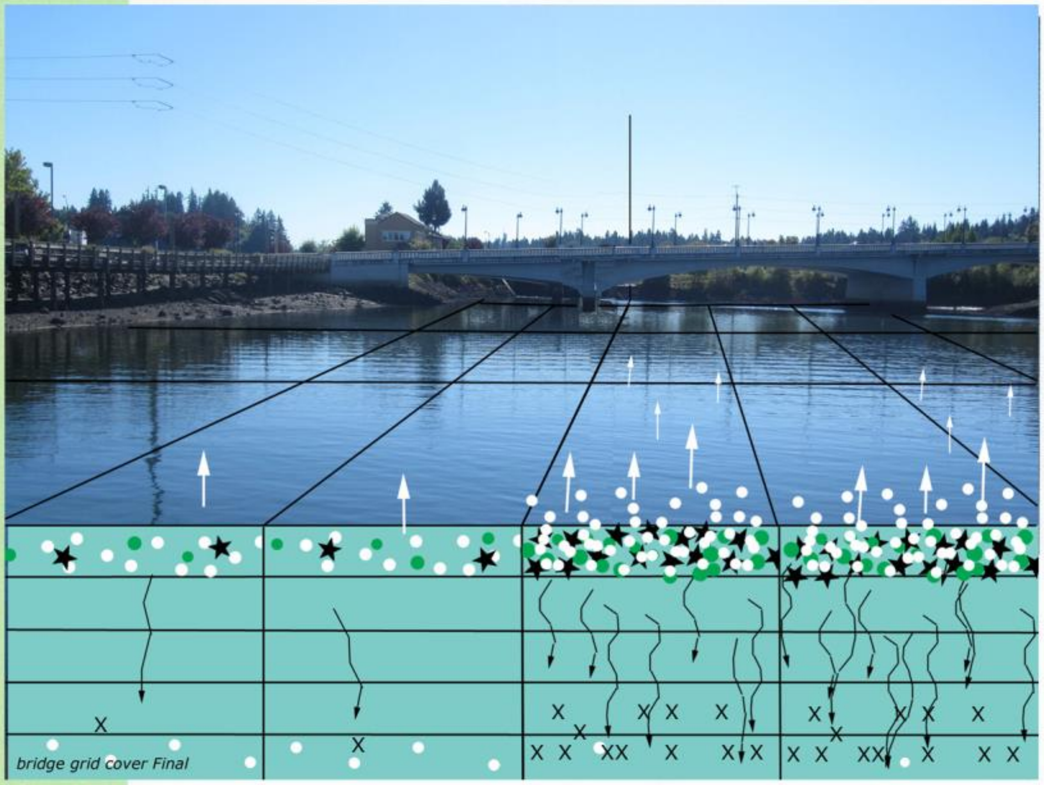

The Washington Department of Ecology's

Deschutes River, Capitol Lake, and Budd Inlet Total Maximum Daily Load Study

Supplemental Modeling Scenarios

This is NOT a Department of Ecology Report.

This Report Defends Capitol Lake.

A Critical Review

by
David H. Milne PhD
TESC Faculty (Retired)
July 2018

Cover Illustration.

“Computer’s Eye View” of the Fourth Avenue Bridge and the Fifth Avenue dam separating Capitol Lake and Budd Inlet. Olympia, Washington.

Estuary Scenario (right of center). High nutrient levels, huge phytoplankton growth and oxygen production at the surface, sinking of organic carbon and high oxygen depletion at the bottom.

Lake Scenario (left of center). Low nutrient levels, modest phytoplankton growth and oxygen production at the surface, lesser sinking of organic matter and low oxygen depletion at the bottom.

The Department of Ecology's

Deschutes River, Capitol Lake, and Budd Inlet.
Total Maximum Daily Load Study.

Supplemental Modeling Scenarios.

September 15, 2015

Publication No. 15-03-002

A
Critical Review

by

David H. Milne
TESC Faculty (Retired)

July, 2018.

The Department of Ecology's
Supplemental Modeling Scenarios Report.

A Critical Review.

David H. Milne PhD
July, 2018

EXECUTIVE SUMMARY.

The Washington Department of Ecology's Report, "Supplementary Modeling Scenarios" purports to demonstrate that Capitol Lake's effect on Puget Sound lowers the dissolved oxygen content of Sound waters and is responsible for violations of water quality standards there. The Report presents outputs of a complex computer simulation, the "Budd Inlet Model," that are said to support the authors' claims. That is not the case. In fact, errors and shortcomings aside, data in the Report, not acknowledged by its authors, support the view that *Capitol Lake's effects on Puget Sound are actually beneficial.*

The following problems with the Report are noted. (There are others, too many for a single page summary.)

1) Water Quality standards violations in Capitol Lake itself were vastly (and incorrectly) overestimated;

2) The calculations of Total Organic Carbon (from plant growth) entering the Sound from the Lake or Estuary scenarios overstate the amount of TOC in the Lake case and understate it in the Estuary case;

3) An inappropriate technique was used to calculate East Bay water residence times;

4) The authors mistakenly assume that Capitol Lake's ecology is phosphorus limited and base many pages of irrelevant discussion and calculation on that assumption;

5) The Budd Inlet model produces many demonstrably wrong answers where compared with observed data; yet the authors consider every dissolved oxygen calculation accurate to within 0.01 mg/L;

6) Answers derived from the authors' method of finding water quality standards "violations" (based on calculated unknown/unknowable conditions in hypothesized pre-modern waters) are not subject to independent confirmation or refutation (not testable) by scientists elsewhere;

7) The authors' hypothesis of how organic carbon created by plants in the Lake enter and affect Budd Inlet is not ecologically realistic and, contrary to their claim, is not testable by the Budd Inlet model;

8) A Figure showing water quality violations in the hypothesized pre-modern (pre-dam) estuary is formatted in a way that makes it impossible to judge the extent of the violations; proper formatting shows that violations are as widespread in that "natural" water (and comparable in size) as they are today with Capitol Lake present;

9) *A "benthic algae photosynthesis" subroutine failed to show high bottom water oxygen on a day when observations demonstrated this at the critical East Bay cell used as the focus of all simulations – a malfunction that calls into question all of Ecology's assertions about dissolved oxygen levels in shallow water;*

10) The authors avoided simulating the effect on the Lake/Inlet interaction that would result from a program of harvesting Lake plants, an option that would almost certainly improve Inlet water quality;

11) *Low dissolved oxygen levels calculated for the "critical cell" in East Bay are mistakenly attributed to Capitol Lake. They are, instead, almost certainly caused by the immense nitrogen load from the External source;*

12) Figures included from other sources, said to bolster the authors' claim, actually show the opposite; beneficial removal by Capitol Lake of nutrient nitrogen from Deschutes River water.

No public policy decisions should be based on the contents of the Supplemental Modeling Report.

The Department of Ecology's Supplemental Modeling Report.
A Critical Review.

By David H. Milne, PhD.
Faculty, TESC (ret.)
July, 2018.

Outline.

1. BACKGROUND: ESTUARIES AND DISSOLVED OXYGEN.

2. GOOD SIMULATION, MISTAKEN INTERPRETATIONS.

3. THE COMPUTER GETS MANY WRONG ANSWERS.

4. THE BUDD INLET ESTUARY; "NATURAL" AND MODERN.

5. ECOLOGY'S BUDD INLET SIMULATIONS: FLAWED SCIENCE.

6. ECOLOGY'S CENTRAL CLAIM: "THE DAM DEPLETES OXYGEN." WRONG.

The Department of Ecology's Supplemental Modeling Report.
A Critical Review.

List of Figures.

CHAPTER 1. BACKGROUND: ESTUARIES AND DISSOLVED OXYGEN.

CHAPTER 2. GOOD SIMULATION, MISTAKEN INTERPRETATIONS.

CHAPTER 3. THE COMPUTER GETS MANY WRONG ANSWERS.

CHAPTER 6. ECOLOGY'S CENTRAL CLAIM: "THE DAM DEPLETES OXYGEN." WRONG.

CHAPTER 7. ORGANIC CARBON CLAIMS: MISLEADING, MISTAKEN, NOT CREDIBLE.

CHAPTER 8. THE LATE-SEASON DEPARTURE OF ORGANIC CARBON.

CHAPTER 9. CAPITOL LAKE: ERRORS AND FALSE CLAIMS.

CHAPTER 10. LOW DISSOLVED OXYGEN IN NATURAL ESTUARIES.

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List of Tables.

Acknowledgements

My profoundest thanks for assistance, review, and encouragement with this project go to the following persons. Our discussions and their suggestions have guided and steered the reporting that follows. If any positive outcome for the whole Olympia-area community is the result, they helped make it happen.

John DeMeyer

Burt Guttman

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Jack Havens

Kaye V. Ladd

Dom Reale

Anonymous WDOE Source #1

Anonymous WDOE Source #2

Lois Wofford

Bob Wubbena

I also extend my heartfelt thanks to my dear wife Dee, without whose support and encouragement during the difficult years in which I researched this material and wrote about it I could not have completed it.

The Department of Ecology's Supplemental Modeling Report.
A Critical Review.

1. BACKGROUND: ESTUARIES AND DISSOLVED OXYGEN.

1-1. Introduction.

Our Budd Inlet harbor is a dynamic moving body of marine water whose inner workings are largely out of sight and remote from our usual daily preoccupations. The obvious daily back and forth tidal flows of its waters, driven by the moon and sun, hide a second powerful flow that is not at all obvious, this one driven by the Deschutes River. It is that flow, called the "estuarine circulation," that dominates Budd Inlet's ecology and well-being. Recognizing and understanding that flow is the key to understanding – and preserving – the health of Budd Inlet and indeed all other estuaries as well.

1-2. The Estuarine Circulation; Giant Unseen Flows.

Figure 1-1 (next page) shows the giant-scale pattern of water movements typical of all temperate-latitude estuaries as applied to Puget Sound. Deep water from the Pacific Ocean enters the Strait of Juan de Fuca and ultimately Puget Sound and moves landward (Fig. 1-1a). At the same time, an enormous current flows outward at the surface.[1] The two currents mix to some extent – some deep water stirring upward and some surface water stirring downward as the waters flow over and under each other. The ocean flow stays at the bottom because the cold salty water is "heavier" (technically, "denser") than the fresh and usually warmer water from the rivers. The incoming bottom water eventually "bumps up against" incoming fresh water from a river or stream (Fig. 1-1d) and mixes with it for the return journey back to the ocean. Because of this gigantic unseen bottom-water flow from the ocean, ultimately mixing and colliding with the fresh water from rivers, Olympia Harbor waters are not fresh; their salt content is fully 85% as high as that of the ocean itself, even though the ocean is some 200 miles away from the Port.

The surface and bottom flows are created *and driven* by the fresh water entering Puget Sound from creeks and rivers. The water "piling up" at the river mouths "runs downhill" toward the ocean, dragging some of the incoming salt water with it.

The sizes of the flows are astonishing. My students and I often calculated the size of the surface flow in Budd Inlet and regularly found it to be some 20 times larger than the Deschutes River that drives it. The Department of Ecology estimates that the outgoing surface flow can be ten times larger than the Deschutes River by the time that flow passes

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[1] Estuaries in desert climates have the reverse pattern – bottom flow out, surface flow in – driven by evaporation, not river flow.

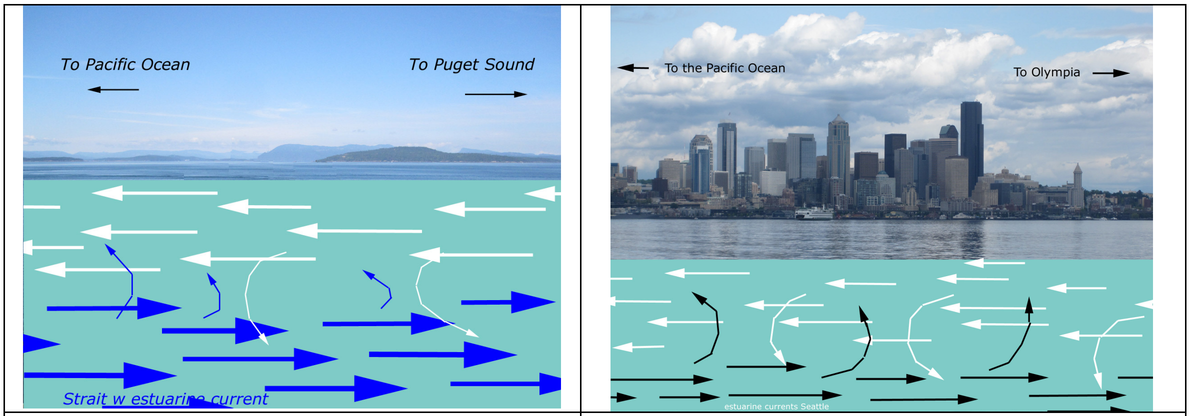

Figure 1-1a. Entry to the Strait of Juan de Fuca of deep water from the Pacific ocean, exit of surface water from regional rivers. Vertical arrows show mixing of the bottom and surface flows.

Figure 1-1b. The incoming and outgoing estuarine circulation currents with mixing as they might appear off Seattle.

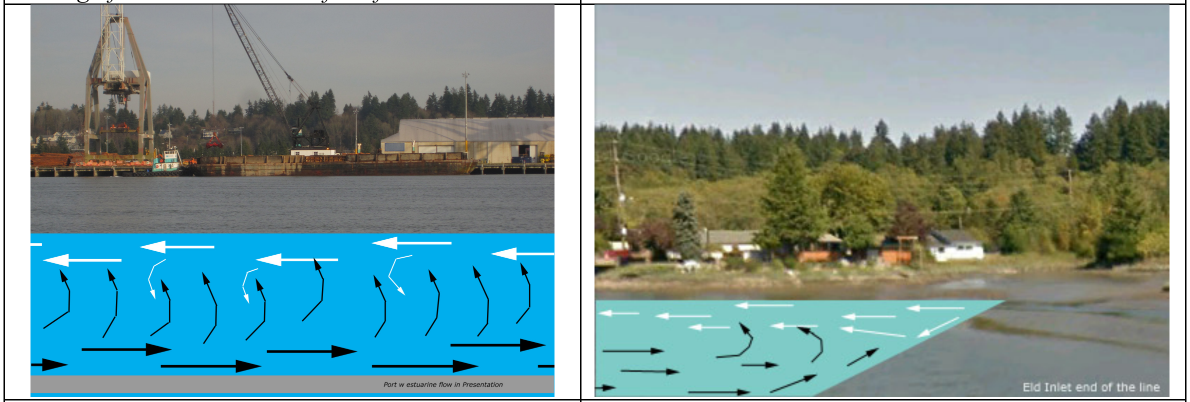

Figure 1-1c. The incoming and outgoing estuarine circulation currents as they might appear in Olympia Harbor.

Figure 1-1d. "End of the line" for all incoming estuarine bottom currents; a collision with incoming fresh water.

FIGURE 1-1. THE ESTUARINE CIRCULATION TYPICAL OF TEMPERATE ESTUARIES.

Priest Point and 50 times larger than the river by the time it exits Budd Inlet at Boston Harbor (TMDL Appendix G p. 49). The bottom flow is very nearly as large as the surface flow.

The tides have nothing to do with this "estuarine circulation" flow pattern. Their only effect is to slosh the whole body of water inward, then outward twice a day, hiding the slower movement of the non-stop estuarine currents from easy view and detection. In fresh waters that have no tides at all (for example, Lake Erie), the same estuarine circulation pattern can be detected where rivers enter the larger water body (Herdendorf, 1990).[2]

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[2] In fresh waters uncomplicated by salt content, the directions of flow of the bottom and surface currents depend upon whether the river water is colder or warmer than the lake water.

1-3. Oxygen Depletion in Estuaries.

All of the preceding is essential background for understanding oxygen depletion in estuaries.

Why focus on oxygen depletion? When we say “water quality is impaired,” we almost always mean “there are low oxygen levels in the water.” Low oxygen levels are by far the most common reason for distress among aquatic organisms, all of which need it for their respiration. “Pollution,” the presence of some chemical substance harmful to marine life in the water, is something else that may be locally very harmful, but low oxygen levels are by far more widespread than pollution. *For that reason, a computer model at the Department of Ecology – the “Budd Inlet Model” – focuses almost entirely on calculating the effects on dissolved oxygen of natural and human-sourced nutrients in the water.*

Low oxygen levels occur naturally in almost all estuaries. We can’t prevent their occurrences entirely, but we *can* prevent them from growing worse.

The next subsections address this.

1-3a. The Oxygen Story in Puget Sound.

A giant initial charge of dissolved oxygen starts toward Olympia in the bottom water entering from the Pacific Ocean (Fig. 1-1a). As the water carrying the oxygen moves landward, it is subject to a rain of organic debris from the surface that settles to the bottom, decomposes, and uses up oxygen. Much of this debris is from natural sources – living and dead phytoplankton, fecal pellets from grazing zooplankton, fragments of organisms large and small eaten by predators, leaf litter and organic material from land carried by streams, and the like. The oxygen-consuming decay is caused by bacteria. *Bacteria can use up as much oxygen as all of the more obvious large marine organisms combined*.

The normal respiration of familiar bottom-dwelling organisms -- clams, worms, crustaceans, sea cucumbers, fish, sea stars and the like –uses up oxygen. In addition, some oxygen is consumed by products of human activities – treated wastewater and phytoplankton growth caused by fertilizers, for example.

There is usually no opportunity for oxygen to be restored to the deep water. Along most of the deep dark bottom of Puget Sound, there is not enough light for plant photosynthesis to balance the respiratory/decay losses. Thus the overall effect of processes near the bottom is to deplete the bottom waters of oxygen more and more as they move farther inland.

Puget Sound is fortunate in having two locations where some of the oxygen lost from the bottom water is restored – Admiralty Inlet (between Whidbey Island and the Kitsap Peninsula) and the Tacoma Narrows. There the channel depths become shallow. Puget

Sound's large tides heave the bottom currents up to the surface where they are forced over these shallow "sills," churning and stirring the water and partially re-aerating it by contact with surface water and air before allowing it to settle back into the deep basins of the Central and South Sound (Strickland, 1983). The result is that "our" bottom water at Olympia is somewhat fresher and higher in oxygen content than it would be if the sills were absent.

Two features of every estuary work to deplete its bottom-water dissolved oxygen as that water approaches the head of the estuary. They are 1) seasonal depletion of DO in the main body of water arising from several factors and 2) the "null zone" at the head of every estuary, operating year-round. The following subsections describe these actions.

1-3b. Oxygen Depletion; Seasonal Factors.

Seasonal decline of oxygen in the bottom waters usually involves large sectors of estuaries. Several factors all converge to create the seasonal low DO conditions.

First, the incoming bottom current bearing replenishment oxygen slows down and shrinks in size in summer. The reason for this slowdown and shrinkage is the very reduced summer flows of the rivers that drive the whole estuarine current system. Figure 1-2 shows year-long flow records of Budd Inlet's Deschutes River at summer-long lows for 1996, 1997, 2002, and 2014, marginally lowest in September with recovery beginning in October.

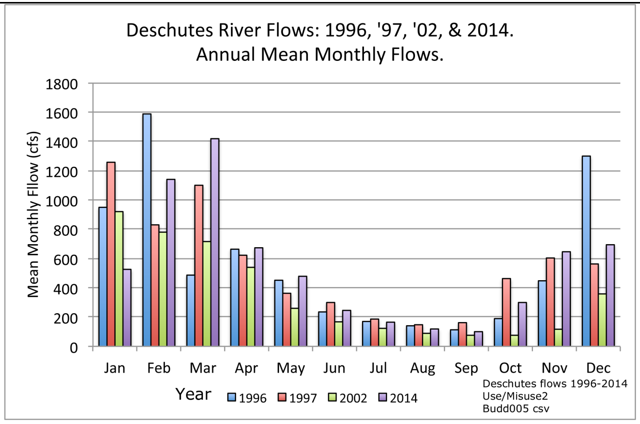

Figure 1-2. Annual flows of the Deschutes River (Olympia Washington) for 1996, 1997, 2002, and 2014. Source: USGS Water Resources site <waterdata.usgs.gov>.

The BISS (1998) study reports that "residence time" of water in Budd Inlet increases from about 8 days in winter to about 12 days in summer – a consequence of the lower flow of the river and the resulting lower flow of the estuarine bottom current.[3]

High temperatures are another driving force for oxygen depletion in summers. Warmer water "holds" less oxygen than does colder water. Worsening matters, the metabolisms of all marine organisms and bacteria "speed up" in warmer water. The organisms need and use more oxygen at a time when the water can't carry as much.

In September the sun is still high enough in the sky to drive exuberant photosynthesis by phytoplankton and algae, which creates an enormous amount of new oxygen. This, however, usually occurs in the uppermost few meters of water where sunlight is abundant.

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[3] BISS = Budd Inlet Scientific Study, conducted 1996-1997. That study is described in detail in Chapter 2.

Much of the new oxygen escapes from the water into the air, the rest is not able to easily make its way to the bottom, and the stepped up biological activity results in the sinking of more oxygen-consuming organic matter. At the bottom, where the waters are at their seasonal warmest, accelerated oxygen depletion is the result.[4] This can occur over large stretches of an estuary.

Figure 1-3 compares dissolved oxygen (DO) levels at the entrance to East Bay (Olympia Harbor) during a low-oxygen September episode and a typical "recovery" episode in October.[5] Each graph shows the DO level from the surface (leftmost bar, each group) to the bottom (rightmost bar, each group) by one-meter intervals.[6] The red line shows the DO Water Quality Standard at that site (= 5.0 mg/L). The bottom depths differ between the two graphs because of different tide stages on the dates of sampling.

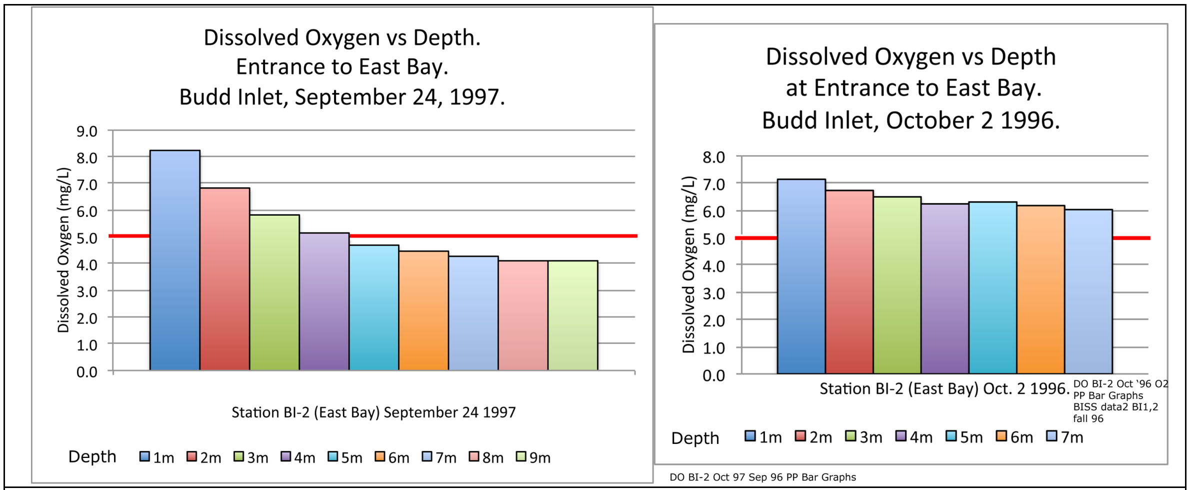

Figure 1-3. Dissolved Oxygen Levels vs. Depth for a site at the entrance to East Bay (BISS Site BI-2) during September 1997 and October 1996. Red line at 5.0 mg/L shows the DO water quality standard at that site. Source: BISS 1998 Spreadsheet.

The bottom water in September (at 9 meters) contains much less dissolved oxygen, ~ 4.0 mg/L, than in October ~ 6.0 mg/L. At the surface, the September water contains more dissolved oxygen (8.0+ mg/L) than does the October water (7.0 mg/L). Water deeper than 4 meters violates the DO Standard for this location in September; water at all depths is higher in DO than the Standard in October. These differences and changes are due mainly to stepped-up bottom circulation in October, warmer water in September, and (to

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[4] There can be dramatic and not-uncommon exceptions to this rule. DO at the bottom can be higher than at the surface. See Chapter 5 where an example is analyzed in detail.

[5] The September episode was during 1997, the October episode was during 1996. Data from September 10 1996 are available and could have been used. The pattern is similar to that of Sept. 1997, however the tide was low on the 1996 date and only a few meters of water were available for sampling. The Sept. 1997 example provides a better illustration of the late summer situation in deeper water.

[6] The bar graph formats presented here are for the benefit of non-scientific readers. For aquatic ecologists, they are the equivalent of "vertical profiles" if rotated 90 degrees to the right.

a small extent) more phytoplankton photosynthesis during the longer, brighter September days.

1-3c. Oxygen Depletion; The Estuarine Null Zone.

The “null zone” is a low-oxygen pocket – or whole region -- that forms where the incoming bottom current collides with incoming fresh water at the head of an estuary. Two processes cooperate to form and concentrate organic carbon (and silt) particles in this zone. These are colloid formation and sediment transport, described below.

The key to understanding this situation is shown in Figure 1-4.

Between the outgoing and incoming estuarine circulation currents is a depth at which there is no net horizontal motion (Fig. 1-4a). There, no water moves landward or seaward. (Vertical motions of water through this interface are routine and common.) At the end of the estuary where the incoming salt water finally collides “head on,” so to speak, with the incoming fresh water stream, the bottom current stops and turns upward. Here the “depth of no net horizontal motion” touches bottom. The point where the last of the bottom current stops and turns upward is the “null zone” (Fig. 1-4b).

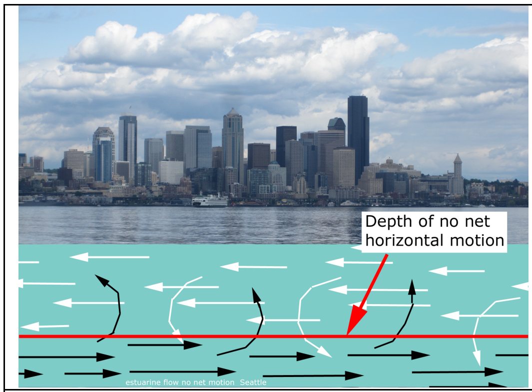

Figure 1-4a. Depth of no net horizontal motion at the interface between the incoming and outgoing estuarine circulation currents. (Extends the entire length of the estuary.)

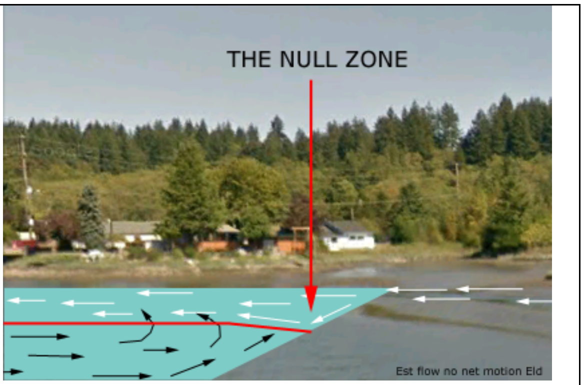

Figure 1-4b. The Null Zone: where the depth of no net horizontal motion touches the bottom at the head of the estuary.

At the landward end of the estuary, the null zone doesn’t stay in the same place for long. Each flooding tide moves it landward, then the next ebbing tide moves it back seaward. The null zone effect on oxygen is distributed over the whole area where it sweeps back and forth.

Two processes concentrate organic carbon particles in the null zone. First, the collision of fresh- and salt-waters prompts chemical and physical changes in organic molecules and tiny particles carried both by the stream and the marine bottom current. These changes cause the particles to “clump,” forming larger particles (“colloids”) that become concentrated in the area where they form. There they decompose, using up dissolved oxygen. Second, where the horizontal movement of bottom water stops (where the depth of no net horizontal motion touches bottom, Fig. 1-4b), small sediment and carbonaceous particles being swept along the bottom settle and accumulate. Both processes cause particles to accumulate in the null zone.

As a result of concentration of suspended particles there, the null zone can be found by measuring water turbidity along the length of an estuary. A marked "turbidity maximum" (Dyer, 1986) occurs where the zone is located.

Mann (1982, p. 231) gives an excellent account of both colloid formation and bottom sediment transport processes around the null zone, using Belgium's Scheldt River Estuary as an example.[7] The estuary has huge tides at its entrance (range ~ 6.5 meters) and is located in low flat country. There the turbidity maximum is centered at about 80 kilometers inland and the sweep of the tides moves it back and forth perhaps 20 km upstream and downstream in each direction from that central location.

Dyer's (1986) description of null zone phenomena focuses on the physical processes of sediment transport in estuaries, with an extended discussion of the formation and movements of the turbidity maximum.

Ecology's computer simulations focus on the effects of nitrogen nutrients on Budd Inlet. *No mention of the null zone is ever made*. The importance of this never-mentioned feature of estuaries is this; the bottom currents in an accurate hydrodynamic model (which the Budd Inlet model is) would create a turbidity maximum at the head of an estuary even if the model's creators didn't explicitly design it with null zones in mind.

Colloid formation is another matter. That is a special physical-chemical process unique to the heads of estuaries that would need to be specifically built into the model by its creators. I don't know whether the Aura Nova consultants who created the model included that or not. But the sediment transport feature of a hydrodynamic model would be enough, by itself, to create a null zone turbidity maximum.

These carbon-concentrating processes with their oxygen-depletion capabilities are totally independent of the presence or absence of nitrogen nutrients. Some of the organic carbon accumulating at the head of each estuary arrives in part from particles of land origin – leaf litter and the like. Unless one watches and tests for its effects, low oxygen seemingly created by nitrogen-fed marine plant growth and decay may actually be due to a null zone effect.

1-4. Reading the Oxygen Record.

Each year observers from the Department of Ecology measure the oxygen concentrations at depths ranging from the water surface to the bottom at locations (= "stations") all

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[7] Mann does not use the term "null zone." Dyer uses the term "null point" for the location where the depth of no net motion touches bottom. I recall that "null zone" was widely used when I began teaching in the 1970's but it seems to have fallen out of common usage.

around South Puget Sound. There are two stations in Budd Inlet; one opposite the Port Dock, the other near the Olympia Shoal (Figure 1-5).

Figure 1-5. Stations sampled yearly for measurements of dissolved oxygen and other water properties by the Department of Ecology. Source: Ecology Ambient Monitoring Program 2018.

On September 23, year 2002, the measurements opposite the Port dock showed many low dissolved oxygen (DO) levels. These and readings made on the same day at the Olympia Shoal station are shown in Figure 1-6. At the Oly Shoal, surface and bottom DO levels were about 12 and 5 mg/L; at the Port station they were lower at about 6 and 4 mg/L, respectively. (The leftmost bar shows the surface reading, the rightmost bar shows the bottom reading respectively in each group.)

At first glance, the much lower DO's across from the Port suggest that something in the water opposite is aggressively using up oxygen -- some pollutant, perhaps from Olympia? Or something from Capitol Lake?

NO. There is a different reason for the low DO's at the Port. A standard way of finding that reason is shown in the following.

1-4a. DO Saturation: Key to Understanding Water Quality.

When surface water has"soaked up" as much oxygen from the air as it can hold, the water is said to be "100% saturated." Its oxygen content will remain exactly at that 100% level for as long as it is in contact with the air and no other process (plant photosynthesis or animal/bacteria respiration) acts to change it. The amount of oxygen that water can hold at its saturation level is greater if the water is colder and less if the water is salty. Thus fresh water at saturation will always hold more oxygen than O2-saturated salt water at the

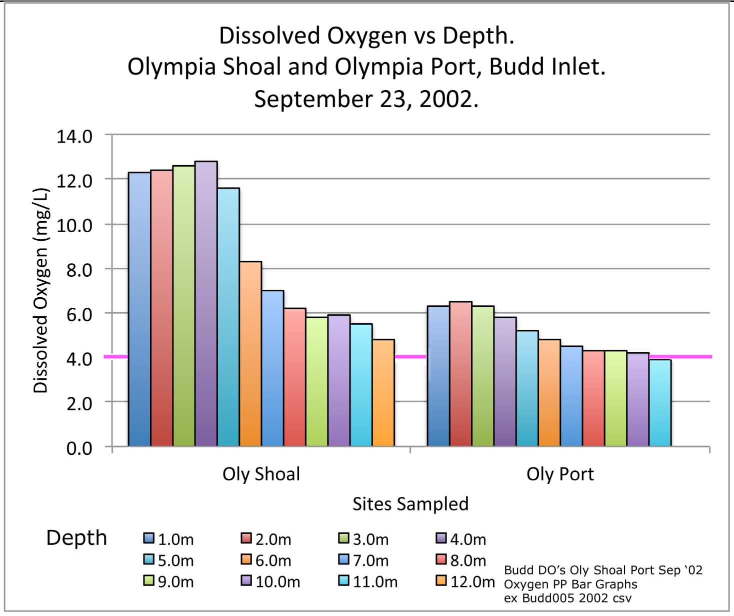

Figure 1-6. Dissolved Oxygen vs. Depth at Ecology stations BUDD 005 and BUDD 002 (see Fig. 1-5.) Source: Ecology Ambient Monitoring Program, 2018.

same temperature. Aside from that easy rule, one must always calculate water's saturation level from tables or computer programs, using the measured temperature and salinity of the water.[8]

Left standing in air with no changes in temperature or salinity, the concentration of oxygen in the water will remain unchanged at the saturation level. If the growth of plants in the water creates new oxygen, the DO level will rise *above* the saturation level. That situation will last only so long as the plants continue to add oxygen. The extra oxygen immediately begins to escape from the water by diffusing into the air. The plants can add new oxygen faster than this diffusive escape can remove it, but once their growth stops, the water spontaneously returns to its 100% saturation level. The escape of the excess oxygen and return to equilibrium (100% saturation) is usually complete by about two or three days after plant growth stops.

In the opposite direction, consumption of oxygen in the surface water by some means or other can lower its oxygen content below the 100% level. In such cases, oxygen diffuses back into the water from the air and restores the 100% level as soon as the consumptive processes stop.

Water with a DO level measured at higher than 100% is said to be "supersaturated." That is a sure sign that plants and/or phytoplankton have been growing profusely and liberating excess oxygen. If the DO level is measured at lower than 100%, it is said to be "undersaturated." That is a sign that something – usually bacteria and aquatic organisms – is removing oxygen from the water by respiration. Plant growth can only take place at the sunlit surface – respiration is usually most powerful in the dark water at the bottom where respiring organisms are concentrated. Because the bottom water has no contact with the air, undersaturation remains unchanged there for long periods of time.

The "pain" of this long explanation gives us the "gain" of being able to interpret dissolved oxygen patterns like those in Figure 1-6 above. At each of the two stations shown, the highest DO levels are at the surface (or just beneath it at shallow sunlit depths). That is because of phytoplankton growth there. The lowest DO levels are at the bottom, where respiring bacteria and marine organisms are concentrated. That's as expected.[9] But those Figures don't show us the 100% DO levels at those stations. The percent saturation levels are shown in Figure 1-7 below.

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[8] An example of using a computer calculation (on line at a USGS website) is shown in Chapter 9. Another method (for fresh water only) is also shown there.

[9] In fact high DO at the surface, low DO at the bottom is the standard pattern to always be expected in aquatic DO measurements. Watch for it throughout this entire document. There is just one instance (described in Chapter 5) where the pattern is completely reversed … for reasons explained in that example.

1-4b. Bottom Water Rising in Olympia Harbor.

Figure 1-7 shows that *the surface water opposite the Olympia Port dock is undersaturated in dissolved oxygen*. At the very surface (leftmost bar, Oly Port figure) the water contains only about 80% as much oxygen as it would normally acquire by standing in contact with air (that is, 100% saturation shown by the blue line). *That should not be the case*; surface water in summers is supersaturated almost everywhere thanks to the photosynthesis of phytoplankton cells. In fact, *undersaturation of surface water is conclusive evidence that bottom water is rising to the surface at that location*.

Figure 1-1c shows this rising water process in action. As the giant bottom current from Puget Sound beyond Budd Inlet enters the Port area, it brings with it the low DO levels that it acquired during its long passage along the bottom. That bottom water is undersaturated. As it continually mixes upward into the outgoing surface current, and especially when it collides with the incoming fresh water at the end of the estuary and is forced to the surface, it lowers the average DO level at the surface.

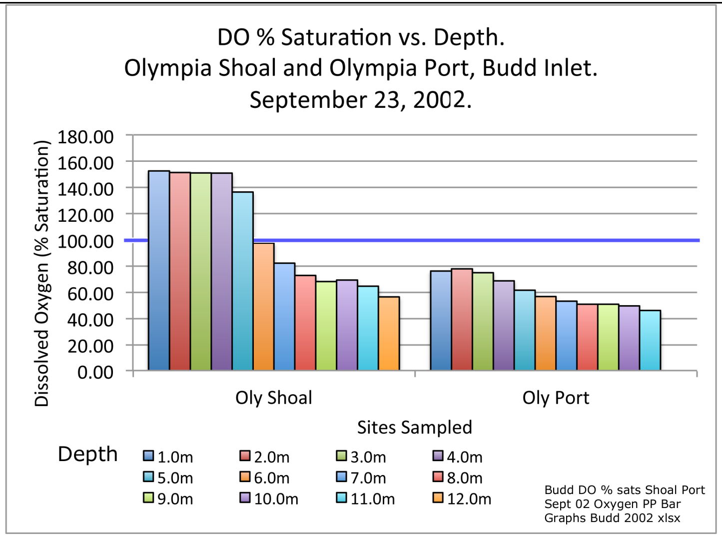

Figure 1-7. Percent oxygen saturation of Budd Inlet waters at two locations, September 23 2002. Blue line shows the 100% saturation level. DO data from Ecology Ambient Monitoring Program, % saturations calculated from USGS DOTABLES (on line) tool.

What about the situation at the Oly Shoal sample site? At that location (north of the Port and "downstream" from it in the outgoing surface flow), the surface water is supersaturated with oxygen. Indeed the surface at that site (leftmost bar) is at about 150% saturation, containing half again as much oxygen as the water would acquire by itself by simply standing in contact with the air.

The extra oxygen at the Oly Shoal surface was added by phytoplankton growth. The plant cells are living in water that rose to the surface, undersaturated in DO, a few days earlier at the Port site and beyond. In the time it has taken for that surface water to drift out to the Oly Shoal, photosynthesis (with some initial uptake of oxygen from the air) has driven the surface oxygen to supersaturation levels.

Someone taking oxygen measurements at the Oly Port station would immediately see that DO levels were very low there and might conclude that those low DO's are caused by something in the water right there at the Port. That would be mistaken. The low DO's were *mostly* already there in water that was carried into the Port area in the bottom current from outside Budd Inlet.[10]

1-5. What's Driving Low September Dissolved Oxygen Levels in Budd Inlet?

The answer to this question is "nitrogen nutrients." In the water, they are taken up by phytoplankton cells, which use them for growth and multiplication. The new plant matter sinks and decays. As mentioned above, all new oxygen is created by plants at the sunlit surface of the water, where most of it escapes into the air as the water returns to its saturation level. Decay is at the bottom, where oxygen is consumed and depleted. The vast flush of new oxygen that the nutrients make possible doesn't help the estuary ecosystem very much, but the decay that follows that flush – the "hangover after the party," so to speak – definitely stresses it. Return of larger river flows in fall steps up the inward-moving estuarine bottom current and brings faster flushing and more oxygen to the estuary bottom. Later during the fall, a giant "turnover" of the whole body of Puget Sound water takes place that completely obliterates all of the oxygen depletion accrued during the year at all depths. This annual "turnover" (described in Chapter 8) essentially re-sets the estuary ecosystem back to its starting point, to begin a new year of ecological action.

What about the sizes of the nutrient nitrogen loads entering Budd Inlet every year? No understanding of the Inlet's situation can be complete without appreciating the volumes of those loads, shown in Figure 1-8.

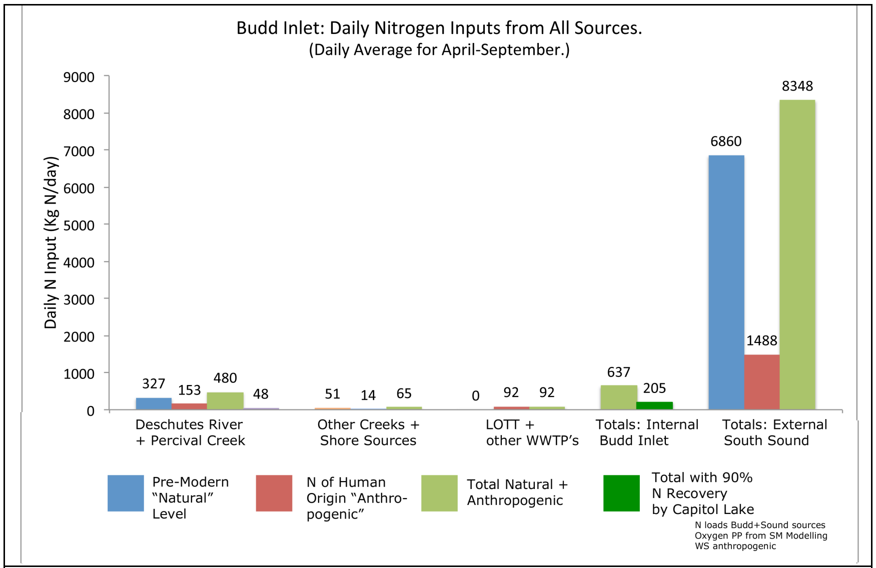

Figure 1-8. Nutrient nitrogen inputs to Budd Inlet from all sources, internal and external. Sources. From left to right, sources are 1) Deschutes River watershed; 2) other small creeks around Budd Inlet; 3) the LOTT WWTP, totals of these three "internal" sources, and 4) South Puget Sound outside Budd Inlet (= "external" sources). [For visualization, I have included Capitol Lake's effect (removal of about 90% of incoming nitrate from the Deschutes River water), not mentioned by Ecology. CH2M-Hill, 1978.] This important Figure is described in detail in Chapter 6, this Review.

Nitrogen enters Budd Inlet from the four sources shown in Figure 1-8. From left to right, they are 1) the Deschutes River watershed, 2) all of the rest of the small creeks around the shores, 3) the LOTT

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[10] "... *mostly* already there …" As the bottom water enters the Inlet, its oxygen concentration continues to drop due to respiration at the bottom and decay of sinking phytoplankton created in the surface rush of nutrient-fueled growth. Between the Oly Shoal and Port stations (about half of the length of Budd Inlet) the bottom DO drops by about 1 mg/L, a result of processes inside Budd Inlet.

wastewater treatment plant, and 4) Puget Sound outside the Budd Inlet entrance (the "external" source). Blue bars show the estimated sizes of the "natural" nitrogen inputs that existed before human activity began influencing Budd Inlet, red bars show the sizes of loads created by human activities, and the pale green bars show the totals.

The dominant feature by far of this graph is the gigantic size of the external nitrogen inputs. That daily nitrogen load – fully 8,348 kg N/day -- drives the Budd Inlet ecosystem. Within Budd Inlet the Deschutes River would contribute the most nitrogen – 480 kg/day -- if it were not filtered through Capitol Lake, which captures and holds almost 90% of that load. The LOTT plant, a top-of-the-line treatment facility, adds about 92 kg/day. The tiny loads carried by the "other small creeks" are inconsequential except for one glaring exception. That is Watershed Park's Moxlie Creek, with one of the highest nutrient nitrogen concentrations of any stream entering all of South Puget Sound, draining into the sluggish semi-isolated cul-de-sac of East Bay.

This perspective informs us for a final look at the whole Budd Inlet situation as portrayed by the Department of Ecology.

1-6. What the Budd Inlet Water Quality Controversy is All About.

One or two times a year in September, the DO levels in East Bay drop below the water quality standard there (5.0 mg DO/L). Those low oxygen episodes last for a few days, then recover (usually by the end of the month). East Bay is the "epicenter" – the "ground zero" of seasonal low DO levels in Budd Inlet. Low September DO levels occur elsewhere around Budd Inlet, always south of Priest Point. For the rest of the year, with occasional occurrences in August, DO levels below the standards are largely rare or nonexistent.[11]

Ecology's computer model personnel blame the yearly low DO episodes in East Bay on Capitol Lake. Their aggressive claim is analyzed in Chapter 6. My view is that they have been misled by the behavior of the estuarine bottom current carrying the huge external load seen in Figure 1-8. By the time that current reaches Priest Point, it has been diminished (by upward mixing into the outgoing surface water) to about 20% of its incoming size. That 20% carries 3.5 times as much nutrient nitrogen as would the Deschutes River with no dam and about 35 times as much nitrogen as does the Deschutes River water after passage through Capitol Lake. By the time that incoming bottom current reaches the dam site, turns upward, joins the out-flowing Capitol Lake water and returns toward East Bay, only about 3% of its total nitrogen load is from the Lake – the rest is from outside Budd Inlet. Most DO depletion, wherever it takes place, is caused by the external load – not the Capitol Lake dam.

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[11] DO levels lower than the standards occur throughout much of central Budd Inlet in October, then recover in November as a result of the "turnover" process mentioned in the preceding section. That is beyond the "view" of Ecology's computer model (which stops in mid-September) and occurs at a time when the low DO's are not a threat to the ecosystem. (See Chapter 8 for a description of this.)

East Bay is impacted by many factors that converge to reduce its dissolved oxygen levels. These are described in detail in Chapter 6.

Regarding Ecology's claims, it strains credulity to accept that some disturbance – nitrogen-driven or hydrodynamic -- that starts at the end of West Bay radiates all the way around the Port Peninsula and far up the dead-end East Bay beyond the Swan Town Marina to finally focus its worst oxygen depletion effect on that isolated backwater.

Figure 1-9 shows Budd Inlet's lowest-DO-levels-of-the-year as calculated by Ecology's computer model for a time before human activities began to change DO levels. In other words, Figure 1-9 shows the lowest DO's occurring in the "natural" (pre-modern) Inlet. The most obvious feature is the DO "hot spot" in East Bay – there long before Capitol Lake and the dam existed. The "critical cell" that Ecology focuses on is the darkest red spot on the map, near the head of East Bay. Many possible explanations for these "violations" of modern standards – the natural nitrogen loads from the external source and Moxlie Creek, and the "null zone effect" – existed then. Ecology's model operators are attempting to shift all of the blame for that pre-modern situation to modern activities.

Despite the fact that Ecology focuses its theories on East Bay, the agency has never (to my knowledge) made dissolved oxygen measurements there. The last observations of DO levels there were (to my knowledge) made by the Budd Inlet Scientific Study team in 1996-97 (see Chapter 2 for a description of this outstanding study). That study shows September low DO's in East Bay and elsewhere (mainly West Bay) on some days, high DO's in those same places on other September days, and no significant low DO's anywhere else during the other eleven months of the year.[12]

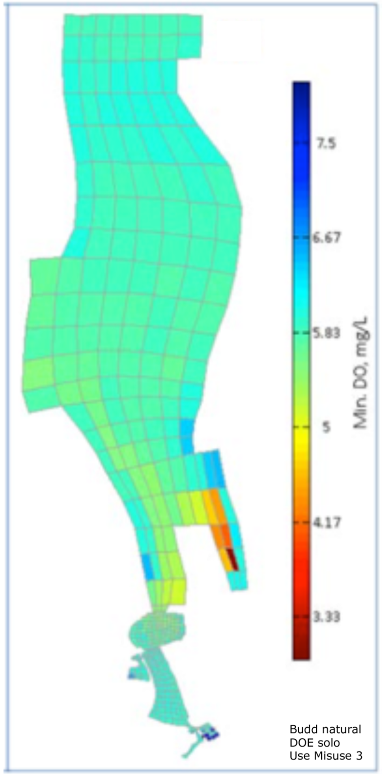

Figure 1-9. Violations of modern dissolved oxygen standards in pre-modern Budd Inlet as calculated by Ecology's computer model. (In this figure, the Capitol Lake basin is tidal estuarine water.) Source: SM Report Fig. 7b, p. 32.

So what is the controversy about? Based on computer model predictions and *only* computer model predictions, Ecology is trying to persuade the public that we must remove Capitol Lake and replace it with a tidal estuary. The "benefit," they claim, would be removal of the once-a-year low-DO "hot spot" in East Bay, and lesser low DO's elsewhere.

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[12] As mentioned in a previous footnote, low DO's develop at all depths in central and outer Budd Inlet in late fall as a result of surface cooling. These abruptly vanish in November. These low DO's occur long after the growing season and are not regarded as "significant." See Chapter 8 for a detailed description of this process.

As I report in the following Chapters, I think they are very mistaken for the reasons I mention. Removal of Capitol Lake would damage, not help, Budd Inlet. It would also cost 400 million dollars (Curry, pers. comm. 2018) and would replace a landscape feature much beloved by the public with malodorous tide flats.

Thanks for reading this! Understanding the features of estuaries is key to understanding the Lake/estuary controversy. And if you hear a speaker mention “low DO’s” in Budd Inlet as a reason for removing Capitol Lake, you might ask “Is the surface water of the Inlet undersaturated with oxygen?” If the speaker doesn’t know what you’re talking about … then he or she is simply repeating talking points provided by estuary promoters.

The Department of Ecology's Supplemental Modeling Report.
A Critical Review.

2. GOOD SIMULATION, MISTAKEN INTERPRETATIONS.

2-1. About This Review.

In September 2015, the Washington Department of Ecology (in the following, "Ecology") released a report entitled

Deschutes River, Capitol Lake, and Budd Inlet
Total Maximum Daily Load Study
Supplemental Modeling Scenarios.

Publication No. 15-03-002

This "SM Report" analyzes data obtained from a computer model that simulates hydrographic and chemical/biological processes in Budd Inlet.[1] Its main focus is on Capitol Lake and the dam that separates it from Puget Sound. It presents many modeling scenarios implicating Capitol Lake as the underlying cause of water quality violations (specifically depleted dissolved oxygen) in adjacent Budd Inlet and discounts or fails to mention several other possible causes.

In the following, I discuss and analyze the SM Report. In brief, it is hastily written with many significant and insignificant errors, flaws, and oversights. Significant errors include a mistaken miscalculation of "oxygen depletion" in Capitol Lake. Additional errors include calculations that understate the amounts of total organic carbon (TOC) in the water in a modeled estuary scenario and overstate the comparable amounts of TOC in a modeled lake scenario. A formatting difficulty occurring throughout the Report is that the scales of graphical Figures are numbered in ways that defy easy interpretation. *Most serious of all, the authors appear to assume from the outset that their premise – "Capitol Lake damages Budd Inlet" – is correct, and thus overlook findings in their own Report that strongly suggests the opposite.* This I address in the Review that follows.

I wrote this paper for two groups of readers; the lay public and for persons with scientific backgrounds who may wish to check my reasoning and calculations. On behalf of the former, I use non-technical language wherever possible. This includes using short-cut references in my text instead of the conventional scientific format of documentation, for example saying "SM Report" instead of "Roberts, Pelletier and Ahmed, 2015" whenever I mention that Report as a source. (Likewise mentioning "TMDL Report" instead of "Roberts, Ahmed, Pelletier and Osterberg, 2012" whenever I cite that earlier document.) The References Section gives the full documentation, both in my abbreviated forms and in scientific format. In the following I refer to my own (the present) document as a "Re-

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[1] This "Budd Inlet Model" is described in Ecology's report of June 2012. See "TMDL Report 2012" in the References Chapter.

view" to distinguish it from Washington Department of Ecology (Ecology) publications, referred to as "Reports."

On behalf of scientific readers, I have documented *all* of my own calculations in detail enough to enable them to trace my logic. Those are presented in sections labeled "Optional." Readers comfortable with science can trace those (sometimes tedious) calculations, others focused on the content can maintain unbroken continuity of reading by skipping those sections.

My time for analyzing the SM Report was critically limited. It seemed likely that I would have to leave this project unfinished. With that in mind, I wrote this Review by Chapters, each of which could stand alone if my departure was required. My time for research and writing did indeed run out and a draft version of this Review was posted on a CLIPA website during 2016 and 2017. The present Review (2018) replaces that draft, with new information added.

2-2. Introduction.

I believe that the origin of Ecology's SM Report is traceable back to the diagram shown here in Figure 2-1. This image is part of a four-part depiction of simulated conditions in Budd Inlet, with this particular image showing the maximum theoretical oxygen depletion caused mainly by water exiting Capitol Lake and all other (tiny) streams around the shores, excluding any effects by the LOTT (Wastewater Treatment Plant) outfall at the end of the Port peninsula.[2] The brown areas in Budd Inlet are those where not even the tiniest of calculated oxygen depletion violations could be detected by the computer. (That is, almost the whole Inlet.) The few colored patches in East Bay show theoretical violations in a peculiar format. That is, each colored square shows the *maximum* calculated oxygen depletion that occurred there at some depth (not specified) on some date (not specified) during the entire simulation period January 25 – September 15, 1997. The size of the maximum theoretical violation can be read from the colored scale to the right. This Figure, with a few others like it, was presented as all the evidence that anyone needs to see to conclude that Capitol Lake degrades Budd Inlet. My involvement with this topic began with my questions about this Figure in 2013.

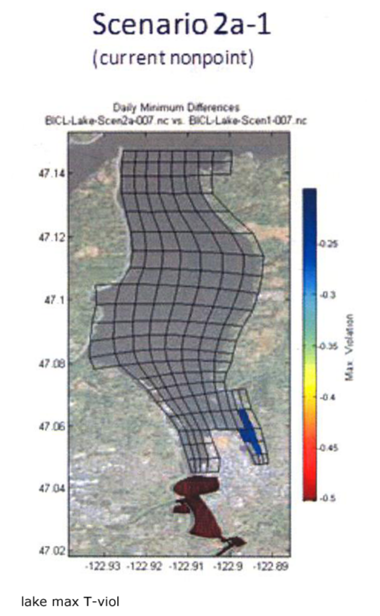

Figure 2-1. Ecology's depiction of the maximum theoretical impact of Capitol Lake and other non-point sources on dissolved oxygen conditions in Budd Inlet (TMDL Report, Figure 90a, p. 206). Fine print in the original at the top of chart reads "Daily Minimum (sic) Differences ECL-Lake-Scen2a-007 nc vs. BCL-Lake-Scen1-007 nc"

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[2] The caption of the 4-part figure in The TMDL Report is "Figure 90. Predicted maximum violation of the DO water quality standard under the lake scenarios. The layer with the maximum violation is plotted for each grid cell." (Alternative "estuary scenarios" in which Capitol Lake is replaced by a 'natural' estuary are presented in a separate TMDL Report Figure.)

In encounters with the Ecology staff (described below), I pointed out that these "violations" were so localized and microscopic as to be almost undetectable by a dissolved oxygen (DO) meter in real life and that if this is really the maximum negative effect of Capitol Lake on Budd Inlet, then in reality there is no problem whatsoever. That set off an alarmed scramble (described below) to "prove" that "oops, we've fixed the model and *now* it shows that the Capitol Lake effect is huge." The 2015 SM Report that I review here is the latest result of that "alarmed scramble."

It is worth noting that Figure 2-1 was available to some two dozen representatives of community groups and agencies assembled to advise Ecology on that agency's development of a plan for the Deschutes Watershed and Capitol Lake for two years prior to my joining the discussion. To my knowledge, not a single member noticed or mentioned the feeble depiction of Capitol Lake's purported "effect" on Budd Inlet.

2-3. The Budd Inlet Computer Model.

The Budd Inlet Model was crafted and first used in 1997 by consultants from the Aura-Nova (Seattle) consulting firm (and other firms and entities) for predicting effects on Budd Inlet of proposed changes in Olympia's LOTT wastewater treatment plant. It subdivides Budd Inlet into about 160 "cells" (or "grid squares") that cover the entire surface of the Inlet (seen in Figure 2-1 above).[3] Beneath each grid square, the water is subdivided into a stack of about 19 "grid cubes" that include all of the water from surface to bottom. The total number of cubes that divide up the three-dimensional body of water that is Budd Inlet is therefore about 160 x 19 = 3040. The computer begins on simulated "January 25, 1997." It starts with a vast amount of observed and interpolated data from (or starting from) that date – water salinity, temperature, dissolved oxygen levels, and other water properties in each one of the 3040 "cubes," the 1997 tide table, 1997 weather and stream runoff data, and more. Using the starting data and built-in calculation routines that mimic the transfers of water between adjacent cubes and processes that create and/or use up dissolved oxygen (and change water chemistry in other ways), the computer then calculates the changes in each cube that take place as time goes by – *every six minutes for every depth at every location* – from January 25 to September 15 (TMDL Report, p. 187).[4] A single "run" of the model from start to finish takes 10 full days to complete even at the lightning speed of the computer (SPSDOS Report 2013, p. 38).

If even one of the six minute intervals at even one depth under any of the grid squares is found by the computer to have less dissolved oxygen in it than the legal regulatory water quality standard[5], the whole grid square is colored according to the size of its simulated low oxygen condition and shows up at the end of the simulation flagged, as in the colored East Bay squares in Figure 2-1. The smallest low oxygen condition triggering a "viol-

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[3] The number of grid squares is not always the same in Ecology reports. For example, two side-by-side grids on p. 32 of the SM Report (reproduced as Figure 4-3, Chapter 4) show different numbers, 160 and 168. I use 160 throughout this report.

[4] In scientific parlance, six minutes is the "iteration interval" of the model.

[5] The regulatory water quality standard is complex. It is described in detail in Chapter 3.

ation" color is a DO level 0.2 mg/L below the standard – the blue top end of the scale in Figure 2-1. As can be seen, the simulation that produced that Figure subjected Budd Inlet to a gargantuan dragnet search of staggering size – colloquially, a search with a fine-tooth comb -- and, even so, failed to find any theoretical violations even this small over almost all of the Inlet.

2-4. Data Sources.

The consulting firm that devised the Budd Inlet Model, in partnership with others, also conducted a year-long field study of Budd Inlet. Beginning in September 1996 and finishing in September 1997, measurements were made regularly at some stations and less frequently at others on some 34 different occasions throughout the study year.[6] The scientists involved measured water quality properties at depths ranging from the surface to the bottom at the locations shown in Figure 2-2. To date, this "Budd Inlet Scientific Study" (= BISS in the following) is the most detailed and reliable study of Budd Inlet ever made.

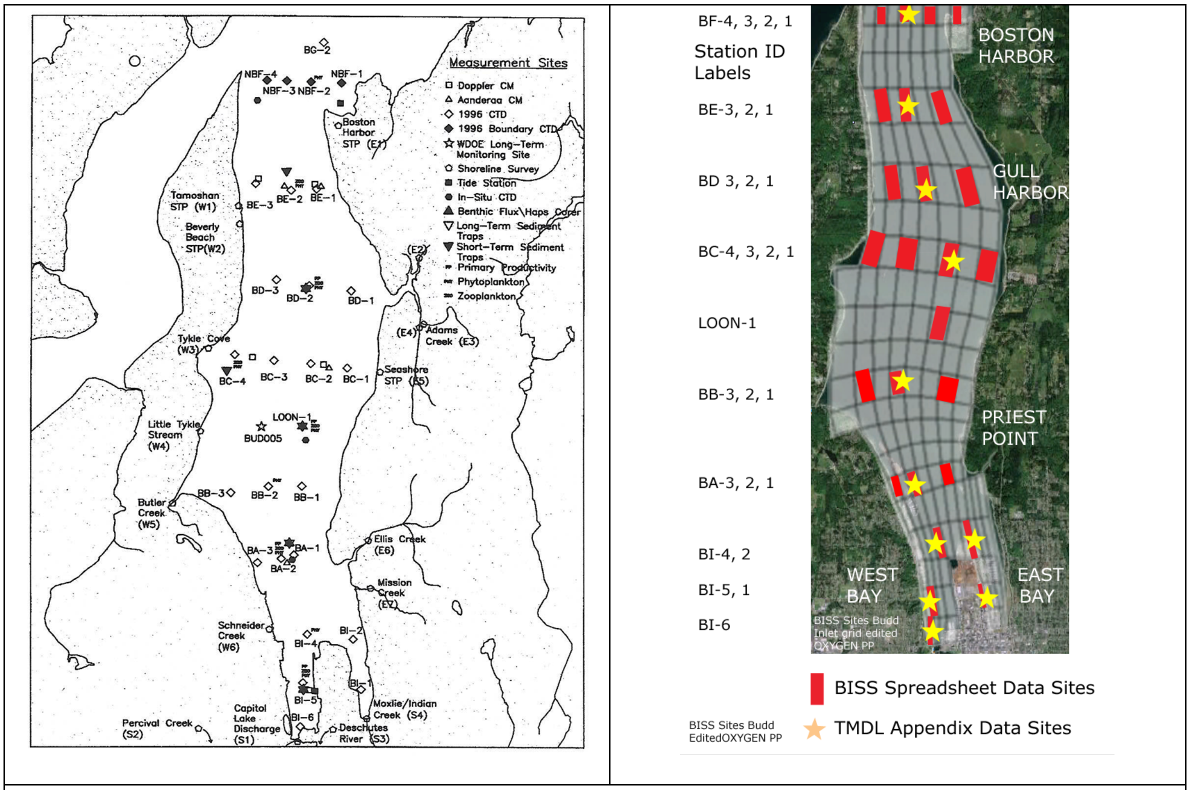

Figure 2-2. (Left) All BISS sample sites in Budd Inlet with a key to observations made at each site. Source: BISS Vol. 1 p. 59, 1998. Figure 2-2. (Right) Sites for which the 1996-1997 BISS data are available in Budd Inlet. Red bars; locations of BISS data in the spreadsheet. Stars; BISS data also shown in the TMDL Appendix. The BISS spreadsheet also has data for a station BG-2 outside the mouth of Budd Inlet shown in the leftmost but not the rightmost figure.

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[6] Most of the "occasions" were separate dates, however several sets of measurements were made during the same day on a few dates.

Some of the data from this study are stored in a gigantic Excel spreadsheet file, which LOTT personnel graciously made available to me. This awesome compilation consists of some 29,000 rows of data spanning the study period, arranged in 14 columns. A sample is shown in Table 2-1. The spreadsheet shows these data at every depth from the surface to the bottom (whose actual depth varies from date to date due to tidal changes) in increments of 0.5 meters.

The Budd Inlet computer model used by the Ecology staff was updated and calibrated by comparing its predictions with the values actually observed by the BISS scientists. These comparisons, made after the calibrated model was judged to be as accurate as it could be, are shown in an Ecology Report that accompanies the 2012 TMDL Report – namely, the "TMDL Appendix." In the Appendix the calibration data are mostly reported as graphs of the computer's calculations with observed BISS data points superimposed. Readers must calculate the computer's numbers by measurement of the graph scales and interpolation. Table 2-1 shows which data are presented in both the Appendix and in the spreadsheet. The Appendix also includes graphs for variables (for example nitrate levels, biological oxygen demand levels, etc.) that are not in the BISS spreadsheet in my possession.

A	B	C	D	E	F	G	H	I	J	K	L	M	N
I	2	BI-1	1/22/97	17:53	7.5	3.9	-3.9	8.12	27.38	21.2789	7.14	1.10082	0.001896
R		BI-1	2/11/97	7:25	7.5	3.0	-3.0	7.93	26.68	20.7563	7.59	3.51059	0.0799
I	3	BI-1	5/29/97	22:08	7.5	3.5	-3.5	11.89	27.34	20.6641	8.00	-999	0.001595
I	4	BI-1	8/21/97	5:29	7.5	3.9	-3.9	15.54	28.31	20.7081	5.02	-999	0.2617
R		BI-1	9/24/97	13:26	7.5	3.5	-3.5	14.73	28.48	21.0101	2.85	9.40895	33.33

Table 2-1. Example of BISS spreadsheet data. Column labels are A Cruise type; B Sweep number; C Site ID; D Date; E Time of Day; F Depth below surface (m); G Depth relative to MLLW; H (see below); I Water Temperature ^{o}C; J Water Salinity ppt; K Water Density (σ_T); L Dissolved Oxygen Concentration (mg/L); M Chlorophyll Concentration μg/L); N Light level. This example shows bottom water at station BI-1 (head of East Bay, includes the colored squares of Figure 1-1) on various dates (Jan. 22 – Sep. 24, 1997), depth 7.5 m below the surface, water temperatures ranging from 8+ to 15+ ^{o}C, salinities ranging from 26+ to 28+ parts per thousand, and DO's ranging from 8.00 to 5.02 mg/L over these dates. "-999" indicates that data were lost or not taken on some occasions. A separate BISS worksheet lists "Errors;" measurements discovered to be flawed when the data were compiled. The colored value in this sample is one of those.

The lines of data shown here are not contiguous in the spreadsheet; they are assembled here for illustrative purposes. Some spreadsheet data are rounded here to two decimal places. Data under shaded headings are also replicated in the TMDL Appendix graphs. The label on Column H says "Elev." I'm not sure what it refers to. I did not use data from this Column, nor from A, B, and N.

The Spreadsheet and the TMDL Appendix were my major sources (referenced here as "TMDL Appendix" and "BISS 1998.") of dissolved oxygen data. I found that these two sources are identical in most cases, but also that each has data not shown by the other (see Chapter 3).

I also consulted data from five additional sources. These are:

1) Dissolved Oxygen (DO) and other measurements at the +1.0 foot tide level in Eld Inlet made by a probe fixed to the bottom; growing seasons 1998, 1999, and 2000;

2) DO measurements by the LOTT Wastewater Treatment Plant staff at five locations in lower Budd Inlet, surface to bottom, from September 2009 through September 2011;

3) DO's vs. depths presented by an Ecology website for two Budd Inlet stations (Olympia Shoal and Port of Olympia) for 1996, 2002, and 2014;

4) DO's and other measurements made by the University of Washington's Oceanography Department at Gull Harbor and Buoy 12, Budd Inlet, in 1957 and 1958;

5) DO's and other measurements made by me with colleagues at five locations in West Bay, lower Budd Inlet, and Capitol Lake, September 19, 2013.

These are listed in the References chapter at the end of this Review and cited where mentioned in this text.

2-5. Encounters with the Department of Ecology.

In Autumn 2012 I was invited to examine the claim that Capitol Lake degrades water quality in Budd Inlet by the members of the Capitol Lake Improvement and Protection Association (CLIPA). At that time I knew that there was discussion of the possible removal of the Lake and conversion of its basin back to the estuarine condition that prevailed before the dam at 5th Avenue was built, but this had been remote from my daily concerns and I had no opinion one way or the other on that proposition. I began by obtaining and reading copies of the TMDL Report and TMDL Appendices and attending monthly meetings of Ecology's "TMDL Advisory Group," a group of professionals, agency representatives, and members of various organizations that met monthly to advise Ecology on restoration of the Deschutes River. This group's agenda included the Lake/ Estuary question.

I quickly realized (from Figure 2-1 from the TMDL Report and others like it – Figure 2-3 shown here, for example) that the computer modeling staff were unfamiliar with aquatic ecology and were missing important interpretations of the model's outputs. It was also clear that no mention was made of Capitol Lake's removal of nitrogen nutrients from the Deschutes River water – an immense benefit to water quality in Puget Sound. These and other oversights were driving the impression that the Lake degrades Budd Inlet.

In early 2014, I requested an opportunity to share my views with the TMDL Advisory Group as a speaker at one of the meetings. The Ecology staff members overseeing the TMDL effort requested a preliminary private briefing to familiarize themselves with what I would say. A colleague and I met with two staffers in March 2014.

Following that briefing, TMDL meetings for the next three months were cancelled. When they finally resumed, the topic was a TMDL effort at Chesapeake Bay featuring a speaker working there.

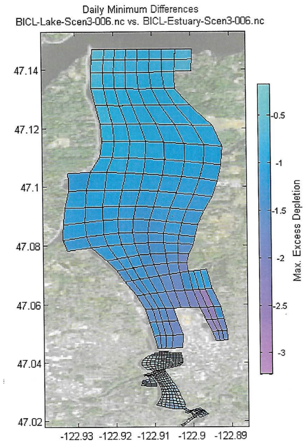

Figure 87. Predicted maximum difference in DO between lake and estuary scenarios for the current levels of nutrient loading (Scenario 3).

Negative values indicate that DO under the lake scenario is lower than DO under the estuary scenario. Cells with no color indicate greater than -0.2 mg/L or positive differences. The layer with the maximum difference is plotted for each grid cell.

Blue Max Figures

Figure 2-3. Budd Inlet purportedly with less dissolved oxygen everywhere "caused" by the Lake, compared with DO levels if an estuary were present. Source: Figure 87, TMDL Report. [7]

During the interim "waiting period," I compiled a written report of my findings (Milne, 2014). In it I described and analyzed many shortcomings of the TMDL Report'schapter on Capitol Lake and presented it to the CLIPA group that I was advising. The report was posted on the CLIPA website, distributed in printed form to various interested parties, and made available to the Ecology modeling staff members.

Also during the interim "waiting period," it was announced by the Ecology staff that a "poster" describing an "improvement" in the Budd Inlet Model had been released (Poster 2014 in References). The modelers had changed the way in which the simulated sediment exchange with the water takes place, and also presented a graph that showed, for the first time, the Lake water removing nitrogen nutrients from Deschutes River water. (This is discussed in detail in Chapter 7.) The effect of this change was to make Budd Inlet appear to be far more degraded by Capitol Lake than is shown in Figure 2-1 and elsewhere in the TMDL Report.

I met with the Ecology staff on two other significant occasions. The first was a dual presentation by the modelers and by me to the Alliance for a Healthy South Sound on

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[7] My detailed response to the Ecology modelers regarding this Figure is contained in my Report (Milne, 2014) and also in Power Point slides presented to them on July 17, 2014. The Figure actually shows a flush of surface water oxygen production by Inlet phytoplankton caused by the ongoing flood of nutrients from the Deschutes River – accurately detected by the computer -- while overlooking the near-inevitable detrimental consequence of that, namely DO depletion at the bottom. Ecology never acknowledged their mistaken interpretation but also never used this Figure again (to my knowledge).

July 17, 2014 (AHSS, 2014). At that time I gave a Power Point presentation correcting dubious interpretations of Figures in the TMDL Report and suggested alternative hypotheses addressing the conspicuous late-summer low DO levels in East Bay. Two members of the modeling staff gave a complementary presentation in which they advanced an important hypothesis explaining how Capitol Lake might degrade Budd Inlet in spite of the fact that the Lake removes nutrient nitrogen from the Deschutes River. This was a cordial, informative exchange that advanced the thinking of all of us on new ways to explore the Lake/Inlet interaction. I left a copy of my presentation with the modelers at this time (Power Point "OK," 2014.)

After the OK presentation, I left a telephone message with one of the modelers suggesting we all get together over coffee and continue our conversation about the model. This turned into something far different. The TMDL overseers worried that "estuary advocates" would demand to know why they hadn't been included and scheduled a meeting of people said to be knowledgeable about simulation modeling and aquatic ecology. The meeting, which included mostly people with little such knowledge, was held on November 3, 2014. Again the modelers and I gave presentations. Mine included a printed list of ways in which I thought the model could be improved for greater accuracy, which with a copy of the Power Point presentation (Power Point OK2, 2014), I left with the modelers. This meeting was somewhat confrontational. The "estuary advocates" brought an expert on freshwater ecology, Dr. Jonathan Frodge, who had critiqued my earlier report (Frodge, 2014). To their chagrin, he and I had an agreeable and informative discussion of aquatic ecology, all overshadowed by our growing realization that this meeting was political, not scientific.

Following this meeting, I turned my attention to addressing the public's widespread negative perception of Capitol Lake. To this end I wrote a report that presents the Lake as a truly remarkable positive feature of Washington's ecological landscape (Milne, 2015). Whether or not Ecology has a copy I don't know; it is available on the CLIPA website.

As a result of our encounters, the modelers appear to have adopted some of my suggestions. The new SM Report (2015) includes a discussion of how the Budd Inlet model has been grafted onto their model of Capitol Lake (SM Figure 6, p. 31), moves away from the earlier preoccupation with the "depth of maximum dissolved oxygen difference" by addressing instead the bottom water in one case (SM Figure 15, p. 38), and gives a nod to statistical confidence limits. None of this is acknowledged by Ecology; the SM Report's References section makes no mention of any of my written or presented contributions.

2-6. The Review That Follows.

In the following Chapters of this Review I address errors, mistaken assumptions, and mistaken interpretations presented by the modelers (Roberts, Pelletier and Ahmed) in the SM Report. Central to all of it is the Budd Inlet Model – an impressive (even "remarkable") tool for examining broad scale changes in Budd Inlet. I believe that the Model, as originally designed for marine water, has been poorly adapted to mimic the ecology of Capitol Lake by the modelers. I also have reason to believe (and have never been corrected on this by the modelers) that the Ecology staff consider every single one of the model's thousands of calculations of dissolved oxygen levels throughout simulated "1997" to be dead-on accurate, close enough to the real levels that prevailed during that year for certainty in every case where the model shows low DO and therefore a real-world water quality standards violation. All such calculated violations are invariably regarded by them as "real."

Wherever possible throughout this Review, I compare the outputs of the computer model and the modelers' interpretations with real, observed data. Where real-life observations show water quality standards violations, that can be trusted. Where the computer calculates water quality standards violations, that is suggestive and instructive – but not conclusive evidence of real-world violations.

This Review is divided into 10 Chapters. Their titles and the main thesis of each one follow.

Chapter 1. Background. Estuaries and Dissolved Oxygen.

This introductory chapter describes the non-tidal water movements in estuaries and how they relate to the forces that deplete and replenish critical dissolved oxygen in estuary ecosystems.

Chapter 2. Good Simulation, Mistaken Interpretations.

This introduction describes Ecology's Budd Inlet computer Model, my early involvement with the lake/estuary controversy, Ecology's bias against Capitol Lake, and an overview of the chapters that follow.

Chapter 3. The Computer Gets Many Wrong Answers.

At least half of the calculations by the model don't agree with data obtained by the BISS field research. At its worst, the day with the highest DO level of the whole season was the day for which the model predicted the lowest DO level of the whole season -- at three sites. One was Ecology's single most important site; the "critical cell" in East Bay.

Chapter 4. The Budd Inlet Estuary; "Natural" and Modern.

"Natural" Budd Inlet before modern times was loaded with DO standards violations. The model shows that modern Budd Inlet with the dam is only marginally worse. Modern Budd Inlet without the dam, however -- with all modern human activities – is "shown" to be stupendously better than it was in pre-modern "natural" days – an unlikely proposition. Ecology's presentation obscures this absurd contradiction and the high-violation levels discovered in the "natural" estuary.

Chapter 5. Ecology's Budd Inlet Simulations: Flawed Science.

Ecology has avoided simulations that would show beneficial effects of Capitol Lake, downplayed simulations that show possible improvements without removing the dam, and made calculation errors and statements about hydrodynamics not supported by model outputs, all slanted toward forcing the conclusion that removal of the dam is the only way to improve Budd Inlet's water quality. This Chapter questions those claims.

Chapter 6. Ecology's Central Claim: "The Dam Depletes Oxygen." Wrong.

The load of nitrogen entering Budd Inlet from beyond Boston Harbor is 16 times larger than the load entering from Capitol Lake. Yet Ecology insists that Capitol Lake causes eight times as much dissolved oxygen depletion in Budd Inlet's East Bay as does the external source. They've got it backward; this Chapter shows why.

Chapter 7. Organic Carbon Claims: Misleading, Mistaken, Not Credible.

Calculations claimed to show that Capitol Lake releases more oxygen-depleting organic carbon to Budd Inlet during the growing season than would be released if the dam were removed actually show the opposite; an estuary in that basin would release more organic carbon *during the growing season*.

Chapter 8. The Late-Season Departure of Organic Carbon from Capitol Lake.

This Chapter presents real-world observations and ecological explanations of why most organic carbon formed by plants in Capitol Lake can't deplete dissolved oxygen in Budd Inlet during the growing season.

Chapter 9. Capitol Lake: Errors and False Claims.

Ecology's most grotesque calculation error has created a widespread public perception that Capitol Lake itself is "deficient in oxygen." The Lake actually has higher DO levels than any other lake (or estuary) in the county, year round. Ecology's calculation error and the real-world facts are described in this Chapter.

Chapter 10. Low Dissolved Oxygen in Natural Estuaries.

Widespread violations of modern dissolved oxygen standards are calculated by the model for pre-modern Budd Inlet before the dam was built. This unwelcome feature of the "natural" inlet complicates efforts to show that "the dam" is responsible for modern low oxygen episodes there. Ecology's response; to "update" the model to eliminate low "natural" DO's. This Chapter presents evidence (from Eld Inlet) that natural DO's are to be expected.

Chapter 11. References.

2-7. Good Science …

The SM Report has a page at its beginning citing the need for "good science" as essential to deciding whether Capitol Lake should remain or be removed. Repeated mention is made of the number of reviews of the model itself – as is proper. There is never any mention of reviews or editing of the Reports that present (or omit) model findings and interpretations.

As the author of a textbook whose three drafts were critiqued by some 52 peer reviewers, I am familiar with what reviewed text material looks like (Milne, 1995). The SM Report has no resemblance to peer reviewed work. The ultimate test of its credibility (and that of other Ecology publications) would be to submit the present draft for publication in a peer-reviewed journal. My expectation is that editorial reviewers would suggest many, many revisions like those in the Review that follows.

3. THE COMPUTER GETS MANY WRONG ANSWERS.

3-1. Overview.

Appendix G2 of the original TMDL Report presents 38 pages comparing the Budd Inlet Model's output with the observed water quality parameters that were used to calibrate it (TMDL Appendix, 2012). There are three pages for each of the Appendix G2 stations, each portraying observed and calculated conditions at the surface, bottom, and a depth midway between surface and bottom. Figure 3-1 shows an example, this one for the dissolved oxygen levels in the bottom water at station BI-6 in West Bay (the station nearest the dam).

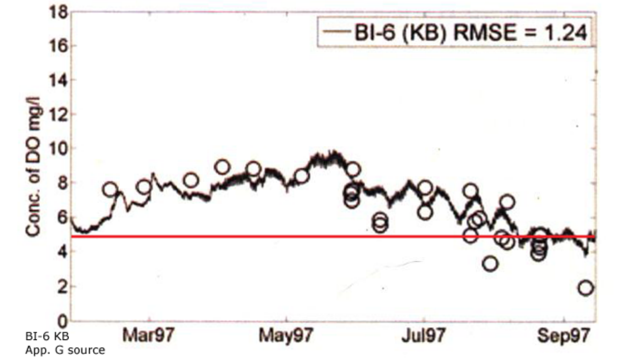


Figure 3-1. Observed dissolved oxygen levels (circles) and Budd Inlet model's calculations (graph line) of those levels near the head of West Bay (station BI-6), in water at the bottom. January 25 – September 15 1997. Red ine shows the DO standard at that station (5.0 mg/L) Source: Appendix G2 TMDL Report, page 1.

These Figures show a remarkable ability of the model to follow (and roughly predict) the observed levels of dissolved oxygen in the water over the simulated "year" (January 25 - September 15, 1997). In those Figures, the computer's graph (dark line) follows the general trend of the observed data (open circles) quite faithfully. However if *every* calculation were accurate, the graph would go through and touch the center of *every one* of the open circles. It doesn't do that. It "misses the mark" by a wide margin in some cases, by a narrow margin in others, and in some cases (where it passes very close to the centers of the data circles as it goes through them) it is "dead-on accurate."

The differences between the positions of the data points and how far the graph is above or below each one is a measure of the average size of the error made by the computer. As Figure 3-1 shows, the computer's graph passes directly through *almost none* of the observed data points. The errors are large. How large is explored in the Sections that follow.

That is the fact to always bear in mind; the computer often gets wrong answers. *Yet the Ecology modelers interpret its outputs as though every one of the thousands of calculations is dead-on accurate.*

3-2. Counting Right Answers.

The data points in the Appendix graphs are at the exact centers of the circles shown there. These circles are about 0.875 mg/L in diameter. If the graph fails to touch ("misses") the circle, the computer's answer in that case is in error by at least 0.44 mg/L (the circle's radius). That is about twice the critical threshold (0.2 mg/L below the water quality standard) used by the modelers in judging whether a violation has been detected.

I examined each of the dissolved oxygen graphs in Appendix G2 (36 graphs; 3 depths for each of 12 stations) for visual determination of whether the computer graph missed the observed data point circle, "hit" it, or was undeterminable (not clearly a hit or miss). To qualify as a "hit," the graph had to touch the exact top or bottom of the data circle or pass through it. A grazing contact along one side of a circle was scored as a "miss;" the graph was close in that case but the top or bottom (on a vertical line through the center) of the data circle was not in contact with the graph on the date of the observation. Figure 3-2 for station BF-3 surface water (near Boston Harbor) shows an example. Figure 3-3 summarizes the "hit" and "miss" pattern for all 36 graphs.

Figure 3-3 shows that the computer's calculations matched observed DO's about 80% of the time in bottom water at sites BI-4 (entrance to West Bay) and BE-2 (center Budd Inlet near the Tamoshan area). At worst, calculations matched the observed values in bottom waters only about 20% of the time at BI-6 and BI-2 (West and East Bays) and BC-2 (Gull Harbor area). Overall, the calculations were accurate in roughly 40-50% of cases (Fig. 3-3).

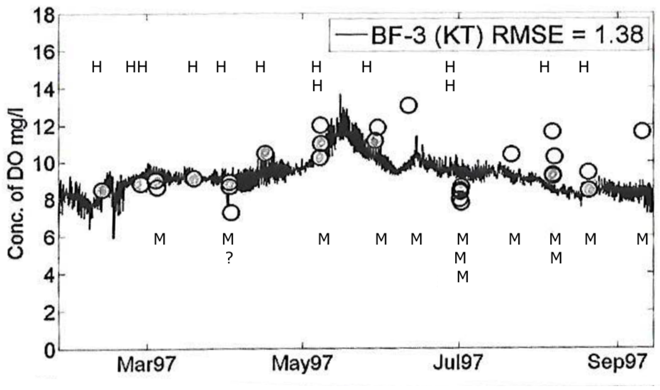
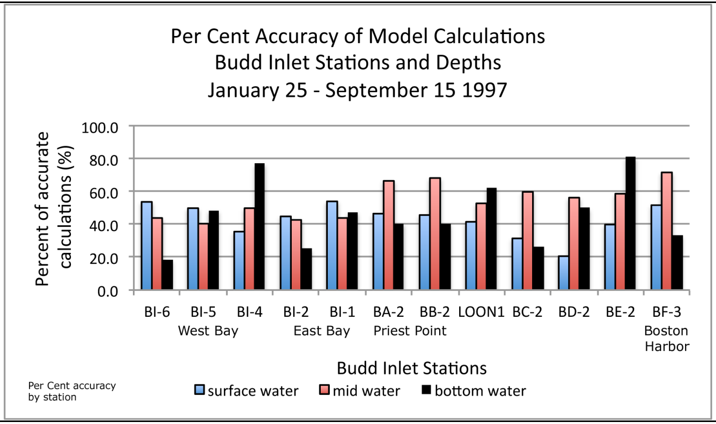


Figure 3-2. Assessment of calculated "hits" and "misses" of observed data circles by the Budd Inlet Model for dissolved oxgyen concentrations in surface water at station BF-3 (near Boston Harbor) by the method described in the text. Hits ("H" in upper row), misses and undeterminables ("M" and "?" in lower row) show 13 accurate, 13 inaccurate and 1 undeterminable calculation. Source Appendix G2 p. 36 TMDL Report.



If the Budd Inlet Model calculates wrong answers (estimates of DO levels) that are always very close to the "right answers" (actual real-life DO levels), that is still very helpful and informative. But it doesn't consistently do that. When it "misses the mark," it can do so by a large margin of error. The following shows one calculation error that could hardly be worse, and that in general the calculations can be far from accurate.

Figure 3-3. Accuracy of the Budd Inlet model. Bars show the per cent of calculations that correctly identified observed DO values (counting all "indeterminable" scores as "hits") by stations from south to north in Budd Inlet. Data from graphs in Appendix G2 TMDL Report.

3-2a. Worst Case Scenario.

In the preceding, I used only data from the modelers' own graphs in Appendix G2. The inability of the model to "get it right" in every calculation is also evident if data from other sources are used. Figure 3-4 (same as Figure 3-1 above) shows the bottom water at station BI-6 with an added overlay of data points from the BISS spreadsheet for that site. The data presented by the modelers (circles) are identical to those from the spreadsheet (triangles) in many instances. The modelers' data include values not found by me in the spreadsheet (for example, two points near July 1 whereas the spreadsheet shows only one) and values found in the spreadsheet that are not shown on the modelers' graph (for example, the very high data point in mid-September).

The lowest observed DO level shown in Figure 3-4 is ~2.0 mg/L (circle at September 10). It was evidently part of the data set used to calibrate the model. The BISS spreadsheet shows no such number but instead lists the bottom water DO level for that date as 12.53 mg/L. That high level of DO was actually observed, as were similar high bottom water DO's at two East Bay sites on the same date. This situation (explained in detail in Chapter 5) was due to intense late-summer photosynthesis by microscopic algae attached to the shallow sunlit bottom.

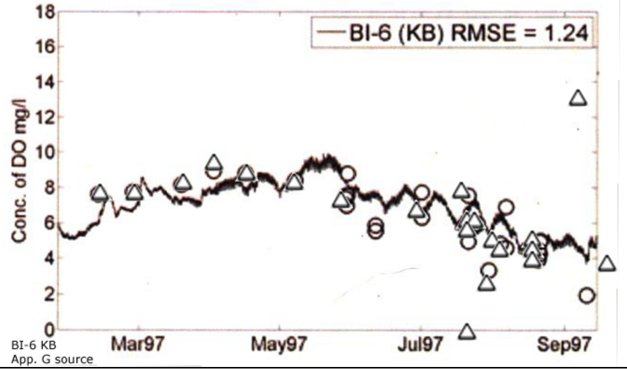


Figure 3-4. Figure from the TMDL Appendix with an overlay of data from the BISS research (triangles). The rightmost triangle is September 24, a few days after the end of the computer simulation interval. Source: BISS spreadsheet.

An accurate simulation of the benthic algae's DO production would have enabled the computer to "see" it. (The line traced by the computer would have "shot up" to 12.53 mg/L on that date, then back down again by the next day.) It did not. In fact, the graph drops to its lowest level of the entire season on that date (Figs. 3-4 and 3-1). T*he computer model predicted the lowest bottom water dissolved oxygen of the entire season on a day when the benthic dissolved oxygen was actually at its highest level of that season*.

The same giant error occurs at station BI-1 in East Bay (see Figure 2-2 for location). The patch of water immediately to the east of BI-1 (actually touching the BI-1 grid square) is Ecology's "critical cell" – the grid square that almost always shows the worst (lowest) seasonal dissolved oxygen levels of the entire year. Here is the situation that the agency blames on Capitol Lake. And exactly here is where a component of the computer model (the "benthic algae subroutine") failed catastrophically, showing a low bottom water DO level when it should have showed the highest level of the entire year.

3-2b. All Model Calculations for the Critical Cell; Flawed?

This is no small laughable error. It implies that *all* of Ecology's DO calculations for East Bay are suspect, as they may well be for all other shallow areas around Budd Inlet where benthic algae are at work, all summer long, wherever else the benthic algae subroutine failed.

A low DO "observed" value is shown in Fig. 3-1 (West Bay) on September 10. That low value is listed in the BISS spreadsheet for that time and place, but it is identified as an error in that spreadsheet. No low "observed" September 10 values are shown in the graphs for East Bay, however those graphs are also lowest on that date.

What about observed data other than the BISS record for East Bay? To my knowledge, there aren't any. Despite its critical central role in the Budd Inlet modeling effort, the Department of Ecology has never (to my knowledge) actually measured DO levels at that location. Nor have LOTT staff, nor has anyone else – to my knowledge. The 1997 data collected during the BISS study are the last ones ever made there. *All* of Ecology's pronouncements on the alleged negative effect of Capitol Lake on that location are based on demonstrably flawed computer calculations.[1]

3-3. The Computer's Margin of Error.

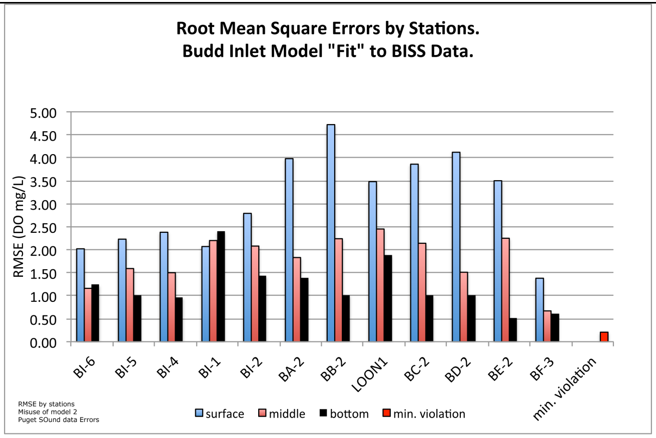


Figure 3-5. Values of the model's "margin of error" (RMSE) in surface, middle depth, and bottom waters at Budd Inlet stations. West Bay is to the left, Boston Harbor is at right. Far right; size of the smallest DO below DO standards that qualifies as a violation. Source: TMDL Appendix.

Every graph in Appendix G2 (for example, Fig. 3-4) shows a number at its upper right hand corner labeled "RMSE." This is the "Root Mean Square Error," the computer's "margin of error" for that location and depth.[2] These numbers are quite large, ranging from 0.52 mg DO/L (bottom, site BE-2) to 4.72 mg/L (surface, BB-2).

The RMSE for each situation is calculated by averaging the differences between each known observed DO level (circles) and the computer's estimates of those observed values

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[1] That said, I expect that if measurements were actually made there, they would show low DO levels at the bottom. East Bay's backwater situation is a textbook example for occurrences of low DO's, for reasons described in Chapter 1.

[2] The RMSE is defined and briefly discussed on p. 57, TMDL Report. I asked the modelers whether "margin of error" is an accurate interpretation of the RMSE during our November 2014 meeting. They said "yes."

(graph lines). The RMSE is thus the average difference between the real values and the calculated estimates of those values. Figure 3-5 shows the sizes of the RMSE's at all sites and depths, and the (small) size of the minimum violation (0.2 mg/L) that the modelers seek to detect using a tool with those large margins of error.

Figure 3-6 shows the likelihood of making a mistaken decision about DO standards violations in four possible situations ("scenarios").

For station BI-6 (closest to the dam; bottom water RSME = 1.24 mg/L [Fig. 3-1]) the DO standard is 5.0 mg/L. Violations occur if the DO falls 0.20 mg/L lower than this, that is lower than 4.8 mg/L.

For a real-life DO of 6.24 mg/L (scenario 1, Fig. 3-6), the average "low side" calculation error by the computer would be one RMSE (= 1.24) lower than this, namely 5.0 mg/L. That is higher than the 4.8 mg/L "cutoff" or threshold for declaring a DO standards violation. When the real-life (but unknown to us) DO level is that high, the computer will almost always correctly recognize "no violation."

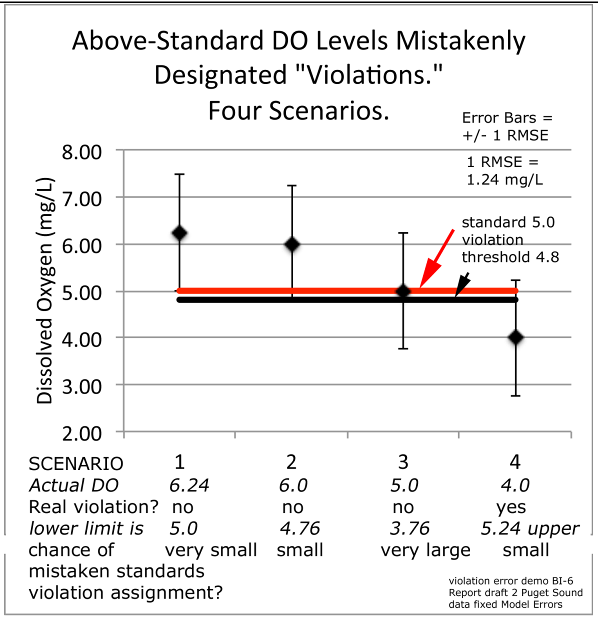

Figure 3-6. Diagram illustrating how unknown DO levels close to the DO standard can be mistakenly designated as "violations" or "no violations" due to the computer's large margin of error.

As the real-life DO level declines, however (scenarios 2, 3, and 4), the "slop" in the computer's predictions overlaps the violation threshold by more and more, increasing the likelihood of "finding" violations when there are really none. Finally, for DO's below the threshold (scenario 4), "high side errors" by the computer could result in the mistaken assignment of "no violation" to a situation in which a violation really has occurred. The closer the real-life DO is to the DO standard level, the more likely it is that the model's calculation will be in error one way or the other – "violation" when there is none, or "no violation" when there really is one.

Until recently,[3] the "violations" maps used by Ecology to show the computer model's output were like the leftmost diagram in Figure 3-7. Each colored square is a location where the computer "found" at least one DO level lower than the DO standard assigned to that location during its exhaustive search between simulated January 25 and September 15. If more than one violation was calculated for a site, the color shows the size of the

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[3] The Dept. of Ecology may have switched to another form of map during 2017. See Figure 3-9, this Chapter.

most serious violation – the "worst case" of the "year" at that place. The scale alongside the map shows the sizes of the violations represented by the colors. The uppermost end of the scale, not numbered by the modelers, is at 0.2 mg/L, the smallest possible violation.[4]

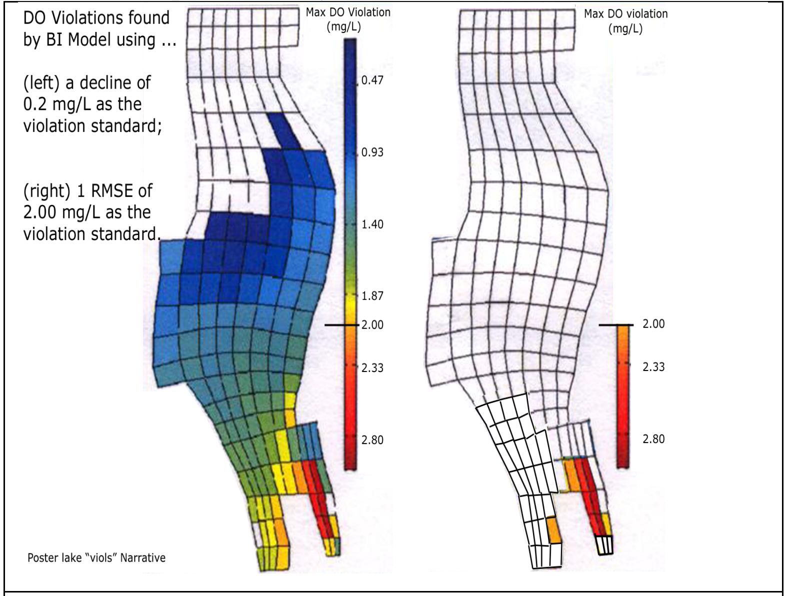

Figure 3-7. Areas in Budd Inlet flagged for violations where calculated values are (a, left) 0.2 mg/L or more below the standard or (b, right) one RMSE (in this example, 2.0 mg/L) below the standard. The modelers' colored scale (a) shows the maximum amount by which each colored square is in "violation." Source: a) Poster 2014; b) Author's calculation presented in Power Point OK2, 2014.

The darkest blue violations on the map are all 0.2 mg/L. These microscopic "violation" were the worst that the model was able to calculate at those sites. Its margins of error for sites in this central region are all much larger than 0.2 mg/L (Figure 3-5). In real life (as discussed in Chapter 8) the measured DO's at those sites during the BISS research were never lower than the standard for that region (6.0 mg/L) during the months simulated. It is certain that many of the blue "violations" shown resulted from large random low-end errors of estimates in a few of the many thousands of calculations made for those sites – but the modelers regarded every last one of those calculations as accurate.

The rightmost map in Figure 3-7 shows a way of screening out some of the uncertainty created by the model's large margins of error. In that diagram, only calculated violations that are lower than the DO standard by one RMSE or more are shown. (For this illustration I used 2.0 mg/L as the RMSE for the whole inlet.) A departure that large seems likely to indicate a real violation rather than a low-end error by the computer. The resulting violations map shows far fewer colored squares – but we can be more confident that the ones shown are not just portrayals of random errors made by the computer.

3-4. The Biggest Source of Error and Confusion of All.

Figure 3-8 shows the oxygen standards for Budd Inlet water quality. They are 5.0 mg/L in the southern harbor sector and 6.0 mg/L over the larger central and northern sectors. A violation occurs if the real life DO level drops below these standards by 0.20 mg/L or more (that is, below 4.8 or 5.8 mg/L).

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[4] … found by me by using a ruler and extrapolation ...

Figure 3-8. The water quality standards for dissolved oxygen in Budd Inlet; 6.0 mg/L in the green sector, 5.0 mg/L in the orange area. The 5.0 standard is used for the Capitol Lake basin in simulations of the Inlet in its "natural" configuration before the dam was built. Source: SM Report Fig. 7, p. 32.

There is a loophole, however, in this straightforward comparison. If the "natural" water as it existed before intensive human activities began was already below the modern standards, then the level of oxygen in that pre-modern water itself becomes the standard. Thus for pre-modern water that occasionally had a DO level of 3.8 mg/L in its natural state, for the part of the season when that low DO occurred the DO level of the modern water would have to drop 0.2 mg/L below 3.8 (that is, to 3.6 or lower) before a violation is declared. This exception protects modern waters that once ran low on DO due to natural causes from attracting undue regulatory wrath for conditions that human activities did not create. It is clearly described on page 35 of the SPSDOS (2013) Report.

A practical problem with this exemption is that very few measurements of natural pre-modern waters were made before human activity became intense. For example, I know of no DO measurements in Budd Inlet earlier than 1957, by which time the Deschutes estuary had already been dammed. We seldom have data from the pre-modern era, in which case we must simply use the modern numerical standards of Figure 3-8 as our guidelines. At the time when the SM Report was printed (2015) the modelers were using this "natural waters" loophole on a grand scale. They asserted that they could "know" what the pre-modern Deschutes estuary was like by using the Budd Inlet Model with inferred data from the past – estimated stream flows, estimated nitrate concentrations, estimated climate and weather, and the like.[5] The model output grid map shown in Figure 3-7 above actually resulted from two parallel runs – a simulation of the "natural" Budd Inlet estuary and one of modern Budd Inlet -- compared point by point every step of the way. The "violation" shown in each colored square could be from when the natural inlet had low DO's and the modern inlet dropped even lower, or where the "natural" inlet water was above the modern standards but modern waters dropped below the standards 6.0 or 5.0 mg/L. The map gives no hint of which situation resulted in the calculated "violation" shown in each square.

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[5] The modelers refer (SM Report p. 26) to TMDL Appendix I for 'natural' conditions of the past. Confusingly, Appendix I (p. I-7) says that "current" values of the Deschutes River flow – and temperatures and other properties – were used in their simulations of 'natural' pre-modern waters. This is in stark contrast to their reply to my questions about this (see Chapter 9, this Review).

This is the most error-prone procedure of all. The model with all of its leeway for error is first used to decide what the natural estuary was like, then it is used again to compare the modern Budd Inlet with the natural estuary. Probabilities of success get squared in such procedures; for example if the chance of "getting it right" once is only ½ , the probability of getting it right twice is only ½ x ½ = ¼.

This procedure also disguises the severity of the oxygen shortages caused by the calculated "violations." In the dark blue center of Budd Inlet (Fig. 3-7), is the "worst case" DO level at 5.8 mg/L (standard 6.0 less 0.20)? Or is it at, say, 3.6 mg/L ("natural" low DO, say 3.8, less 0.20)? The former would still be "good" water quality, the latter would be critically low in oxygen.

In summary, the "natural water exception" magnifies the probability that the computer produces wrong answers. *It also prevents outsiders from checking the answers*. To do so they would need a copy of the model and a computer and staff comparable to Ecology's to compare the grid maps for the modern and natural estuaries – resources not available to the public and other interested parties.

3-5. Minimizing Errors; Possibilities and Ecology's Responses.

Is there a way to be more confident that the "violation grid maps" really identify locations that are likely to have DO violations? Yes. The answer is to trust averages of numbers, rather than every individual number by itself. For example, suppose that all of the calculated DO values for, say, location BI-1, surface water (0 m depth) and date Sept. 15 for the 6-hour interval centered on a high tide of that day were averaged. (That average would be the mean of about 65 calculations.) If that average was 0.2 mg/L or more below the DO standard for that location, we could be confident that real-life violations should be expected at that time, place, and depth.

For even more powerful confidence, a standard statistical technique for dealing with uncertainty (calculation of "confidence limits") might be applicable. However, a professional statistician's opinion is needed in this case.[6]

The modelers have in the past refused to resort to averages and have insisted that every individual number be taken at face value. In the SPSDOS 2013 Report (p. 35) they have said that averages cannot be used to "mask" the fact that a grid cell's DO dropped even momentarily below the DO standard for that area. They have taken each individual calculation at face value and assume that it is accurate enough for real-life policy decisions.

Their confidence in the dead-on accuracy of every calculation is shown in Report SPSDOS (2013) on page 87. There they describe a location with a modern DO standard of

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[6] Confidence limits can be used and are easy to calculate when the value obtained by each measurement or estimate is completely independent of the values obtained from all other measurements. In the computer's case, the value of each estimate is calculated from the sizes of previous measurements (that is, the values are "not independent"). Only a professional statistician can advise in such situations.

5.0 mg/L where the calculated DO of the 'natural' water dropped to 4.95 mg/L for all or part of just one day out of the 302 days simulated by their model.[7] Using the "natural water exception" loophole, they judge modern waters at that time and place by comparison with 4.95 mg/L -- not the standard, 5.00 mg/L – showing their confidence that their calculations are always accurate even to the second decimal place.

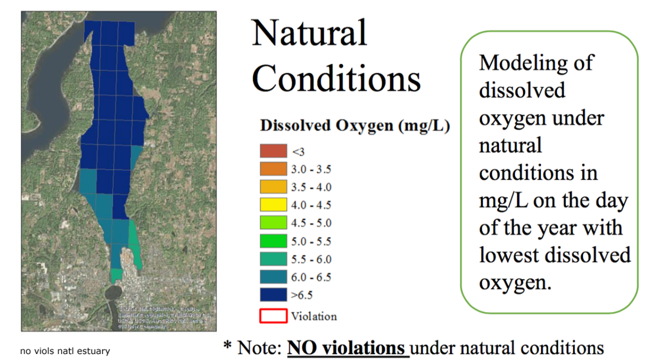
Personnel of the HDR engineering firm asked the modelers about accuracy in the firm's comments on the draft SPSDOS Report (2013). In their words:

"*Page 19: The DO decreases calculated by the model range from 0.2 to 0.4 mg/L in limited areas due to point sources. These are very modest changes in the DO levels in these locations. Due to these small calculated DO decreases, the following question arises: Is the model sufficiently accurate to predict these DO decreases? And more importantly, is there sufficient confidence in the DO decreases calculated by the model to mandate expensive nitrogen removal upgrades at point source treatment facilities to reduce nitrogen loadings?*"

The Department of Ecology did not respond to the HDR query (Clark, 2016).

3-6. No More "Natural Estuary" Calculations?

Calculating the DO violations in the "natural" pre-modern estuary – and showing the results to the public – may be coming to an end. Grid maps of the natural estuary pose a problem of giant proportions for Ecology's drive to implicate Capitol Lake – one so worrisome that they have once again "updated the model." This time around they have changed it so that it no longer shows any DO standards violations in the natural estuary at all (Figure 3-9). That would eliminate the complex method of calculating "violations" in the modern estuary – a good thing – but would also warp the model in ways that could make all of its predictions untrustworthy. That topic is analyzed in Chapter 10.



Natural Conditions

Modeling of dissolved oxygen under natural conditions in mg/L on the day of the year with lowest dissolved oxygen.

* Note: **NO violations** under natural conditions

Figure 3-9. Slide from recent Dept. of Ecology presentation November 16, 2017 showing "natural" estuary with no DO violations anywhere, a result of a model change. Analyzed in Chapter 10, this Review. Source: Weiss, 2017.

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[7] The model used here refers to all of Central and South Puget Sound, but is similar to the Budd Inlet model in its mode of calculation.

4. THE BUDD INLET ESTUARY; "NATURAL" AND MODERN.

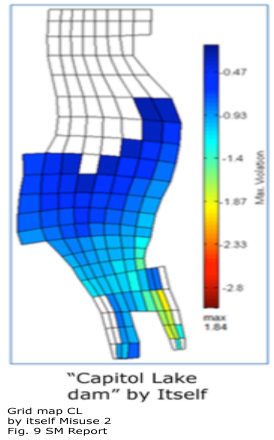
4-1. Overview of Chapter 4.

The Ecology modelers have found over the years that the Budd Inlet Model shows low DO levels that violate modern water quality standards in Budd Inlet, even in its "natural" (pre-modern) condition before it became modified by intense human activities. This runs counter to a popular bias that "natural" is always "good" or even "better than" "human-modified" and complicates their effort to blame Capitol Lake for low DO levels in the modern Inlet. The grid map of the "natural" inlet in the SM Report is loaded with water quality violations. So is the map of modern Budd Inlet with Capitol Lake and the dam in place. The "modern" map is no worse than the "natural" map – a finding that suggests that Capitol Lake has prevented Budd Inlet from getting worse as human activities have intensified around its shores.

This Chapter reports that finding by filling the blank in Figure 4-1. This Chapter also shows that "Budd Inlet with the dam" is no worse than "Budd Inlet without the dam" – and probably *better*. *"Better" because Capitol Lake provides the only factor in play that is able to reduce the natural nitrogen load reaching Budd Inlet as well as the human-caused load.*

4-2. The Missing Natural Budd Inlet Grid Map.

Ecology's SM Report has several repetitions of the modern Budd Inlet (with the dam) grid map showing water quality violations throughout most of Budd Inlet (Fig. 4-1b). A comparable grid map of the "natural" (= pre-dam) estuary is nowhere to be found (Fig. 4-1a). If the "modern" map showed Budd Inlet to be much worse than the Inlet in its natural state, that would help make a case for removing the dam. Why haven't the modelers shown us this?

?	
Figure 4-1a. The Budd Inlet "Natural" (Pre-Modern) Estuary without the dam.	*Figure 4-1b. Modern Budd Inlet with the dam. Source: SM Report Fig. 9, p. 34.*

The reason is that (in the SM Report, at least) the model shows that pre-modern and modern Budd Inlet are both about the same in terms of water quality violations, and that modern Budd Inlet with no dam would be astonishingly better than both. The model says that

1) the dam has kept Budd Inlet from getting significantly worse as human activity has intensified, and

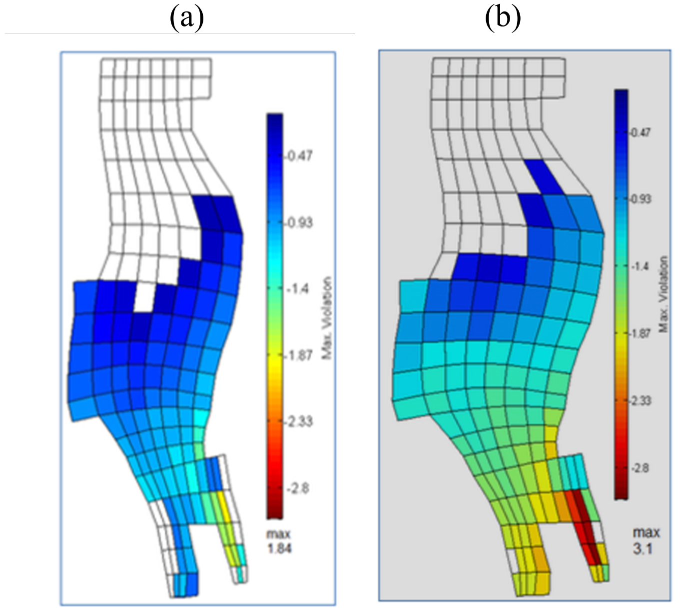
2) all modern human activity would leave Budd Inlet's water quality about the same as it was in the natural pre-modern estuary if only the dam could be removed.

The first may or may not be true; the second is very unlikely.

The sections that follow "fill the blank" in Figure 4-1, and more.

4-3. Reminder. Interpreting Grid Maps.

Figure 4-2a (left) shows the modelers' calculated portrayal of DO violations in modern Budd Inlet allegedly caused by "the dam" by itself (same as in Fig. 4-1b above). Figure 4-2b (right) shows the effects of all modern anthropogenic (that is, human-caused) agents of oxygen depletion -- "the dam," the LOTT Wastewater Treatment Plant outfall between the KGY peninsula and Priest Point, several small creeks, and anthropogenic sources outside (external to) Budd Inlet.



"Capitol Lake dam" by Itself

"Capitol Lake dam" + All Other Anthropogenic Sources

SM viols lake and total Figures

Figure 4-2. Figures from the SM Report showing calculated widespread DO depletion in Budd Inlet due to (a) "Capitol Lake dam" by itself, and (b) "Capitol Lake dam" plus all other anthropogenic (human-caused) sources. The scale colors show the maximum calculated violation in each cell. Source: SM Figures 9 (dam) and 8 (total), p 34 and 33.

The "all causes" map shows more of the Inlet affected by human activities and some areas more severely affected (redder and yellower colors) than would be the case with "the dam" by itself. In these grid maps, each colored square shows the worst DO "violation" of the entire simulated year (January 25 – September 15, 1997). Recall that these maps are made via a massive computer search of the water in each grid square for dissolved oxygen levels that are lower than the water quality standard. The square is "flagged" (colored) if a violation is detected but left uncolored if there are never any violations. The square would be flagged even if a violation occurred just once, at just one depth, and lasted for just six simulated minutes, and would be indistinguishable on the map from a violation of that size that occurred all summer long at that location at all depths.

All of the grid map Figures have colored DO scales. The scales usually show the size of the calculated water quality violation, measured in mg/L below the standard for each location. Dark blue is usually the smallest possible violation (= 0.20 mg/L below the DO standard).

The overall blue color of most violations in Figure 4-2a shows that the about half of the widespread calculated violations "caused" by the dam are the smallest possible "violations." Small, ephemeral, and prone to calculating error though they may be, they create the visual impression that Capitol Lake has a huge negative effect on Budd Inlet.[1]

4-4. Ecology's "Non-Grid" Natural Estuary Map.

The SM Report does contain a "natural estuary" grid map – but not like the one that should fill the blank in Figure 4-1. It's shown in Figure 4-3, which reproduces Ecology's Figure 7 from the SM Report (p. 32). The leftmost grid map (a) shows the dissolved oxygen standards for Budd Inlet, namely 5.0 mg/L in the southernmost reach (orange grid), 6.0 mg/L in all of the rest (green grid). The rightmost map (b) shows the calculated "natural" pre-modern Budd Inlet estuary with no anthropogenic (human-caused) sources of DO depletion, including "no dam."

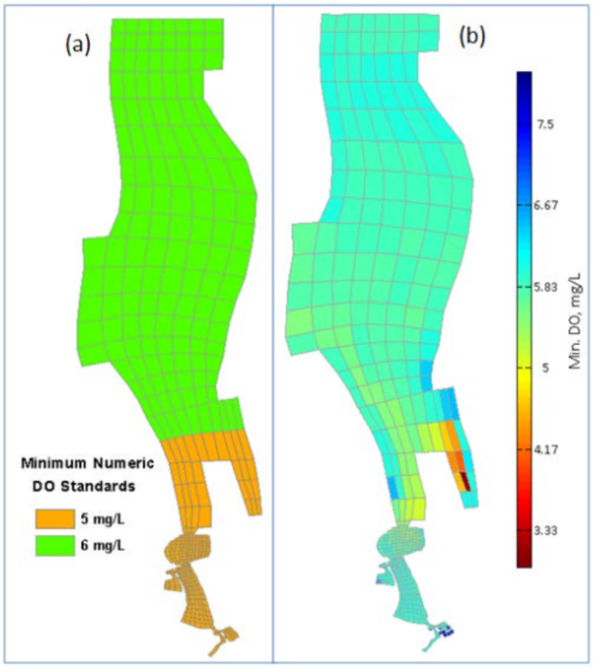


Figure 4-3. (a). Modern water quality standards that apply to Budd Inlet. (b) Minimum dissolved oxygen levels in Budd Inlet as calculated by the modelers for 'natural' waters before they were altered by human activity. (In Fig. 4-3b, the "Capitol Lake" area is an estuarine extension of West Bay.) Source: Both images constitute Figure 7 (p. 32) in the SM Report.

The pre-modern estuary is shown in a format that makes it impossible to see at a glance whether its water quality is better or worse overall than that of modern Budd Inlet. The scale that accompanies it shows the minimum level of DO present at each location when the worst violations occurred – not the sizes of the violations themselves, as do the scales of all other grid maps of modern Budd Inlet (see Figure 4-2 above). Readers must figure out for themselves from the subtle gradations of color whether and where parts of the natural estuary were "in violation."

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[1] See Chapter 3, this Review, for a demonstration that about half of all "blue" grid squares result from calculation errors (as do some uncolored squares). See Chapter 6 (Figure 6-6) for a visual impression of the gigantic size of the external anthropogenic source compared with the Capitol Lake/dam source and a demonstration that "the dam" is probably overshadowed by the external source in its effect on DO water quality violations in Budd Inlet.

This critically important Figure is described by just one sentence in the SM Report; "*The minimum DO under natural conditions is predicted to fall below the water quality standards in portions of Budd Inlet, with lowest DO predicted in East Bay.*" (p. 32, SM Report). One could hardly guess that this bland presentation shows the water quality in the pre-modern inlet to be no better than that in modern times.

4-5. Ecology's Natural Estuary Converted to Standard Grid-Map Format.

It is possible to convert Figure 4-3b to the format and scale of all of Ecology's other grid maps of Budd Inlet for easy comparisons at a glance. The result of that conversion is shown in Figure 4-4a (left). That is the dissolved oxygen violations grid map that should have been in the empty frame of Figure 4-1a. *It is a grid map that the Department of Ecology hoped the public would never see.*

Figure 4-4a shows that calculated water quality violations were about as widespread in the pre-modern undammed "natural" estuary as they are in modern Budd Inlet (Fig. 4-4b). If an interpretation were needed in just one sentence, it would be this; "*Despite decades of intensifying human activities around its shores and in its watershed, modern Budd Inlet with the dam is shown by the model to be about as unimpaired as it was in pre-modern times.*"

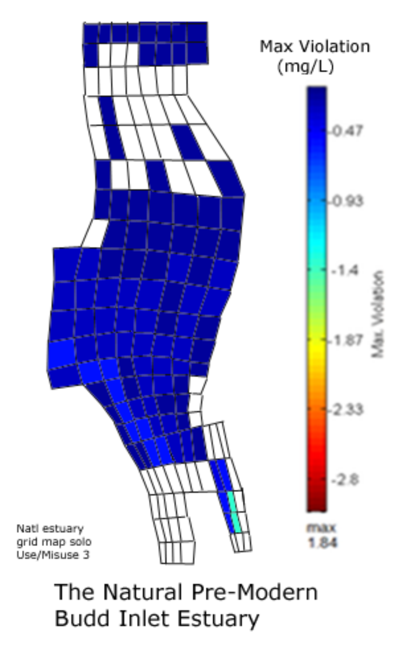

Figure 4-4a. Dissolved Oxygen standards violations in the Budd Inlet "Natural" (Pre-Modern) Estuary. See text for derivation.

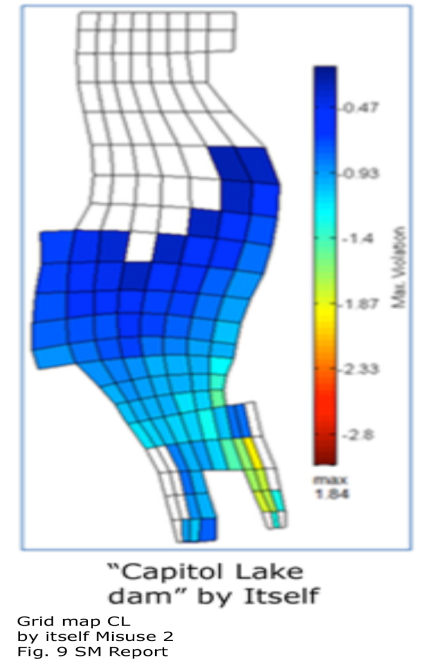

Figure 4-4b. Dissolved Oxygen standards violations in Modern Budd Inlet with the dam. (Same as Figs. 5-1b and 5-2a above.) Source: SM Report's Fig. 9, p. 34.

It is important to recall how the "modern" Budd Inlet grid map (Figure 4-4b) was created. During that simulation, calculated DO levels in "modern" Budd Inlet were compared, grid cell by grid cell, depth by depth, moment in time by moment in time, with their counterpart DO levels in the "natural" estuary (Fig. 4-3b). Wherever and whenever the "natural" estuary's waters were in violation of modern DO standards (as shown in Figure 4-4a), the "modern" Budd Inlet water was compared with the "natural" water to see if its DO levels had dropped even lower. If so, a violation was flagged for that instance. The "modern" Budd Inlet map showing the effect of the dam (Figs. 4-2a and 4-4b) therefore shows *how much worse* the Budd Inlet water has gotten compared with its condition in the pre-modern Inlet. Over most of its blue extent, it is not much worse than during “natural” times. (In fact, “blue” violations represent about 0.20 mg/L, a difference so small that one can hardly measure it in the field.) And in some areas (for example the uncolored northern two tiers) the water quality in modern Budd Inlet is the same as (or better than) that in the “natural” estuary. And always recall that “blue” violations are the most likely ones to be errors resulting from the computer’s large “margin of error” (see Chapter 3).

How was Ecology’s portrayal of the natural estuary (Figure 4-3b) converted to the one shown in conventional grid map format (Figure 4-4a)? My procedure is described in an optional section at the end of this Chapter for readers who care to follow it or try it for themselves.

4-6. The Modern Budd Inlet Estuary.

The SM Report portrays Budd Inlet “without the Capitol Lake dam” – a grid map of the effect of removing the dam on the Inlet’s water quality (Figure 4-5). In that scenario, tidewater extends from West Bay all the way up the present-day Lake basin to Tumwater Falls. The map shown is actually not just the result of removing the dam; it also shows the effects of all other human-caused nitrogen inputs to Budd Inlet.

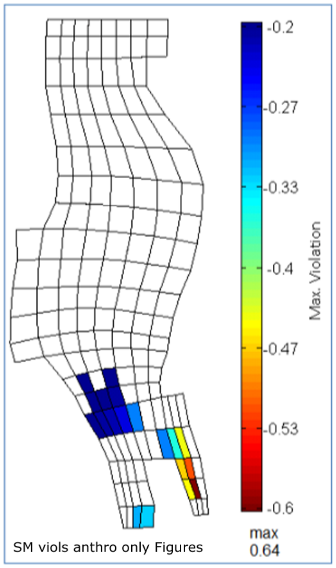

Figure 4-5. Budd Inlet DO violations; no dam, all other anthropogenic nutrient sources present. Source: SM Report’s Figure 17, p. 40.

At face value, this “modern estuary” grid map shows that removal of the dam makes the estuary “worse” in DO terms in only a few areas compared with its “natural” condition (Fig. 4-4a); at the “big blue patch” opposite Priest Point Park and (as always) in East Bay.

A closer look at the bewildering array of simulations of different scenarios that accompany it makes it seem likely that the “no-dam-by-itself” scenario is artificially packaged to look good (in fact “too good to be true”) and that the *real* “Capitol-Lake-dam-by-itself” scenario is much better than presented in Figure 4-4b above. But first, it is useful to keep in perspective the sizes of the anthropogenic factors affecting Budd Inlet.

4-6a. The Sizes of the Nutrient Nitrogen Sources Affecting Budd Inlet.

Figure 4-6 is a thumbnail sketch of the sources of nutrient nitrogen to Budd Inlet. (For close-up details, see Chapter 6.) The sizes of the human-caused inputs are shown by red bars, natural inputs are shown by blue bars, and totals of the two by light green bars.

The first take-away message is that the “external” inputs (from outside Budd Inlet, far right) are gigantic compared with all internal shoreline sources discharging directly into Budd Inlet. The second take-away message is that in all cases, the human-caused inputs (red bars) are smaller than the natural inputs (blue bars). The effect of human activity has been to add a thin “veneer” of additional nitrogen to large natural components that existed before intensive human activity began affecting the water quality. Numbers (not readable in this miniature Figure) are: Deschutes River 327 N, 153 A; Other shoreline sources 51 N, 14 A; LOTT Plant 0 N, 92 A, and External 6860 N, 1488 A; where “N” is the natural daily nitrogen input and A is the anthropogenic daily load in kg N/day. (The Deschutes River figures are the loads before Capitol Lake reduces them by 50-90%.)[2]

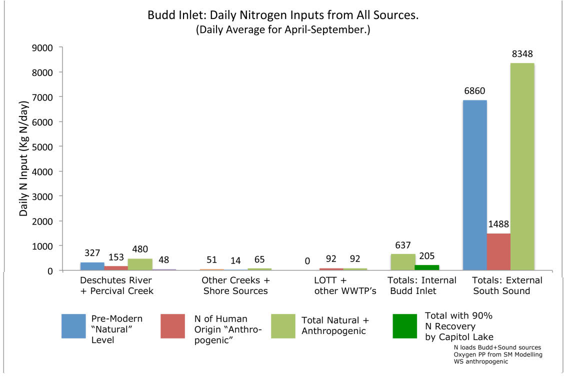

Figure 4-6. Sizes of nutrient inputs to Budd Inlet from four categories of sources. See Fig. 6-4, Chapter 6, for a detailed derivation of this Figure.

4-6b. Budd Inlet Without “The Capitol Lake Dam.” Getting Organized.

A major portion of the SM Report consists of a bewildering scramble of grid maps, text, Figures, Figure captions and passing mention of numbers, all analyzing the effects on Budd Inlet with “no dam” and how the effects change if one or another of the anthropogenic nitrogen source inputs is reduced or eliminated. (Natural nitrogen inputs are *never* reduced in any scenarios.) Table 4-1 (separate page) organizes and summarizes these scenarios.

The columns in Table 4-1 show the following.

Column A describes the scenario conditions simulated and names the Figure showing that simulation outcome as numbered in the SM Report.

Columns B, C, D and E show the changes made (if any) in the anthropogenic nitrogen inputs from each of the four sources shown in Figure 4-6; the Deschutes River watershed, the other small creeks around Budd Inlet’s shores, the LOTT wastewater treatment plant, and the external waters of Puget Sound outside Budd Inlet. (The anthropogenic inputs are the red bars in Figure 4-6). 100% means no change in that input, 50% means it has been reduced by half in this scenario, and 0 means that that input has been eliminated entirely.

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[2] Ecology does not list the sizes of the inputs used in the simulations in the SM Report. The numbers in Fig. 4-6 are taken by me from tables in the TMDL Appendix, used by Ecology in previous simulations. It is possible to reconstruct a few of the numbers used by Ecology from tangential remarks in the simulation descriptions (see optional section 4-10.) They are the same (external) or slightly larger (LOTT, Deschutes watershed, other watersheds) than those in the Fig. 4-6 caption. Their sizes don’t matter, for this discussion.

Column F gives a brief description of “what happened” when that simulation was tried and identifies the Figure in this Review (on a later page) that shows that outcome.

The second row in Table 4-1 was inserted by me. That is a scenario that shows the “effect of no dam” by itself. Ecology’s much-repeated Figure 17 (SM Report; Figure 4-5 above), supposedly showing that, actually does not. It shows the effect of no dam but with all other sources contributing their full loads of anthropogenic nitrogen. I have also indicated in Row A (“with dam by itself” scenario) the sources that Ecology should have used or eliminated to simulate that scenario. (Perhaps these were the values that Ecology actually did use; however they are not listed in the SM Report.)

Why bother with this huge Table? The answer is, I use it to try to make a “best guess” at the effect on Budd Inlet of *removing the dam by itself* – not compounded by including the effects of other anthropogenic nitrogen sources (as Ecology does in Figure 4-5) – and also to give a second opinion “best guess” at the effect of retaining the dam by itself.

4-6c. Table 4-1. Summary and Overview of the SM Report's Scenario Simulations.

A	B	C	D	E	F
Right: Sources → Below: Ecology Figure in SM Report.	Deschutes River	Other Watersheds	LOTT	External	Effect (compared with Ecology Fig.17; shaded).
A) Fig. 9 with dam by itself;	*10%	*0	*0	*0	"violations" all over the map. Fig. 4-7a, this Review.
B) no dam by itself (No Ecology Figure.)	*100%	*0	*0	*0	not shown by Ecology. Fig. 4-7c, this Review.
C) Fig. 17 no dam all sources present;	100%	100%	100%	100%	baseline; Figs. 4-5, 4-7d, this Review.
D) Fig. 18b no dam external source only	0	0	0	100%	huge; clears whole inlet except East Bay.
E) Fig. 19c no dam, watersheds reduced	50%	50%	100%	100%	eliminates "blue patch" opposite Priest Point Park.
F) Fig. 22d no dam all sources @ 100% but LOTT outfall moved to Boston Harbor	100%	100%	~ 0	100%	same as Row E, slightly better. Fig. 4-7c
G) Fig. 23c no dam external reduced	100%	100%	100%	50%	same as Row E, slightly better.
H) Fig. 24c no dam LOTT zero with watersheds reduced	50%	50%	0	100%	same as Row E, notably better.

Table 4-1. Comparison of simulation scenarios in the SM Report (pages 14 – 47). Scenarios are listed in Column A in the order of their appearance in the SM Report, with one addition (Row B) by me. All rows show Budd Inlet with no dam except the first row. Numbers show the percent of each source's anthropogenic nitrogen inputs still operating in each scenario (100% = that source's inputs have not been reduced.) All natural inputs are at 100% in all scenarios. Starred numbers show values that should be used in that scenario (added by me); Ecology does not list them. The shaded row is Ecology's "no dam" baseline scenario with which the others are compared.

4-6d. Figure 4-7; Grid Maps of the Dam/No Dam Simulations.

The outcomes of my effort to compare "dam" vs "no dam" effects on Budd Inlet are shown in Figure 4. The four grid maps are juxtaposed such that the upper row shows Budd Inlet with the dam present over a lower row that shows Budd Inlet with the dam absent. The left column shows the dam/no dam effects isolated by themselves, the right column shows the dam/ /no dam effects in company with all other nitrogen source inputs operating.

Figures 4-7a, -b, and –d are from the SM Report, Figure 4-7c is derived by me.

Figure 4-7d – Budd Inlet with no dam but all other anthropogenic sources present – implies almost no DO standards violations at all. However recall that grid maps formed by comparing the modern situation with the "natural" situation show *how much worse* the modern situation is than the natural situation. Figure 4-7d shows that whatever the modelers did to remove the dam from the model didn't change the "natural" background picture very much. That is not surprising; the "no dam" simulation uses the same gusher of Deschutes River nitrogen nutrients as was used in the "natural" simulation (Fig. 4-4a). If the

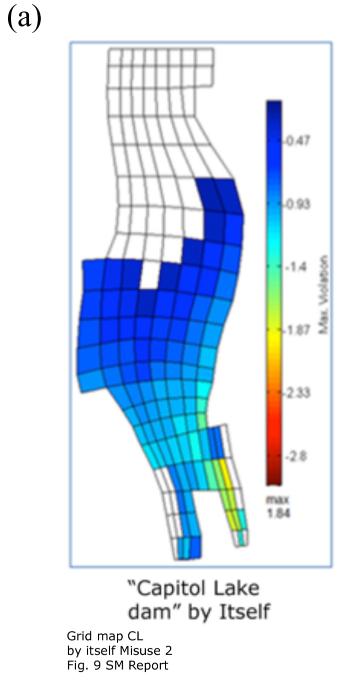

Figure 4-7a. Budd Inlet DO violations; dam present but no other anthropogenic nutrient sources. Source: Fig 9 p. 34 SM Report.

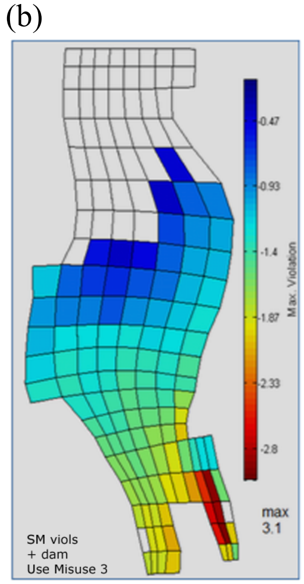

Figure 4-7b. Budd Inlet DO violations; dam present with all other anthropogenic nutrient sources. Source: Fig. 8 p. 33 SM Report.

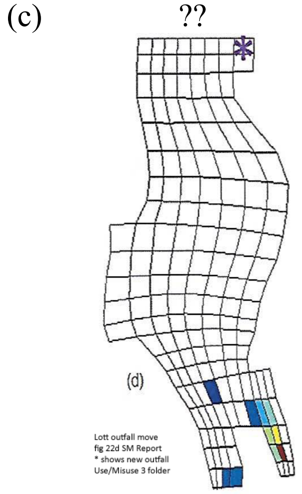

*Figure 4-7c. Budd Inlet DO violations; no dam, no LOTT (outfall moved to *), all other anthropogenic nutrient sources present at 100%. Source: derived by me, see text. (SM Report Figure 22d.)*

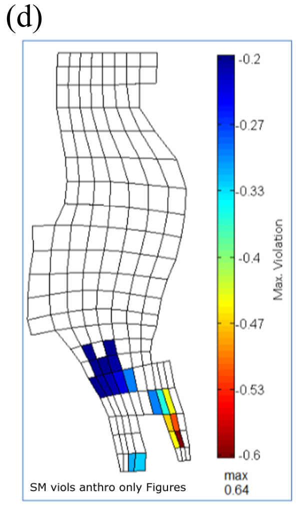

Figure 4-7d. Budd Inlet DO violations; no dam but all other anthropogenic nutrient sources present. Source: Fig. 17, p. 40 SM Report.

violations themselves were shown, the grid map of Budd Inlet with no dam would be as "blue" as Figure 4-4a with much more color in East Bay.

The effect of removing the dam by itself *and with no other sources complicating the picture* is not shown in the SM Report (see Row B, Table 1). I created that Figure (4-7c) from the information in Table 1. The result -- Figure 4-7c -- shows almost no negative effects at all attributable to removing the dam. By dramatic contrast, its counterpart Figure 4-7a shows (small) negative effects attributable to the dam by itself almost everywhere. To an ecologist's eye, the "no dam by itself" outcome is just plain "too good to be true."

For readers interested in how I arrived at Figure 4-7c ("no dam and no other nutrient sources"), that derivation is shown in detail in the Optional sections at the end of this Chapter. Briefly I examined Table 1 for a simulation that approaches most closely the "Budd Inlet without dam" scenario in Row B of the Table; full blast 100% Deschutes River input, zero, zero and zero for Other creeks, LOTT, and External sources. The closest example was that of Row F (LOTT outfall out of the picture, Other creek effects small even at 100%, and almost no measurable external effects when all other sources are at zero (Row D).

4-7. "With Dam" Scenarios Compared; Ecology's vs. This Review's Versions.

Is it possible to check up on Ecology's "Budd Inlet with dam by itself" (with no other anthropogenic sources) claim (Fig.4-7a)? To do that, one would need to find the scenario in Table 1 that most closely approaches the conditions shown in Row A; that is Deschutes River with 90% of both anthropogenic and natural nutrient loads reduced by Capitol Lake and the three other input sources at zero, zero, and zero.

The closest approach to a "dam by itself" scenario in Table 1 is Row H. The Deschutes River anthropogenic nitrogen input is reduced by 50% (mimicking the effect of Capitol Lake), the LOTT input is reduced to zero, and the very small and localized "Other creek" sources are reduced by half. The huge external input is left intact at 100%; there's nothing we can do about that. The grid map resulting from that simulation is shown in Figure 4-8b. For our grand finale, the "natural Budd Inlet estuary" is also repeated for comparison in Figure 4-8a.

Recall that the two portrayals of "Budd Inlet with dam" do not show the whole story. Each shows the additional violations that would be "piled on" the natural estuary; that is, how much worse off Budd Inlet is with the dam than it would be without it. The complete grid map of violations would be "blue all over" (the natural estuary map) with even more blue (and other colors) added by the two scenarios to the right. Even piled on, the additional violations caused by "the dam" in either case (Fig. 4-8b and 4-8c) are so tiny (blue) that composite violations map shows "no real problem here."

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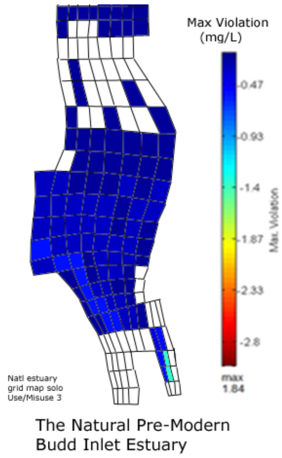
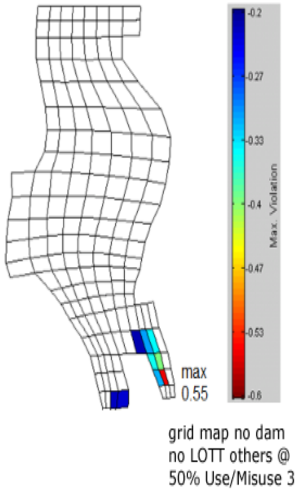
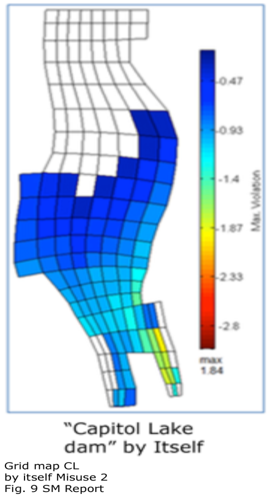
<td> </td>
<td> </td>
<td> </td>
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<tr>
<td>Figure 4-8a. Dissolved Oxygen standards violations in the Budd Inlet "Natural" (Pre-Modern) Estuary. Source: Derived from Ecology's Figure 7, SM Report.</td>
<td>Figure 4-8b. Budd Inlet with dam and no other human-caused inputs. Source: ID'd by author as closest to Ecology's "with dam" scenario Fig. 24c, SM Report.</td>
<td>Figure 4-8c. Budd Inlet with dam and no other human-caused inputs. Source: Figure 9 p. 34 SM Report. Ecology's version.</td>
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4-8. Summary of With/Without Dam Scenario Outcomes.

1) The "natural" estuary with current levels of natural nitrogen inputs (and none from non-human sources) is loaded with water quality standards violations (Figure 4-8a);

2) "The dam by itself" is claimed by Ecology to make the Inlet even worse than it was in its natural state almost everywhere (Figures 4-8c);

3) The effect on Budd Inlet of "no dam by itself" as shown by Ecology is actually "no dam but with all other sources operative" (Figure 4-7d);

4) One of the scenarios (Row F, Table 1) gives a rough estimate of what "no dam by itself" really looks like (Figure 4-7c);

5) The scenario in Row H, Table 1, allows an estimate of what "with dam by itself" would look like (Figure 4-8b), which is almost certainly better than that shown in this Figure. (Better, because Capitol Lake would capture more than 50% of the anthropogenic nitrogen and because any effects of the other watersheds and external source would be eliminated.)

The simple bottom line is that Budd Inlet with Capitol Lake in place is almost certainly better off than it would be if the Lake were removed, but the Department of Ecology shows the opposite.

4-9. Budd Inlet is Better Off With the Dam than Without it.

Unscrambling the scrambled tangle of scenarios and assertions made in the SM Report has been one of the most difficult intellectual challenges I've faced in years. By their nature, computer simulations are complex beyond measure and fully capable of revealing phenomena that are, on the face of it, anti-intuitive. In this case, it is ecologically unthinkable that a Lake capturing almost all of the nutrients – *of both natural and anthropogenic origin* that the Deschutes River would otherwise pour directly into Budd Inlet -- has a negative effect on the Inlet whereas removing the Lake would somehow make water quality out there dramatically improved. Yet this is what Ecology tries to use its computer model to prove.

The un-edited, un-peer-reviewed scramble of verbiage, numbers and maps that is the SM Report makes analyzing their claim even more difficult. Nowhere do they provide a detailed description (in the form of data) of what they mean by "no dam." What was actually changed in the model to make those simulations? Nowhere do they summarize the numerical values that the computer used in the scenarios they tested. (Some numbers are mentioned tangentially in some brief scenario descriptions.) Nowhere is there a Table resembling my Table 1 above summarizing the scenarios for readers, or a Figure resembling my Figure 4-6 reporting the sizes of the nutrient inputs to Budd Inlet. Analyzing all this to try to see if their presentations support their claims is a near-impossible task.

My conclusion is that the Ecology modelers, perhaps confused themselves by the complexity of the task,[3] have mistakenly claimed that "no dam" is better than "with dam" for Budd Inlet. My own conclusion, from their own publications and real-world ecological intuition, is that the opposite is true:

Budd Inlet is better off with the dam than without it.

4-10. Optional. Figuring Out the Data Used by Ecology in the Scenarios.

The modelers do not list the anthropogenic nitrogen input values used in the Table 4-1 scenarios for each of the four sources of inputs to Budd Inlet, but some of them can be inferred as shown in Table 4-2.

1	Total anthropogenic load	1980 kg N/day	mentioned on SM page 40
2	External source	1488 kg N/day	mentioned on SM page 41
3	Deschutes, other, & LOTT	492 kg N/day	line 1 above minus line 2
4	Deschutes and other	296 kg N/day	from 50% reduction x2 SM p. 42
5	LOTT	196 kg N/day	line 3 above minus line 4
6	Deschutes by itself	--	no way of determining this value
7	Other (including Moxlie Cr)	--	no way of determining this value

Table 4-2. Anthropogenic Nitrogen Inputs used in the SM Scenarios of Table 4-1. (Natural Inputs not shown (all at 100%, all scenarios).

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[3] See Chapter 6, discussing likely model confusion attributing external source effects to Capitol Lake.

These anthropogenic input values compare with those shown in Figure 4-6 above as follows (underlined values are from Figure 4-6); external 1488 and 1488 same; LOTT 196 vs 92; Deschutes + Other 296 vs. 167. For the SM scenarios the modelers have used much larger values for the LOTT input and for the (Deschutes River + Other) sources than are named in the main data tables that the modelers cite in their TMDL Report.

4-11. Optional. Transforming the Natural Estuary Grid Map.

How was Ecology's portrayal of the natural estuary (Figure 4-3b) converted to the one shown in conventional grid map format (Figure 4-4a)? My procedure is described in this section for readers who care to follow it or try it for themselves.

I examined a full screen image of Ecology's 'natural' estuary map (Fig. 4-3b), obtained from an on-line ecology website ("SM Report on line," References) using Photoshop software (Photoshop Elements 12 Expert Level).

First I constructed a black-and-yellow scale bar and scaled it to fit the modelers' erratic color scale gradation (shown in Figure 4-9a). I then used the "polygonal lasso" selection tool to carefully select the interior color of one square on the image in Figure 4-3b, taking care not to include any parts of the grid lines. I then clicked "Similar" under Photoshop's Selection Menu. This highlights ("selects") every grid square in the Figure that has a "similar" color *and also that color on the modelers' scale bar.*

The selected similar color on the modelers' scale always spanned a small range whose upper and lower limits could be measured with my own calibrated scale. I hand-annotated all selected grid squares on a printed copy of the grid, noted the DO range indicated on the scale, and repeated the process by deselecting the image and selecting another grid square. (Notation by hand was easier than storing all of the values in computer memory at this stage.) I continued this until every grid square on the printed map was filled. Later in the procedure I transferred the key colors of the violations to a preliminary computer-generated grid map – Figure 4-9b – as described below.

Table 4-3 summarizes these measurements. These could be grouped into three partially overlapping categories in the central inlet (the "green zone," Figure 4-3a) and three additional partially overlapping categories in the southernmost inlet (the "orange zone, Figure 4-3a). Columns A and B (Table 4-3) show the upper and lower limits of these categories. Mean values of the categories are shown in Col-

Sizes of Water Quality Violations in Natural Estuary.				
A	B	C	D	E
upper DO (mg/L)	lower DO (mg/L)	Mean (mg/L)	Max. Violation (mg/L)	Key Color (preliminary for Fig. 5-5b)
(Central Inlet)				Central Inlet std = 6 mg/L
5.90	5.70	5.80	0.30	blue
5.83	5.60	5.72	0.40	green
5.70	5.40	5.55	0.60	orange
(Lower Inlet)				Lower Inlet std = 5 mg/L
4.90	4.50	4.70	0.50	orange

umn C.

Water quality violations occur when values fall 0.20 mg/L or more below the standard. Column D shows the size of the violation at the lowest value of each category.

4.60	4.20	4.40	0.80	yellow
4.30	< 3.00	3.65	>2.00	red

Table 4-3. Conversion of the scale of Figure 4-3b (amount of oxygen in the water, mg /L) to the scale of Figure 4-4a (size of DO violation, mg/L). Size of the 'violation' (Column D) is the difference between the lowest DO value of each selected batch of similar grid squares (Column B) and the size of the standard; 6.0 for the central inlet, 5.0 for the lower inlet.

Early in this work it was not possible to use the same colors for violations as those used by the modelers. I assigned colors to the violation categories as shown in Column E and created a preliminary grid map using those colors (Figure 4-9b). Subsequently I created the finished natural estuary grid map (Figure 4-4a) by converting the preliminary colors to those used by the modelers.[4]

4-12. Optional (continued). Details and Reliability of the Selection Process.

The Photoshop "similar selection" process clearly identifies the squares with similar colors in, say, 90% of cases while leaving some doubt about others. (In the doubtful squares, the selection lines may follow only three of the four grid square sides, or wander across some grid square boundaries, or appear as small shimmering "islands" in the centers of some otherwise unselected squares, etc.) I resolved doubt in most cases by selecting the doubtful squares themselves and clicking "Similar" on the Selection Menu. Where doubt was not completely resolved, if any part of a grid square was selected I considered the whole square to be selected.

There was little overlap of the grid squares selected in this way. Perhaps five of all of the grid squares ultimately selected by all of the similarity searches were highlighted more than once throughout this process. In those cases, I assigned the lower of Photoshop's two "DO readings" to such squares. Groups of squares that were never matched with DO scale values of 4.8 – or 5.8 mg/L or lower (orange or green violation thresholds in

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[4] The preliminary grid map was presented in the first draft of this report posted on the CLIPA website.

Figure 4-4a), or whose mean DO's exceeded these limits were judged to be in compliance with water quality standards and were left uncolored in Figure 4-9b, the intermediate step in this process. The sizes of the violations thus estimated were assigned colors; these were "painted" into the appropriate grid squares to create the preliminary violations map with its own color coded violations scale (Figure 4-9b). (The grid map to be painted was created by tracing all of the grid lines in Ecology's map with Photoshop's line tool, finally merging all of the lines into a single layer and coloring each grid square with the paint tool.)

Because of the labor-intensive time-consuming nature of this process, I stopped there and showed the preliminary map in the first draft of this report. Continuing recently, I converted the violations colors to those used by Ecology and painted the grid map with those colors, obtaining the final corrected natural estuary grid map (Figure 4-4a, above).

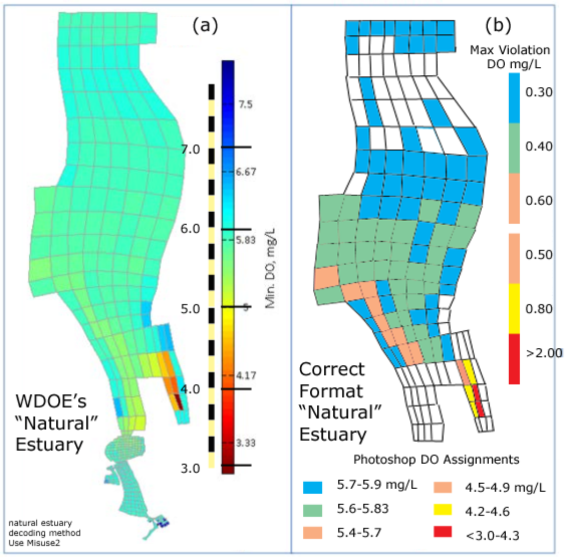

Figure 4-9. Conversion of Ecology's "natural" estuary DO levels to Ecology's conventional format for displaying water quality violations. Left: Ecology's "natural" estuary DO's with my readable scale. Right: Preliminary grid map of Budd Inlet in Ecology's conventional format obtained via Photoshop from the leftmost Figure. See text.

4-13. Optional. The Derivation of "Budd Inlet With No Dam" (Figure 4-7c).

A scenario that shows the effect of "no dam" by itself should include the Deschutes River source at 100% of its "natural" nitrogen content and zero for every other source (as in Row B, Table 1). (Any lesser Deschutes River input with "no dam" would be secretly giving "no dam" credit for removing both natural and anthropogenic nitrogen, something that only happens when the Lake is in place.) Deciding which of the four scenarios actually shown by Ecology approaches the Row B combination most closely is based on the following.

First, I disregarded the "Other Watersheds" category of nitrogen inputs; that total is very small (see Figure 4-6) and mostly confined to East Bay.

Second, the huge External source by itself (Row D, Table 1) shows almost no effect whatsoever on Ecology's simulated Budd Inlet; the grid map of that scenario (not shown here) is clear of violations everywhere except for a few small ones in East Bay.[5]

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[5] See Chapter 6. I believe that the external source is responsible for a lot more DO depletion in Budd Inlet than the modelers recognize.

Third, scenarios that reduce or eliminate the LOTT plant effect (Rows D, F and H, Table 1) wipe out most of the “big blue patch” of violations that is the dominant feature of the baseline scenario (Figure 4-7d).

All things considered, Row F shows the closest approach to a “no dam by itself” scenario. The Deschutes watershed input and Other watersheds are at 100%, the crucial LOTT input is moved to the mouth of Budd Inlet (and is effectively 0), and the External source left at 100%, as claimed by the modelers, has almost no effect on violations in the simulations.

Figure 4-7c shows the map from the scenario in Row F. That map (SM Report’s Figure 22d) is the closest thing to a “no dam by itself” scenario to be found in the SM Report.

The Department of Ecology's Supplemental Modeling Report.
A Critical Review.

5. ECOLOGY'S BUDD INLET MODEL: FLAWED SCIENCE.

Back in 2008, the directors of three state agencies signed a letter advocating removal of Capitol Lake and reopening its basin to tidal waters.[1] At that time the idea was new and worth exploring. Unfortunately, despite a wealth of contrary evidence compiled since then, the agencies have persisted with this objective with immovable determination. Ecology's drive to eliminate Capitol Lake, using the Budd Inlet Model as its centerpiece, has been especially resistant to redirection.

In ordinary science, if the preponderance of real-world observations and facts don't support one's hypothesis, most scientists accept that the hypothesis is not true. Not Ecology. Ecology's reaction to skepticism about its claims based on the Budd Inlet Model has always been to change ("update") the model and run it again, never to defend or better explain what they claimed to prove the first time or … unthinkable to them … admit they were mistaken.

Ecology maneuvers its model findings to enforce the view the Capitol Lake must be eliminated in the following ways:

1) by omitting running simulations likely to show a positive effect of the Lake on Budd Inlet;

2) by downplaying outcomes of simulations that show ways of improving Budd Inlet other than by removing Capitol Lake;

3) by distracting readers and reviewers with simulations of trivial unlikely scenarios and science-like meaningless graphs;

4) by resorting to "explanations" of the Lake's effects that can't be checked by analyzing any known real-world data.

To make matters worse, the modelers have made errors in key calculations and have based important claims on ecologically impossible assumptions.

All of these faults are prominent in Ecology's SM Report. These are described and analyzed in this Chapter.

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[1] The directors were Jay Manning (Dept. of Ecology), Phil Anderson (Dept. of Fish and Wildlife), and Peter Goldmark (Dept. of Natural Resources).

5-1. Avoidance of Simulations Likely to Exonerate Capitol Lake.

5-1a. The Missing Simulation of Plant Harvesting … Background and Evasion.

When the TMDL Report came out in 2012, sections that focused on Capitol Lake said nothing whatsoever about the Lake's uptake of nitrogen nutrients by its lush growth of plants. The Lake was (and still is) removing the huge load of nitrogen carried into it by the Deschutes River and preventing it from reaching Budd Inlet during the growing season -- an immense benefit to the Inlet's water quality. The Lake's nitrogen uptake has been well known since 1977 when the CH2M-Hill consultants carried out the most comprehensive study of Capitol Lake ever made (CH2M-Hill, 1978).

Ecology's "TMDL Advisory Group" – some two dozen representatives of area agencies and organizations – hadn't commented on this omission at the time when I began attending meetings (2013). I questioned it and met with the Advisory Group's leaders to propose bringing it up in a presentation to the group. (Others, notably members of CLIPA,[2] also starting asking questions about this during the meetings at that time.) The TMDL meetings were abruptly canceled and by the time I was able to give a presentation (to a different group, jointly with Ecology modelers) the agency had "updated the model" and produced a Poster with a new approach.[3] That is, the nitrogen uptake by the Lake was acknowledged, but the new claim was that the uptake didn't matter because the plants that captured the nitrogen were immediately carried over the dam into the Inlet where their decay depleted oxygen there. (The key phrase used by Ecology to refer to this claim, then and now, is that "organic carbon" – "TOC" – from the Lake depletes oxygen in Budd Inlet.)

The Poster Figure (also presented as Figure 11 p. 36 in the SM Report) is shown here for reader recognition (Figure 5-1). The Estuary TOC calculation (upper graph, blue) is in error and under-calculates at least half of the proposed Estuary's organic carbon production for the simulated (Lake Basin) area. It also hides the large remainder of the missing organic carbon in Budd Inlet outside the simulated area. The Lake TOC contribution to Budd Inlet (upper graph, green) can't possibly be as high as shown in any real-world plant-filled lake. I show these errors of calculation and interpretation in Chapter 7.

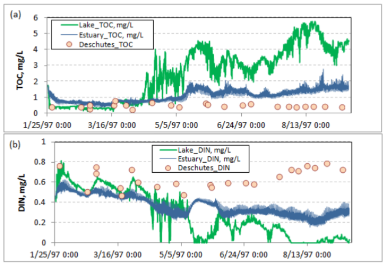

Figure 11. a) Total organic carbon (TOC) and b) dissolved inorganic nitrogen (DIN) concentrations at the location of the Capitol Lake dam under Lake (with the dam) and Estuary (without the dam) scenarios compared with concentrations in the Deschutes River at E Street.

Poster graph Grab2 > Figures

Figure 5-1. Basis of Ecology's "organic carbon" claim. See Chapter 7, this Review. Source: Figure 11, SM Report, p. 36.

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[2] CLIPA = Capitol Lake Improvement and Protection Association, the leading local group advocating preservation of the Lake. The CLIPA webpage is cited in References, this Review.

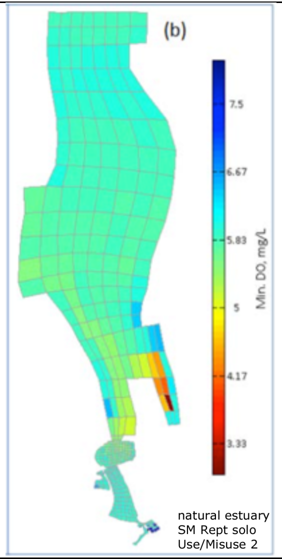
[3] The "update" was an "adjustment" of the uptake of dissolved oxygen from the water by the sediments. This adjustment had nothing to do with real-life data; it was said to create a better match between the Budd Inlet model and features of a larger regional model for all of Puget Sound. The Poster also presented a new grid map of Budd Inlet showing very widespread negative effects of Capitol Lake – more persuasive than Ecology's first feeble attempt at this shown in the TMDL Report.

We seldom have an opportunity to physically remove nutrient nitrogen from natural waters – but the opportunity is there in Capitol Lake. That could be done by periodically harvesting the macroscopic plants, removing organic carbon and nitrogen from the Lake and clearing the way for more nitrogen and carbon removal by regrowth and follow-up harvesting of the plants. Ecology did not model this scenario. *This deliberate omission is the most irresponsible feature of the entire SM Report.*

Blithely assuming the role of harvesting experts while speaking from utter ignorance of real-life aquatic ecology, the modelers assure us that they already know that such a simulation would be unhelpful.[4] Based on their guesses about phosphorus, phytoplankton, the tonnage required and the like, they chose not to simulate plant harvesting (p. 69, SM Report). *That is the foremost example of Ecology's avoidance of conducting simulations that might show beneficial effects of Capitol Lake.*

5-1b. The Missing Simulation of Moxlie Creek's Effect on East Bay.

Another simulation avoided by Ecology is that of isolating Moxlie Creek to analyze its effect on East Bay. East Bay is the epicenter of low dissolved oxygen conditions for all of Budd Inlet. Virtually every simulation of different combinations of human-caused effects results in a map showing more-or-less low dissolved oxygen there. Even a simulation of the "natural" Budd Inlet estuary before it was affected by any human activities at all shows the East Bay low DO "hot spot" (Figure 5-2).



natural estuary
SM Rept solo
Use/Misuse 2

Figure 5-2. The Budd Inlet Model's "natural estuary" (pre-modern Budd Inlet) simulation result. Red shows large DO violations in East Bay. Source: Fig. 7b in the SM Report, p. 32.

The East Bay DO violations there are usually the most persistent and severe in all of Budd Inlet. It is likely that these low DO's are created by Moxlie Creek (at the head of East Bay) and supported by Mission Creek (just south of Priest Point Park). Both creeks have nutrient nitrogen concentrations that are among the highest of all waters that enter South Puget Sound (SPSDOS 2011). Their small flow volumes are not enough to drive strong estuarine circulation in the constricted East Bay embayment and a curtain of rising fresh water from the LOTT outfall might be creating partial blockage of the estuarine circulation there. A breakwater restricts the size of the entrance and a flotilla of moored boats and docks restricts contact between the water and the atmosphere. Finally, an oxygen-reducing process never mentioned by the modelers (the "null zone effect," see Chapter 1) is probably at work in East Bay.

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[4] To the contrary, Capitol Lake is an ideal location for physical removal of tons of vegetation. A preliminary estimate is that some 7 metric tons of nitrogen nutrients *or more* could be removed from the Lake each summer (Steelhammer, pers comm. 2018). See Steelhammer & others, 2018.

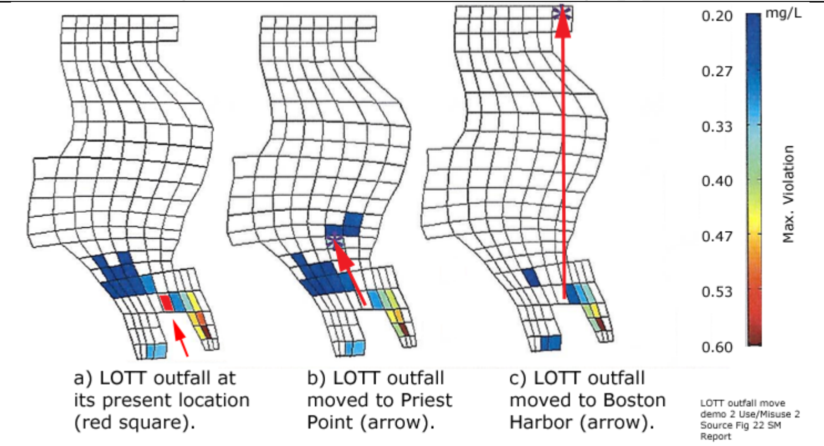
As the Budd Inlet Model was configured in 2014, Moxlie Creek was not treated separately; it was lumped together with several other small creeks and shoreline sources around Budd Inlet (Kolosseus, pers com. 2014). I suggested that it be isolated and its effects simulated. To my knowledge, isolation of Moxlie Creek as a separate source has not been done.[5]

Several of the "other" creeks lumped together with Moxlie Creek in the simulation (Butler, Ellis, Gull Harbor) are far from East Bay. Moxlie and Mission Creeks enter East Bay (Moxlie) or are close-by in a position to influence it (Mission). Moxlie Creek's effect could still be simulated in the present model by running a simulation with no LOTT, no Deschutes River, and no External Source contributions to Budd Inlet, leaving only the small "Other Watersheds" contribution. Then deleting the Other Watersheds. To my knowledge, the modelers have not done so – or at least not shown the findings of any such simulation.

If Moxlie Creek is the source of the DO depletions in East Bay, that would kill all talk of blaming "the dam" as deleterious to Budd Inlet once and for all. This critical simulation has been avoided.

5-2. Downplaying Solutions Other Than Eliminating Capitol Lake.

Figure 5-3 shows the effects of relocating the LOTT outfall (the discharge pipe for treated wastewater) away from its present location. In all of these scenarios, all human-caused sources of oxygen depletion (the LOTT outfall, the minor contributions of three small local treatment plants, and a few tiny creeks are included. Specifically, all "dam" effects are excluded.



a) LOTT outfall at its present location (red square).

b) LOTT outfall moved to Priest Point (arrow).

c) LOTT outfall moved to Boston Harbor (arrow).

LOTT outfall move demo 2 Use/Misuse 2 Source Fig 22 SM Report

Figure 5-3. Simulated changes in Budd Inlet dissolved oxygen resulting from relocations of the LOTT treated effluent outfall. All anthropogenic nitrogen inputs are present. Outfall at (a) in its existing location, (b) at Priest Point Park, and (c) at Boston Harbor. Source: Figure 22 SM Report, p. 45, same as "no dam" baseline scenario, Figure 4-5, this Review.

Scenario (a) shows the outfall at its existing location with small oxygen

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[5] Three simulations in the SM Report removed or reduced the "other watersheds" category that includes Moxlie Creek. In one, *all* local sources of human-introduced nitrogen nutrients (Deschutes River, "other watersheds," and LOTT) were eliminated leaving only the external source (see Figure 18 SM Report; also Table 4-1 Row D this Review). In the second, inputs from the Deschutes and other watersheds were reduced by half (Fig. 19c SM Report p. 42; Row E Table 4-1). The third reduced all watersheds' inputs by half, set LOTT at zero and kept the external source at 100% (Row H Table 4-1). The effect in all cases was to obliterate most violations – but East Bay was largely unchanged.

standards violations (as colored squares) in that scenario. Scenario (b) shows what the oxygen situation would look like if the outfall was moved to the Priest Point area, scenario (c) shows the effects of moving it to Boston Harbor.

Scenario (c) suggests that moving the outfall to Boston Harbor would eliminate more than half of the minor DO violations occurring in southern Budd Inlet while leaving the larger ones in East Bay untouched. The overall effect is positive, though small, and policy makers – not Ecology – would have to decide whether the cost of moving the outfall would be worth the benefit. The modelers acknowledge nothing positive, dismissing this simulation with the words "Shifting the outfall location would not improve oxygen significantly."

That is an example of the strategy of downplaying all other feasible actions except for "elimination of the dam," leaving the perception that the latter is the only possible way of improving Budd Inlet water quality.

5-3. Trivial Simulations, Meaningless Graphs.

The SM Report presents a barrage of Figures aimed at showing that "the dam" causes widespread DO depletion throughout Budd Inlet. These Figures raise more questions than they answer.

Regarding nitrogen, the modelers present three Figures using data from other sources, reproduced here. They show nothing that supports Ecology's claims. One is from a source (Evans-Hamilton, not cited in the SM Report's References) that I have not seen.

Figure 5-4 shows nitrogen concentrations in the Deschutes River and at an unidentified site in Capitol Lake ("CL-6") said to be near the dam. It shows, as expected, that the Lake doesn't remove nitrogen from the water during the winter. Nitrogen concentrations near the dam appear to begin to drop by early June, as expected – but there the data abruptly end.

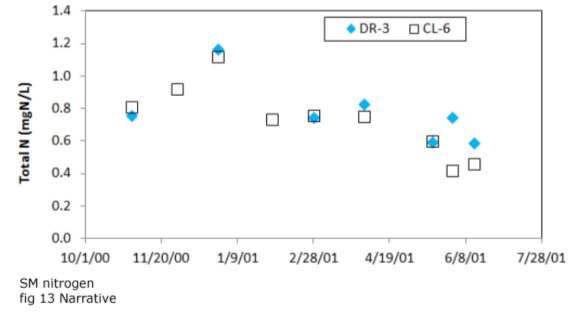
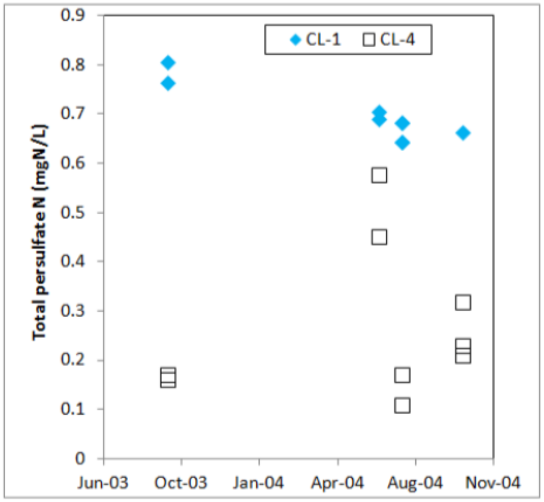


Figure 5-4. Modelers' portrayal of "total nitrogen" in the Deschutes River and at location CL-6 ("near the dam") vs. dates in 2000/2001. (Site CL-6 is not shown on an accompanying map of Capitol Lake.) Attributed to CH2M-Hill 2001 by the SM Report. This Figure is Fig. 13, SM Report, p. 37.

Figure 5-5 shows additional data included in the SM Report, equally devoid of anything that supports the modelers' claims. It shows the concentrations of "persulfate nitrogen" (obtained via a technique that measures nitrogen in drifting bits of organic matter as well as the dissolved organic nitrogen – DIN -- in the water) at two sites in Capitol Lake, one at the extreme south end of the Middle Basin (CL-1) and the other near the dam (CL-4). This Figure shows dramatic drops in persulfate nitrogen in summers 2003 and 2004. That is exactly what we already know about the Lake, namely that it removes nitrogen from the water as the water flows toward the dam.



pers nitrogen
SM fig 14 Narrative

Figure 5-5. Removal of persulfate nitrogen from Lake water as the water moves toward the dam. Sites in Capitol Lake are CL-1 (near the entry of the Deschutes River to the Lake) and CL-4 (in the North Basin near the outlet at the dam). Attributed to Roberts, Bos and Albertson, 2008. Source: Fig. 14 (in part), SM Report p. 37.

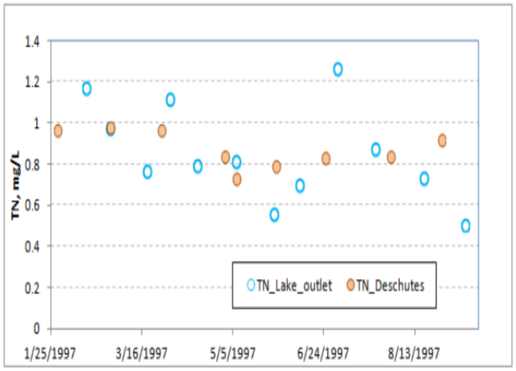


Figure 12. Total nitrogen concentration in the Deschutes River and at the location of the Capitol Lake outlet near dam during 1997.

Source: Evans Hamilton Capitol Lake data used in the 1997 Budd Inlet Scientific Study and Ecology continuous monitoring data for Deschutes River at E Street. Evans Hamilton data graph

Figure 5-6. "Total Nitrogen" concentrations in Deschutes River (orange dots) and Capitol Lake near the dam (blue circles), January 1 to about late August, 1997. SM Report Figure 12 p. 36, including caption. Modelers' sources "Evans-Hamilton" and "Budd Inlet Scientific Study" are not cited in their References.

Figure 5-6 from an Evans-Hamilton source (not seen by me) shows no significant change in the "Total Nitrogen" between the Lake Outlet and the Deschutes River between January and August, 1997, then a drop in TN by August's – and the data set's – end. This, as do the other two, shows the Lake's nitrogen removal function in action – none in winter, some in spring and summer – not what Ecology wants us to think.

To someone casually flipping through the pages of the SM Report, the graphs give an "appearance of science". Internal contradictions like these would never escape a peer reviewer if the SM Report had been submitted for real-world publication.

In the "trivial simulation" category, one scenario in the SM Report addresses nitrogen inputs to Budd Inlet from "boater wastes" and "marina wastes" (SM Report Tables 4 and 5, p. 51). While these subjects merit attention, including them while omitting studies of the effects of Moxlie Creek and harvest removals of plants from Capitol Lake shows Ecology's focus on topics not likely to be significant while avoiding those likely to exonerate Capitol Lake.

5-4. "The Dam" (Not Capitol Lake) is the Problem … or is it?

The SM Report emphasizes "the dam" as the cause of oxygen degradation in Budd Inlet, rather than some water quality property such as nutrient levels. By this semantic strategy Ecology directs public focus toward hydrodynamics and away from water quality as the reason for the alleged negative effect of Capitol Lake on Budd Inlet. Blaming it on water quality makes it possible for skeptical reviewers to question their claim; hydrodynamics is a near-impossible subject for skeptical reviewers to assess. However, it is also difficult for Ecology to make that case. The following shows that they haven't done so.

Page 34 of the SM Report presents three claims that describe how the modelers think the Lake exerts its negative effect. The first is a classic example of a hydrodynamic effect that is impossible for readers to question. That is:

1) "The dam creates a pulsed flow that alters circulation in southern Budd Inlet."[6]

The modelers never define "pulsed flow" for readers nor do they say how "pulsed flow" changes circulation in Budd Inlet, let alone East Bay. They may mean the changes in flow that result from opening and closing the gates in the 5th Avenue dam. Those gates are adjusted near-daily with the intent of maintaining the water level of Capitol Lake as near as possible to a "Set Point." In winter the Set Point is 5.8 feet above Mean Sea Level, during the summer the Set Point is 6.4 feet > MSL. (The latter is roughly at the +15 foot local tide level.)[7] The high Deschutes River flows during winter necessitate opening the gates three or four times every day at that time to maintain the lake level. Only about one adjustment per day is needed in summer to maintain the Set Point water level.

The gates are never opened during the one or two daily intervals when the tide level is higher than the lake level. That is, under modern ordinary circumstances, saltwater is never deliberately admitted to the Lake through the tide gates. The gates are opened only when the Lake level is about six inches (or more) higher than the salt water level outside; the flow is mostly fresh water outward with slight mixing by salt water "leaking" inward during those openings (see BISS 1998 for a description of gates and the opening regime).

Salt water does enter the Lake daily, however, via another route during late summer and fall. A fish ladder (width 9.5 feet) for migrating salmon is positioned at the east end of the dam alongside the tide gates. In 1997 it was closed during the winter but left open from August through December to enable entry of salmon to the Lake. Recently it appears to be open throughout the entire year. Most of the flow through this opening is fresh water going outward. However when the tide rises higher than the lake level, salt water enters the lake. When that happens, a torrent of brackish water pouring through the

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[6] For completeness, the other two are: 2) "The dam and lake alter the concentrations and loads of carbon." 3) "The dam and lake alter the concentrations and loads of nitrogen. The assimilation of inorganic nitrogen by freshwater plants (e.g., *phytoplankton*) with corresponding production of organic carbon alters discharges into Budd Inlet." Items 2 and 3 are analyzed (and shown to be beneficial to Budd Inlet) elsewhere, in Chapters 7 and 8.

[7] I am not certain of the local position of mean sea level. A tide calculating routine available at http://tbone.biol.sc.edu/tide shows a line corresponding to MSL on a 1997 Budd Inlet tide graph that is at about +9 feet above MLLW.

ladder opening into the Lake can be seen by onlookers (Figure 5-7). At present it appears that there is never a time when ordinary tidal and river flow are completely blocked by gate closure.

Figure 5-7. Saltwater with jellyfish pouring over the fish ladder, entering Capitol Lake. (Flow into the Lake is toward the top of the figure.)[8] *November 21, 2015.*

The designers of the original Budd Inlet Model considered the pattern of flow from the tide gates to be so irregular (and unimportant) that they didn't try to simulate it exactly in the Model (BISS, 1998). Instead, they devised an averaging subroutine. Presumably that subroutine is still in the Model. Exactly what "pulsed flow" looks like in the real world, how it creates water quality problems (or *improves* water quality-- ?), or whether it is a spurious feature of the model output caused by the averaging subroutine all need to be explained by the modelers.

If "pulsed flow" really causes problems, those could easily be eliminated without removing the dam simply by changing its operation. In fact a pattern of "pulsed flow" might even be discovered that could improve Budd Inlet water quality. These possibilities could be explored using the Budd Inlet Model:

a) manage the dam to pulse the flow in synchrony with the tides;

b) manage the dam to pulse the flow out of synchrony with the tides;

c) manage the dam to pulse the flow at randomly chosen times;

d) eliminate pulsed flow altogether by simply leaving the gates unadjusted.

But first, the modelers need to explain exactly what "pulsing" they are talking about, how they discovered this "problem" by using simulations, and how it affects DO levels in faraway East Bay. *They must show readers a simulation that compares Budd Inlet with and without "pulsed flow."*

5-5. "Increased Residence Time" – So What? – and a Botched Calculation.

The modelers present Figure 5-8 (their Figure 10 in the SM Report, also shown in the Poster) as evidence that "the dam" has a negative effect on Budd Inlet. The Figure shows

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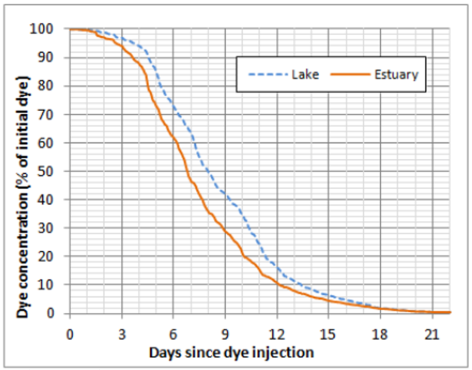
[8] The transport of jellyfish (and other marine organic matter of all sorts) into the Lake provides a small oxygen-preservation service for Budd Inlet not acknowledged by Ecology. The organic material decays there, consuming oxygen in the O2-rich Lake, thus sparing Budd Inlet's sparse O2 supply.

the modelers' claim that the "residence time" of water in East Bay (that is, the average amount of time that water resides there before it moves out) is longer with the dam in place than if the dam were absent. The calculation is flawed, so is their explanation, and in any case, even if it were true … why would that cause oxygen depletion?



Residence time graph
SM Figures

Figure 5-8. Simulated decline of a tracer dye released in bottom water, East Bay, with time. Source: SM Report's Figure 10 p. 35 and Poster (2014). (Calculated using the "e-folding time, mentioned in the Poster.)

The graph in Figure 5-8 shows the decreasing concentration of dye "added" (by the model that is) to the bottom water in a grid cell in East Bay as time goes by. The graph shows the amount of dye that remains in that cell at various times after its release. For example, a week after the "addition" of the simulated dye (7th day, x axis) some 60% of it would still be there if the Lake is in place, but only 46% of it would still be there if an Estuary were present in place of the Lake (y axis).

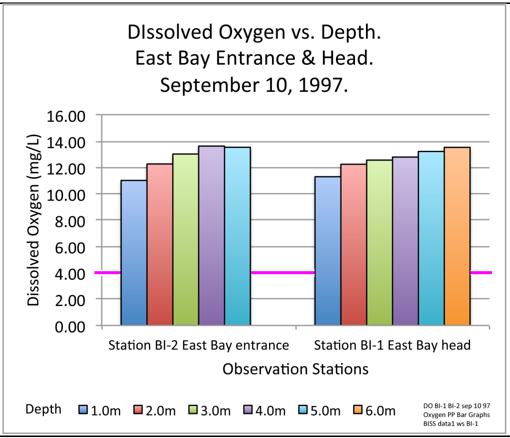
The modelers don't tell us the time of year when the simulated dye release was made, or the depth, or the location of the grid cell release point. Nothing is said about how or why the flow trajectory of water from Capitol Lake would increase the residence time of East Bay water. No mention is made of how a longer residence time might be caused by "pulsed flow" or any other feature of "the dam."

The modelers used a calculation technique that is wrong for East Bay – namely, the "e-folding time." This statistic is used for basins in which the water is "well mixed" – blended from top to bottom by wind stirring, surface cooling or (less often) some other factor. (This situation is commonly seen in lakes during winter and spring, and Budd Inlet in late fall.) East Bay in September is not a "well mixed" system – it is a "two-layer flow-through" system with a net outgoing surface current nudged along by Moxlie Creek and a small compensating incoming bottom flow, ultimately from the Pacific Ocean, linked by an ongoing rise of incoming bottom water to the surface (that is, the "estuarine circulation"). For such systems, the residence time is calculated from the volume of the basin and the rates of inflow and outflow (see BISS Report Table 2-1 p. 2-3, 1998) – not the e-folding time.

The e-folding technique usually gives a longer residence time than does the flow-through calculation. In another report that models all of South Puget Sound, the same modelers (with two other authors) calculate the e-folding time for Budd Inlet at 18 days (SPSDOS Draft, Figure 55 p. 104). The residence time for Budd Inlet as calculated for a flow-through system by the BISS team is 8 - 12 days (BISS 1998).

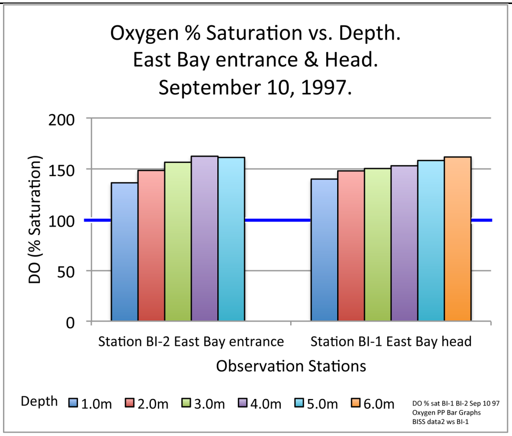
But even if "the dam" really does increase the residence time of water in East Bay, so what? The negative effect of an increased residence time as described by the modelers is that it … “creates more stagnant conditions and allows for greater consumption of DO by heterotrophic bacteria as they decompose organic matter in the water column and the sediments.” That is only half of the story. Not mentioned is the fact that increased residence time also creates more time for phytoplankton, algae, and the algal mat on the mud bottom – especially in a well-lit, shallow intertidal embayment like East Bay – to create more oxygen via photosynthesis – a compensating factor. The Budd Inlet Model failed in spectacular “crash and burn” style to predict exactly this – something the modelers don’t mention.

Figures 5-9 and -10 show that phenomenon in East Bay (station BI-1, also at BI-2) on September 10, 1997, as observed by the BISS team. The oxygen level at the bottom (rightmost bar of each group) was actually higher than at the surface (leftmost bar) on that day (Figure 5-9); the percent DO super-saturation of the water indicating large-scale photosynthesis was likewise highest at the bottom (Figure 5-10). The DO levels are the net result of both photosynthesis (positive) and consumption by sediments and bacteria (negative), with photosynthesis far overwhelming consumption. On that day, this was the exact opposite of what the modelers are telling us.



DO BI-1 BI-2 sep 10 97
Oxygen PP Bar Graphs
BISS data1 ws BI-1

Figure 5-9. Dissolved oxygen concentrations vs. depth, BISS stations BI-2 and BI-1 (East Bay). September 10, 1997. Red line shows 4.0 mg/L ecological stress threshold. The water quality standard here is 5.0 mg/L. Data Source: BISS spreadsheet.



DO % sat BI-1 BI-2 Sep 10 97
Oxygen PP Bar Graphs
BISS data2 ws BI-1

Figure 5-10. Dissolved oxygen saturation levels vs. depth, BISS stations BI-2 and BI-1 (East Bay). September 10, 1997. Blue line shows 100% saturation. Percent saturations calculated via USGS DO TABLES tool from observed water salinity and temperature data from BISS spreadsheet.

Figure 5-9 shows the per-cent saturation level of dissolved oxygen at those same two stations on that date. Water standing in contact with the atmosphere with no other processes (photosynthesis or consumption) operating will arrive at 100% saturation and stay there by exchanging oxygen with the air. Both stations show supersaturation at the surface (indicating intense photosynthesis by phytoplankton there) and even greater supersaturation at the bottom (indicating intense photosynthesis by benthic algae there).[9]

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[9] All of these details were also the same at station BI-6 immediately in front of “the dam” on that same date.

The model predicted its lowest bottom water DO levels of the simulated year in both locations on that date, when in reality the bottom water DO levels were then at their highest of the year. *This implies that the Budd Inlet Model lacks a way of accurately simulating photosynthesis by benthic algae in shallow sunlit subtidal situations*. That is precisely the situation in East Bay.

Oxygen created by benthic photosynthesis is a key contributor to shallow estuarine systems. The computer's failure to calculate it in this conspicuous case implies that the model may not be correctly calculating it in *any* case, most of them more typical than this one. That is, the model calculates oxygen depletion in shallow bottom water but doesn't simulate a process that causes oxygen replenishment. *This calls into question all of Ecology's DO predictions for East Bay, even on dates where the more usual condition – low DO at the bottom, high DO at the surface – prevails.* It also implies that failed shallow water benthic oxygen calculation over all of Budd Inlet – not just East Bay – may have compromised DO predictions along all shores.

5-6. Summary.

The SM Report omits critical simulations that could show a beneficial effect of Capitol Lake on Budd Inlet and identify Moxlie Creek with other factors endemic to East Bay as the sources of oxygen depletions now blamed on the Lake. It flashes many irrelevant graphs (that show the opposite of what Ecology claims) before the reader's eyes.

A claim that "pulsed flow" from the dam causes longer residence time of the water in East Bay is unsupported by any description of how that occurs, or any description of the frequency, velocities and volumes of the pulses, or how the size of the effect varies with the frequency of the pulses, or how the effect from "the dam" manifests itself in East Bay and (seemingly nowhere else), all things that a scientific reader would need to know. The claim is made simply because "the modelers said so."

The model made wildly inaccurate predictions of DO levels in East Bay in a way that suggests it can't simulate benthic photosynthesis. This worrisome failure would seem to cast doubt on *all* of Ecology's predictions of dissolved oxygen levels in that shallow critical area and in all other shallow waters.

6. ECOLOGY'S CENTRAL CLAIM: "THE DAM DEPLETES OXYGEN." WRONG.

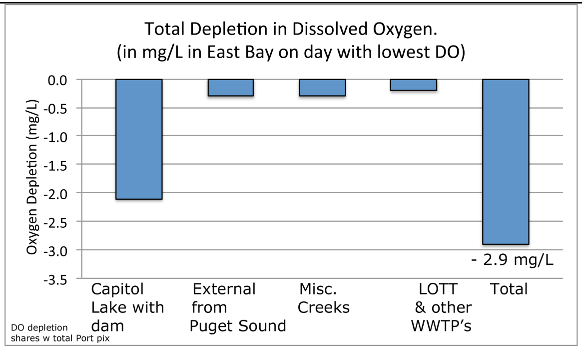

Figure 6-1. Relative sizes of DO depletions in East Bay attributed by Ecology to (L to R) Capitol Lake, External sources outside Budd Inlet, Miscellaneous small creeks entering Budd Inlet, and the LOTT treatment plant. Source: DERT presentation to the Olympia Port Commission November 14, 2016; attributed by DERT to Ecology.

Figure 6-1 is from a slide created by Ecology personnel and presented by various speakers to the Olympia City Council, the Thurston County Commissioners, the LOTT governing board, and others who requested a presentation on the Lake/Estuary question. It purports to show that the "Capitol Lake with dam" has a disproportionately large impact on dissolved oxygen levels in a "critical cell" in East Bay, compared with other potential sources of DO depletion. This Figure is the centerpiece of Ecology's present-day claim that the Lake is the principal cause of low oxygen levels in Budd Inlet.

It's wrong. This Chapter shows why. In fact, the "External from Puget Sound" source mentioned in the Figure is almost certainly the main cause of the O2 depletion attributed to the Lake.

6-1. Overview. Why the Claim is Mistaken.

Oxygen depletion is driven by nitrogen enrichment of marine waters. The amount of nutrient nitrogen entering Budd Inlet from Puget Sound is 17x larger than the amount entering from "Capitol Lake with dam." At least 20% of this "external" nitrogen enters West Bay, where it still outweighs nitrogen of Deschutes River (= "Capitol Lake") origin by at least 3 to 1. From there external-source nitrogen moves back outward toward the "critical cell." Because it is coming from the direction of the dam (and mingled with genuine Deschutes nitrogen), the modelers have mistaken it for nitrogen of wholly Deschutes origin, hence assigning the oxygen depletion it causes to "the dam."

There are other errors. The "critical cell" in East Bay persistently shows up in runs of models that simulate the "natural" pre-modern pre-dam estuary. The low late-summer DO level there is a natural estuarine phenomenon, probably including a "null zone" effect,[1] probably aggravated by modern human activities but not caused by them. The modelers do not acknowledge the fact that Capitol Lake plants capture and retain most of the huge nitrogen overload from the Deschutes River, vastly reducing the amount available for phytoplankton growth and oxygen reduction in Budd Inlet.

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[1] The null zone effect is described in Chapter 1: "How Estuaries Work."

6-2. The Availability of Nitrate Nutrients at the East Bay Location.

Oxygen depletion in marine coastal waters ultimately traces back to the availability of nitrogen nutrients (mainly nitrates) that "feed" the phytoplankton, whose cells eventually sink, decompose, and consume oxygen in the process.

Nitrate enters Budd Inlet from four sources distinguished by Ecology; the Deschutes River, other creeks and non-point sources around the shores, the LOTT treatment plant and the "external" South Sound waters north of the mouth of the Inlet. Ecology distinguishes between "natural" nitrate and "anthropogenic" nitrate, the latter created by human activities (Fig. 6-2). Figure 6-3 shows the comparable daily entries of "natural" nutrient nitrogen to Budd Inlet attributable to natural ecosystem processes that are apart from human activities.

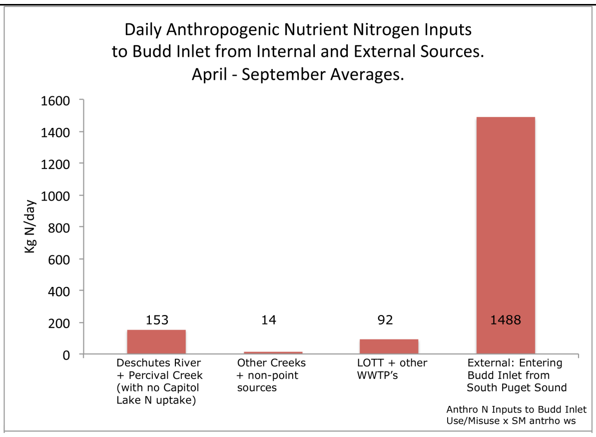

Figure 6-2. Anthropogenic nutrient nitrogen inputs to Budd Inlet from four sources (daily averages for April through September). Source: TMDL Report Table 35, also *SM Report p. 41.*

The grand totals from the N input sources, anthropogenic + natural, are shown in Figure 6-4 (next page).[2] The entry of nutrient nitrogen from Puget Sound vastly outweighs all inputs from all of the sources around the shores of Budd Inlet.

The giant inward flow of N nutrients from the waters beyond Budd Inlet enters by crossing a line from Boston Harbor to Cooper Point. The amount that reaches Priest Point and the vicinity of the "critical cell" in East Bay is much reduced by processes described in the next section.

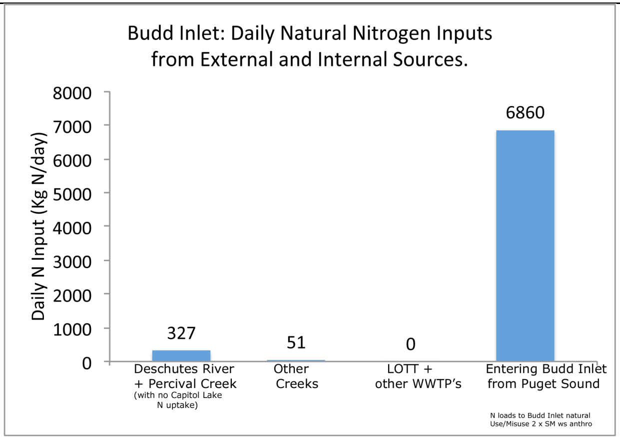

Figure 6-3. Natural nutrient nitrogen inputs to Budd Inlet from three sources. Daily summer averages, April – September. Source: Tables 35 and 36, TMDL Report; External "natural" from external total (Table 35) minus "anthropogenic"(SM Report p. 41).

6-3. The Arrival of Nitrogen Nutrients at Priest Point.

The nutrients entering Budd Inlet from the South Sound are carried by an enormous bottom current, a dominant

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[2] Some values of input nitrogen loads used by Ecology in simulation scenarios are somewhat larger than those shown here. No list or source citation is given in the SM Report, readers must infer them from tangential remarks in the SM text. The orders of magnitude are the same as in Fig. 6-4. See Optional – 4, end of this Chapter.

feature of the "estuarine circulation" of every estuary (see Chapter 1). Figure 6-5 shows a diagrammatic view of what's left of that current and a corresponding outgoing surface current in the vicinity of the Port of Olympia.

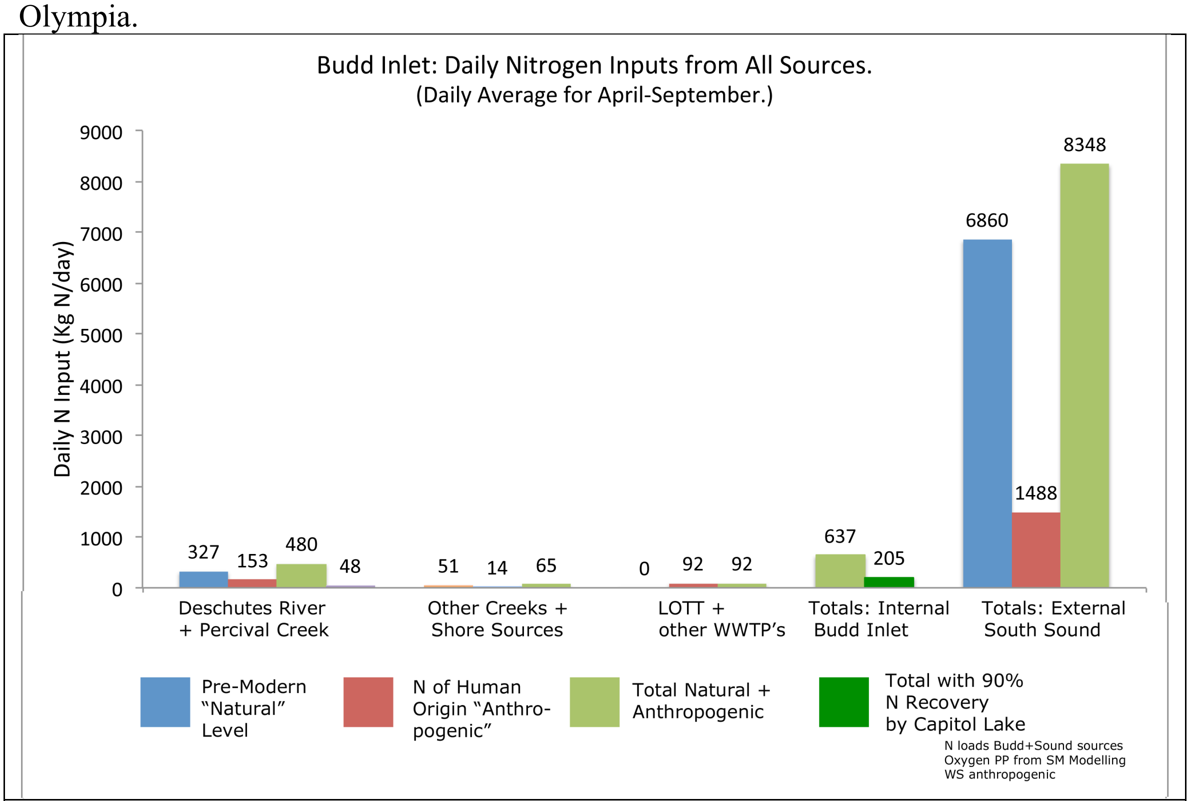

Figure 6-4. Nutrient nitrogen inputs to Budd Inlet from all sources, internal and external. Sources: See Captions, Figs. 6-2 and 6-3. [For visualization, I have included Capitol Lake's effect (removal of about 90% of incoming nitrate from the Deschutes River water), not mentioned by Ecology. CH2M-Hill, 1978.]

As the bottom current moves inward, it loses parts of its nutrient nitrogen load by mixing upward with the outgoing waters at the surface. By the time it reaches Priest Point, the huge initial load of nitrogen has dwindled away to about 20% of its original value (that is to about 1670 kg N/day; TMDL Appendix G p. 49). The nutrient load from the Deschutes River, on the other hand, has only a short distance to go to reach the East Bay area and most (or all) of it actually gets to Priest Point.[3]

The amounts of nutrient nitrogen available from various sources to ultimately cause oxygen depletion in the East Bay critical cell are

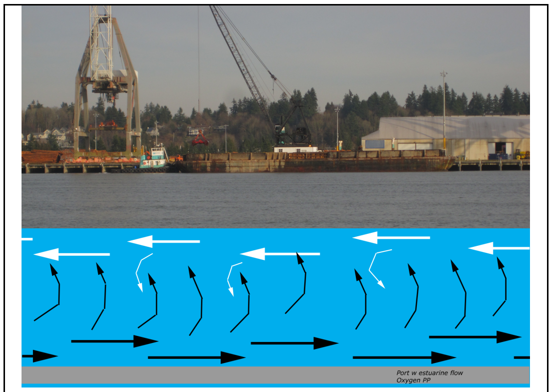

Figure 6-5. Estuarine flow in West Bay. An incoming bottom current flows all the way to the dam, mixing upward with outgoing water from the Deschutes River as it goes. The bottom current carries Nitrogen nutrients from points of

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[3] Some of the Deschutes water mixes downward into the incoming external water, but all of that water rises back to the surface and moves seaward, eventually carrying all Deschutes-origin nitrogen with it.

origin outside Budd Inlet.

shown in Figure 6-6a. Each amount is juxtaposed over the amount of oxygen depletion said by Ecology to be caused by that source in the critical East Bay cell (Figure 6-7).

The sizes of the sources are wildly incongruent with the claimed oxygen depletions. *The Deschutes source delivering only a third as much nitrogen (at most) as the South Sound source is said by Ecology to create fully eight times as much oxygen depletion as the larger source.*

The SM Report never identifies the "critical cell" in East Bay explicitly, but one can infer from the text (p. 40) that it is the red cell identified in Figure 6-7. That cell is adjacent to observation station BI-1 of the BISS field study (see Fig. 2-2, Chapter 2 of this Review.)

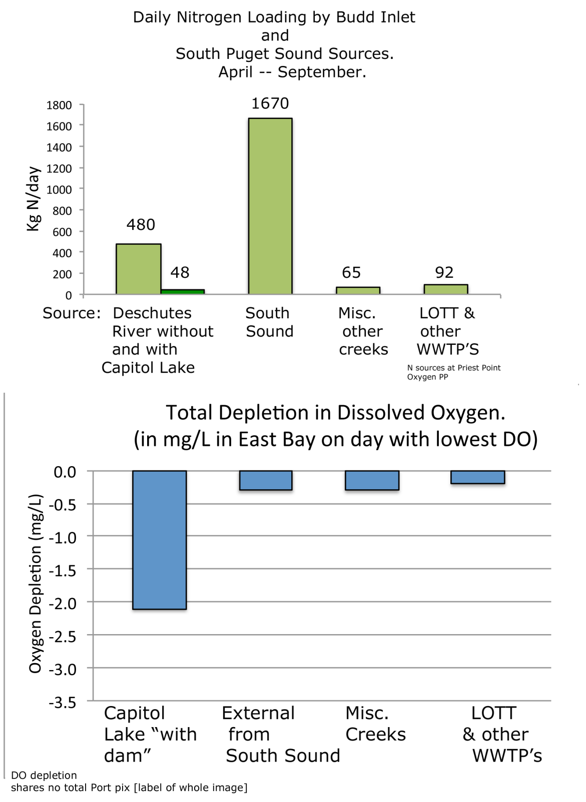

Figure 6-6. Upper. Daily loads of N nutrients delivered by four sources to the Priest Point area. Lower. Oxygen depletion in East Bay attributed by Ecology to each source. (The N value shown for the South Sound source is the amount present at Priest Point.)

6-4. The Movement of Nitrogen Nutrients Into and Out of West Bay.

The bottom current is driven by the flow of the Deschutes River. Under the river's influence, it continues past Priest Point and *almost all of it enters West Bay*. (A small fraction, perhaps 1 %, is drawn in by tiny Moxlie Creek and moves directly toward the "critical cell" area.) In West Bay, the nutrients carried in the bottom water are mixed upward into the outgoing surface water (as shown in Figure 6-5) where they move back toward the Priest

Point area, either incorporated in phytoplankton or still unassimilated. *Almost all* of the nutrients from South Sound that get as far as Priest Point end up returning seaward, mixed and carried by Deschutes River water from the direction of "the dam."

Water in prolonged contact with the surface becomes 100% saturated with atmospheric oxygen via absorption from the air.[4] Phytoplankton photosynthesis drives the DO % saturation even higher, at and just below the surface. Water below the sunlit surface zone is almost always unsaturated with oxygen due to the respiration of organisms and bacteria and the absence of processes that can replenish the depleted oxygen. The hallmark feature of upwelling water is that it is less than100% saturated right at the surface itself.

The water in West Bay shows exactly this expected pattern, all the way from Priest Point to the dam (Figure 6-8).

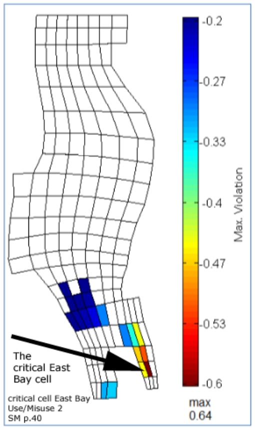

Figure 6-7. The critical East Bay cell said by Ecology to be impacted by "the dam." Source: Fig. 17 and text on page 40, SM Report.

Figure 6-8 shows the % DO saturation of Budd Inlet waters from the surface to the bottom along a transect from opposite Priest Point (opposite "WB Marina" in the Figure) to "Bayview" near the dam, measured September 19, 2013 by me and colleagues. Each cluster of bars shows one observation location (of five total). In each group, the leftmost and rightmost bars show the surface and bottom % DO saturations, respectively. A blue line shows the 100% saturation level.

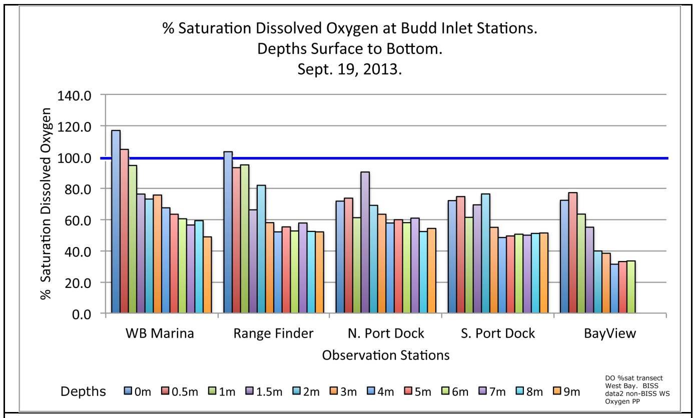

Figure 6-8. Percent oxygen saturation of West Bay waters increasingly distant from the 5th Ave. dam. September 19, 2013. Blue line shows the 100% saturation level. (Observations by the author and CLIPA colleagues.)

Moving from Bayview to WB Marina (the direction in which the Deschutes River net surface flow moves, right to left in Figure 6-8), the surface water becomes progressively more saturated, then supersaturated as more and more time elapses after its upwelling. This is due to oxygen absorption from the air and phytoplankton photosynthesis. That upwelled bottom water is from the external source outside Budd Inlet. By the time the total surface flow reaches Priest Point, the flow is already10 times larger than the flow of the Deschutes River itself by inclusion of the upwelled external water (Source: TMDL Appendix G p. 49). Some 75% of the surface flow nutrients moving outward are now from the external source (97% if Capitol Lake is credited with removing 90% of the natural + anthropogenic inputs by the Deschutes River).

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[4] This topic (saturation) and its relationship to vertical water motion is described and illustrated in Chapter 1.

What do the modelers see in the waters near the entrance to East Bay? A large flow loaded with external source nutrients coming from the direction of "the dam." They may be mistakenly assigning that whole nutrient load to "the dam" itself (Figures 6-1 and 6-6b).

6-5. Dissolved Oxygen Depletion in East Bay Caused by "The Dam" – *Zero*?

Percent oxygen saturation values shown in Figures 6-9a and 6-9b for the entrance and head of East Bay, respectively, resemble the pattern in West Bay. The surface water at the head of East Bay (Fig. 6-9b) is slightly unsaturated, as are the subsurface waters, suggesting that this water is upwelling from the bottom.[5] When the outflowing surface water reaches the East Bay entrance, it has had time to acquire additional oxygen from the air and photosynthesis to become supersaturated (Fig. 6-9a). As in West Bay, this suggests bottom water flowing into East Bay toward the head of the inlet, rising to the surface, then (propelled by Moxlie Creek) flowing out at the surface.

The question is, "bottom water from where?" The fresh Deschutes River water entering West Bay at "the dam" begins its journey outward at the surface. Bottom water moving headward in East Bay can only be that entering from the external source water outside the estuary. *It is likely that "the dam" has no effect on dissolved oxygen in East Bay whatsoever. Zero. None.*

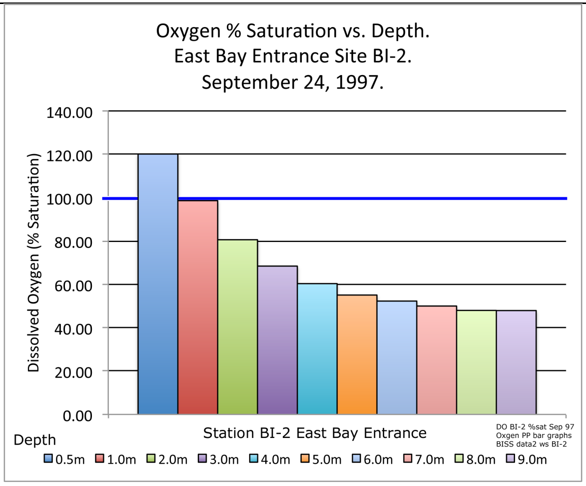

Figure 6-9a. Per cent dissolved oxygen saturation of water from surface to bottom at the entrance to East Bay (BISS station BI-2), Sept. 24 1997. Source: BISS spreadsheet with % DO's calculated using USGS "DOTABLES" tool; see USGS, DO Tables in References.

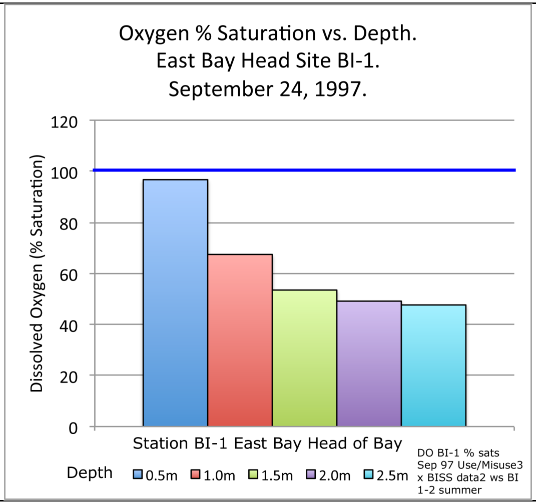

Figure 6-9b. Per cent dissolved oxygen saturation of water from surface to 2.5 meters depth near the head of East Bay (BISS station BI-1), Sept. 24 1997. (This station is adjacent to Ecology's "critical cell," SM Report.) Sources: as in Figure 6-9a.

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[5] Figure 6-9b shows only the DO % saturations from the surface to 2.5 meters. Measurements made at BI-1 were all in error below that depth (BISS spreadsheet error worksheet); the error values are not shown here. Only the leftmost four bars in Fig. 6-9a are strictly comparable with the whole of Figure 6-9b. The bottom at BI-1 on this occasion (September 24, 1997) was actually 7.5 meters deep.

6-6. Summary. Likely Causes of Low DO Conditions in East Bay.

As shown in Chapter 5 (pp. 5-10 ff), the shallow waters of East Bay can have astonishingly high photosynthesis (hence DO production) right at the bottom (as on Sept. 10, 1997; see Figures 5-8 and 5-9, this Review). More often, the Bay in September is the site of the lowest calculated DO's in all of Budd Inlet, both in its "natural" (pre-modern) condition and at present. If "the dam" isn't causing the present-day low DO's, then what is?

Ecology's "critical cell" is near the dead-end head of East Bay where several local factors cause low DO conditions. One is the high nutrient concentration of Moxlie Creek. Another is the restriction of the Bay entrance (seaward of the "critical cell") by a breakwater that extends about halfway to the opposite shore. Yet another is the blockage from oxygen replenishment from the air by boat bottoms and docks at the East Bay marinas (occluding some 15% of the low-tide Bay surface, by my estimate). The boats and structures also shade the water beneath them, possibly inhibiting algal photosynthesis and oxygen production. It is possible that the rising fresh water from the LOTT outfall outside the Bay entrance creates a "curtain" of sorts that further isolates the Bay. The feeble flow of Moxlie Creek draws in a small amount of nutrient-laden bottom water from the external source current entering Budd Inlet. Finally a phenomenon never mentioned by Ecology – the estuarine null zone – is probably at work in East Bay (see Chapter 1).

Given the flow pattern of Budd Inlet as a whole and the abundance of alternative causes of low DO in East Bay, the idea that "the dam" is causing the problems there is mistaken.

6-7. Conclusions and a Recommendation.

The nutrients entering Budd Inlet from the external South Sound source move headward in West Bay and back out again in a way that invites the mistaken interpretation that their source is Capitol Lake. Many factors other than "the dam" could explain low DO conditions in the East Bay "critical cell."

Outside the modeling realm, I have a recommendation.

Namely, do real-world real-time oxygen measurements in the water of the "critical cell" in East Bay.

This pivotal place in Budd Inlet that has been made central to a community decision on whether or not to spend $400 million removing the dam (Curry, pers. comm. 2018) is not currently being observed. Ecology regularly samples a site in West Bay (see Chapter 2), but has not seen fit to acquire any data from East Bay.

To my knowledge, no one has actually measured DO levels there since the end of the BISS research in September 1997. All of Ecology's posturing on water quality there is based on computer calculations. The computer routinely gets wrong answers (Chapter 3, this Review), there are myriad possible alternative explanations of low-DO occurrences there (preceding Section), a Budd Inlet model component that should have added oxygen to the bottom water failed catastrophically there on September 10, 1997 (the "Benthic Algae subroutine," see Chapter 5), and Ecology's claims that "hydrodynamics" are to blame are unsupported (see Chapter 5).

Given all that, there are many reasons to question Ecology's central claim, that Capitol Lake (aka "the dam") is responsible for the low DO levels seen in the isolated backwater that is East Bay.

The Department of Ecology's Supplemental Modeling Report.
A Critical Review.

7. ORGANIC CARBON CLAIMS: MISLEADING, MISTAKEN, NOT CREDIBLE.

7-1. Overview.

The SM Report's central claim regarding Capitol Lake's supposed negative effect on Budd Inlet is that the Lake causes depletion of oxygen in the waters of Budd Inlet. It happens, say the modelers, because the plants growing in Capitol Lake create "organic matter" -- dead stems, particles, etc., that immediately enter Budd Inlet and use up oxygen in various ways.

That claim is Ecology's strategy for sidestepping the indisputable fact that Capitol Lake intercepts nitrogen nutrients and prevents them from entering Budd Inlet until after the growing season – a huge beneficial environmental service provided by the Lake.

Two computer-generated graphs are used to support Ecology's "organic carbon" claim. The graphs are riddled with errors stemming from the modelers' unfamiliarity with aquatic ecological processes, mathematical mistakes, less than full disclosure of the adverse effects indicated for a "restored estuary," and perhaps their own misunderstanding of what the graphs portray.

7-2. Background.

For readers who are not familiar with the Lake/ Estuary controversy, I first present a reminder of the main facts and issues.

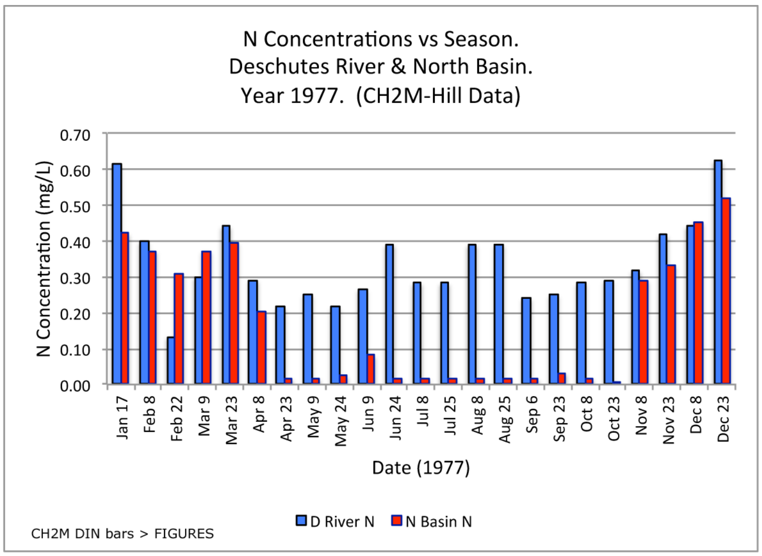

Figure 7-1. Nutrient nitrogen concentrations in the Deschutes River

During summers, Capitol Lake acts as a vast trap for nutrient nitrogen.[1] This has been known since 1977 when the CH2M-Hill consulting firm issued a report describing a year of detailed study of the Lake (CH2M-Hill, 1978). Figure 7-1 shows the nutrient nitrogen

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[1] "Nutrient Nitrogen" is nitrogen in one of three chemical forms; nitrate (NO_3^-), nitrite (NO_2^-) and ammonium (NH_4^+). It is critical to plant growth, very soluble in water, and does not easily become trapped in bottom sediments. Nitrate is usually the most common form in nature, ammonium is usually the scarcest. Collectively these are known as "DIN" or "NN" (Dissolved Inorganic Nitrogen or Nutrient Nitrogen, both the same as used in the Review).

trap process in action for year 1977 (data from Figure 34 p. 56, CH2M-Hill). Figure 7-2 shows similar uptake of nutrient nitrogen by the Lake in 2004.

at the south end of Capitol Lake (blue bars) and in Lake water in the North Basin near the dam (red bars), 1977. Differences in bar lengths show the uptake of N by the Lake during almost every time of year, most markedly during summer and fall. (data from CH2M-Hill 1978.)

The plants in the Lake take up NN and use it to produce new cells, stems, leaves, flowers, seeds and roots. The mats of algae and rafts of pond lily leaves seen on the Lake's surface each summer, with the dense growths of submerged plants, are the reservoirs in which the trapped nitrogen is held.

Nutrient nitrogen is a fertilizer that drives plant growth in all ecosystems – salt water, fresh water, and on land. That plant growth produces oxygen ("good" in ecosystem dynamics), takes carbon dioxide out of the air or water (*very* good in our modern CO_2-loaded global environment), and produces "food" for the ecosystem's consumers (animals, fungi, bacteria) – all normal and essential ecosystem functions.

A "down side" is that when the newly grown plant material is finally eaten or decays, it uses up exactly as much oxygen as was created when that plant material was first manufactured by photosynthesis. If this oxygen consumption takes place in deep water where O_2 levels are normally low, the oxygen-utilizing animals there - fish, crabs, insect larvae, clams, and the like – run short and may die. *That is the down side that we worry about in Puget Sound.*[2]

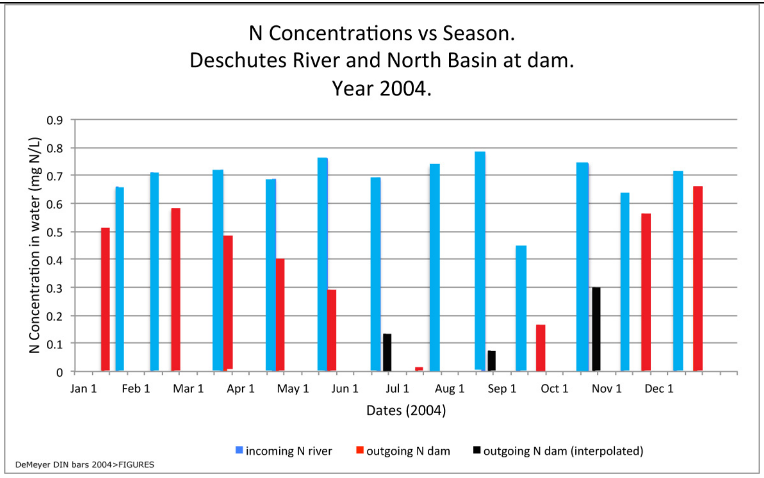

Figure 7-2. Nutrient nitrogen concentrations in the Deschutes River (blue bars) and in water exiting the Lake's North Basin over the dam (red bars), 2004. Same interpretation as Figure 7-1. Black bars are interpolated values for missing data. (DeMeyer data in References.)

The Deschutes River has the second highest concentration of NN in its water of all major streams entering Puget Sound south of the Narrows (Table 7-1). Because the Nisqually River has such a large volume of flow, that river delivers more total NN to Puget Sound than any other stream,

Stream	2006-07	Sept 2007
	mg N/L	kg N/day
Chambers Creek	1.15	112
Deschutes River	0.90	198
Woodland Creek	0.75	57
Moxlie Creek	0.75	15
Mission/Ellis Creek	0.75	0.8
Kennedy Creek	0.45	3.5
McLane Creek	0.25	0.8

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[2] There is *never* a problem of oxygen depletion in the deep water of Capitol Lake, where the oxygen supply is virtually inexhaustible. See Chapter 9.

Nisqually River	0.20	199

Table 7-1. Average NN concentrations in stream waters 2006-07 (left column) and amount of NN delivered by streams to Capitol Lake (Deschutes) and Puget Sound (all others) each day, Sept. 2007 (right). Sources: SPSDOS, 2011. Fig F-3 p. 124 (left) and Table 7 p. 28 (right) from that source.

despite its low NN concentration. But next on the list and far ahead of any other stream is the Deschutes River. All of its NN would go directly into Budd Inlet, were it not intercepted by the Lake (Figures 7-1 and 7-2). That trapped NN -- some 20+ tons per summer – is the equivalent of about 80 50-lb bags of conventional fertilizer poured from the Fourth Avenue Bridge into Budd Inlet *every day, all summer long*.[3]

The reason why excess NN is not always a good thing for Budd Inlet is that the water at the bottoms of East Bay and West Bay experience a "low-oxygen" condition every summer, particularly in September. This occurs naturally in almost all northern hemisphere estuaries at this time.[4] By summer's end, a whole season's plant growth, driven by NN, has occurred. Plant and animal products (leaves, fecal pellets, whole phytoplankton cells, fragments of carcasses, exoskeletons etc) have been sinking to the bottom all summer long, and resident bottom organisms (clams, crustaceans, bacteria, etc) have consumed oxygen by eating or decaying the sunken biomass. When the amount of dead carbon-containing organic material becomes too great, all of this consumption – particularly by bacteria – can drive the deep water oxygen level to zero, with negative effects on the organisms that need it.

On the other side of the ledger, the deep water oxygen is continually replenished by a salt water stream coming all the way from Pacific Ocean along the bottom. This bottom water is subject to oxygen depletion over the whole course of its travel from the ocean to Budd Inlet. Fortunately, South Puget Sound benefits from the forced upward churning of the bottom water as the tides drag it over the shallow sill at the Tacoma Narrows, enabling it to pick up oxygen via contact with the atmosphere before it sinks again. The result is that the bottom water in our area contains more dissolved oxygen than would be usual so far from its ocean source (Strickland, 1983).

Nevertheless, during the warm, high-biomass days of September the bottom waters of East and West Bays usually experience their lowest DO's of the year. The net effect of adding nutrient nitrogen to the Sound, as the undammed Deschutes River would do, would be to ramp up plant growth in the sunlit surface water, ultimately to lower DO even further at the bottom.

The Department of Ecology said nothing about the Lake's ability to trap NN in its first TMDL Report (2012). In the months after I (and others) brought it to public attention (Spring 2014; Milne, 2014), the modelers began looking for ways in which the Lake could be shown to damage Budd Inlet even though it was preventing NN from reaching the salt water. Their answer was (and still is) the claim stated at the beginning of this

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[3] 50-lb bags of fertilizer that consists of 10% active ingredient nutrient nitrogen.

[4] This includes the more-or-less permanent natural estuarine "null zone," but low DO is usually more widespread throughout whole headward extent of late-summer estuaries for reasons described in Chapter 1.

Chapter: “Yes, the Lake traps NN and stores it in plant biomass, but then the biomass itself immediately goes over the dam into Budd Inlet in the form of organic carbon, then decays and releases the trapped NN in the saltwater.” If so, marine plant growth would follow with as much consequent deep-water oxygen depletion as if Deschutes water entered Budd Inlet directly with no dam to delay it.

It is true that, sooner or later, some, most, or even all of the new plant biomass formed each summer in the Lake must be eaten or break down and decay, consuming oxygen in the process. The critical questions are “Where?” (in the Lake? Budd Inlet? Both?) and “When?” (“sooner,” during the summer growing season, or “later,” after the growing season?) These questions are addressed in Chapter 8. Here I examine the validity of Ecology’s claim that, by this mechanism, the Lake lowers Budd Inlet oxygen more than an undammed estuary would do.

The following is the most detailed, painstaking dissection of an Ecology claim in this entire Review. That is because of the complexity of the calculations needed to unravel the claim and the need to show them so that readers can follow every step of my logic, if desired. The result shows that Ecology’s claim is based on ignorance of aquatic ecology, a huge error in calculation, and failure to mention that one of their graphs (the estuary case) hides a heavy impact on Budd Inlet by putting it outside the Lake basin, beyond the 5th Avenue Bridge, where the graphs can’t show it.

7-3. The Production of Organic Carbon by Lake and Estuary.

The modelers use the graphs shown in Figure 7-3 to support their claim that Capitol Lake plant matter significantly decreases dissolved oxygen in Budd Inlet. The upper graph (Fig 7-3a) shows “total organic carbon (= TOC)” levels in Capitol Lake or the estuary that would result if the Lake were removed, as calculated by their computer, day by day, from January 25 through September 15, 1997. The lower graph (Fig. 7-3b) shows levels of nutrient nitrogen (called “DIN” by the modelers) in the water, also as calculated for both Lake and estuary for the same time period. Pink dots on both graphs show *actual observed values* of TOC and DIN on various dates. *The measurements (pink dots) of observed TOC and DIN were made in the Deschutes River above the Lake. The estimates of TOC and DIN by the computer (blue and green graphs) show their calculated levels in the water at the other end of the Lake basin*, near the location of the 5th Avenue

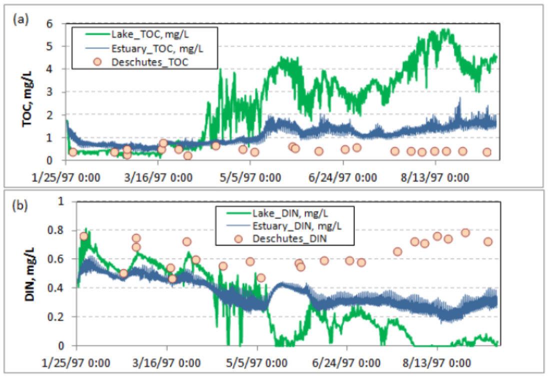

Figure 11. a) Total organic carbon (TOC) and b) dissolved inorganic nitrogen (DIN) concentrations at the location of the Capitol Lake dam under Lake (with the dam) and Estuary (without the dam) scenarios compared with concentrations in the Deschutes River at E Street.

Poster graph Grab2 > Figures

Figure 7-3. Fig.7-3a (Upper). “Total organic carbon” (TOC) in water at the position of the dam if the Lake is present (green graph) or if an Estuary were present (blue graph). Figure 7-3b. (Lower) “Dissolved Inorganic Nitrogen” (DIN) at the dam, same scenarios. Graphs = computer calculations, data points show observations in the Deschutes River, 1997. Source: SM Report Figure 11 p. 36. See also

Bridge and dam (henceforth, the “dam site”).

Poster, 2014.

In the lower Figure (7-3b) both Lake and Estuary DIN graphs are lower on the Figure than are the observed DIN data points. The differences in positions show the amounts of DIN removed from the water by the photosynthesizers that create TOC.

By calculating those DIN differences and the amounts of TOC created and comparing them with the alleged TOC’s presented by the modelers in the upper graph (Figure 7-3a), one finds that *there are serious discrepancies in the modelers’ calculations and interpretations*. The Lake TOC graph is accurate but the interpretation is ecologically unrealistic. The Estuary TOC graph is wrongly calculated and also hides the fact that half of the total TOC production takes place out in Budd Inlet beyond the Lake basin sector simulated by the computer, where the computer can’t see it -- and neither can readers of the SM Report.

The method I used to show this is presented step by step in Optional Section 7-d (Tables 7-2, 7-3, and 7-4) to enable readers so inclined to follow my calculations. The results, for readers inclined to skip ahead, are shown in Section 7-5 below.

7-4. Optional. Estimating TOC from DIN Uptake, using Figures 7-3a and 7-3b.

On both upper and lower graphs, I estimated the values of the observed data points (pink dots) from scale measurements of the graphs. I estimated the date on which each TOC and DIN observation (“pink dot”) was made, also by scale measurements. The measurements were made on full-screen images of each graph using the centimeter scale of Photoshop software.[5] My scale-estimated dates and River TOC and DIN values are shown in Table 7-2 (Columns A-D). I used the same technique to estimate the

Basic Data from the Poster Graphs (Figures 7-3a and 7-3b).

A	B	C	D	E	F	G	H
Date of TOC obser-vation RIVER	Amount of TOC observed mg C/L RIVER	Date of DIN obser-vation RIVER	Amount of DIN observed mg N/L RIVER	TOC shown by green graph, Fig 7-3a date in Column A mg C/L LAKE	DIN shown by green graph, Fig 7-3b date in Column C mg N/L LAKE	TOC shown by blue graph, Fig 7-3a date in Column A mg C/L ESTUARY	DIN shown by blue graph, Fig 7-3b date in Column C mg N/L ESTUARY
Jan 25	-	Jan 25	-	1.85	0.69	1.85	0.53
Jan 29	0.35	Jan 29	0.77	0.35	0.77	0.92	0.57
Feb 19	0.35	*Feb 20*	0.49	0.35	0.46	0.69	0.48
Feb 27	0.52	*Feb 28*	0.75	0.29	0.67	0.69	0.55
Feb 27	0.23	*Feb 28*	0.68	0.29	0.67	0.69	0.55
Mar 19	0.52	*Mar 17*	0.55	0.40	0.52	0.81	0.45
Mar 20	0.75	*Mar 18*	0.46	0.75	0.46	0.75	0.45
Mar 28	0.46	*Mar 27*	0.72	0.92	0.65	0.92	0.52

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[5] One could in principle try to read the data directly from the graphs themselves, but the results would be crude and in any case the erratic date scale gradation provided on the x-axis by the modelers makes this near-impossible.

Apr 1	0.23	*Mar 31*	0.59	0.81	0.59	0.81	0.49
Apr 16	0.63	Apr 16	0.56	2.31	0.44	0.81	0.55
May 1	0.46	May 1	0.59	2.88	0.40	1.04	0.42
May 7	0.35	May 7	0.48	3.12	0.34	1.04	0.34
May 28	0.63	May 28	0.59	4.27	0.08	1.73	0.44
May 29	0.52	May 29	0.56	4.15	0.18	1.50	0.42
Jun 11	0.40	*Jun 10*	0.59	3.92	0.18	2.02	0.34
Jun 26	0.46	*Jun 25*	0.59	2.88	0.22	1.56	0.36
Jul 2	0.58	Jul 2	0.59	3.17	0.20	1.21	0.38
Jul 22	0.40	Jul 22	0.66	3.92	0.20	1.27	0.35
Jul 30	0.40	Jul 30	0.73	4.85	0.00	1.38	0.36
Aug 5	0.35	*Aug 6*	0.72	5.31	0.00	1.56	0.32
Aug 12	0.40	*Aug 13*	0.77	5.42	0.00	1.85	0.33
Aug 18	0.40	*Aug 19*	0.74	5.77	0.05	1.62	0.27
Aug 27	0.40	*Aug 28*	0.79	4.38	0.07	1.85	0.34
Sep 9	0.40	Sep 9	0.73	4.27	0.08	2.42	0.40

Table 7-2. Dates and values of TOC and DIN observations and estimates. River values are observed, Lake and Estuary values are calculated. All values shown in this table were estimated by interpolation from scale measurements of Figures 7-3a (TOC's) and 7-3b (DIN's). Observed River values are from positions of pink data points. Calculated DIN and TOC values are from the tops of the respective green or blue graphs for the dates in Columns A and C. Some (italicized) DIN dates differ by 1 or 2 days from the TOC dates, possibly due to rounding artifacts in the estimate method. For ease of calculation and graphing, hereafter in this Review I have used the TOC dates in Column A for both TOC and DIN observations.

values of Lake and Estuary TOC's and DIN's calculated by the computer. These measurements were made *from the x-axis to the respective tops of the green and blue graphs* on the same dates as for the River observations. These estimated values are shown in Table 7-2 (Columns E-H).

For the estuary case, I assumed that the uptake of DIN by the algae in the estuary is given by the difference between the amount observed in the River and the calculated amount still in the estuary water at the dam site *at the end of the same day* (Columns D and H, Table 7-2). These uptake values are shown in Table 7-3 (Column I).

Estuary Case.						
A	B	D	H	I	J *(=DIN-C)*	JJ
Date	Amount of TOC observed (mg C/L) RIVER	DIN in River this date* (mg N/L) RIVER	DIN at dam this date* (mg N/L)	DIN uptake Col. D-H (mg N/L)	New TOC from DIN uptake Col. I x 7 (mg C/L)	Total TOC DIN-C + River TOC Col. J + Col. B (mg C/L)
Jan 25	-	-	0.53	-		
Jan 29	0.35	0.77	0.57	0.20	1.41	1.76
Feb 19	0.35	0.49	0.48	0.01	0.07	0.42
Feb 27	0.52	0.75	0.55	0.20	1.41	1.93
Feb 27	0.23	0.68	0.55	0.13	0.92	1.15
Mar 19	0.52	0.55	0.45	0.09	0.64	1.16
Mar 20	0.75	0.46	0.45	0.01	0.07	0.82
Mar 28	0.46	0.72	0.52	0.20	1.41	1.87
Apr 1	0.23	0.59	0.49	0.09	0.64	0.87
Apr 16	0.63	0.56	0.55	0.01	0.07	0.70
May 1	0.46	0.59	0.42	0.16	1.13	1.59
May 7	0.35	0.48	0.34	0.14	0.99	1.34
May 28	0.63	0.59	0.44	0.14	0.99	1.62

May 29	0.52	0.56	0.42	0.13	0.92	1.44
Jun 11	0.40	0.59	0.34	0.24	1.70	2.10
Jun 26	0.46	0.59	0.36	0.22	1.56	2.02
Jul 2	0.58	0.59	0.38	0.20	1.41	1.99
Jul 22	0.40	0.66	0.35	0.30	2.12	2.52
Jul 30	0.40	0.73	0.36	0.36	2.55	2.95
Aug 5	0.35	0.72	0.32	0.39	2.76	3.11
Aug 12	0.40	0.77	0.33	0.43	3.04	3.44
Aug 18	0.40	0.74	0.27	0.46	3.25	3.65
Aug 27	0.40	0.79	0.34	0.44	3.11	3.51
Sep 9	0.40	0.73	0.40	0.32	2.26	2.66

*Table 7-3. Amounts and uptakes of DIN and resultant total TOC at Bridge Site. Columns A, B, D and H are the same as those of Table 4-2 for ease of visualization. Column I; amount of estuary DIN taken up by algae. Column J; the amount of new TOC that would be created by the DIN uptakes shown in Column I (= Column I values x 7). Column JJ; total TOC at dam site (Col. J + Col. B). (Rounding of products alters some 2nd place decimals). *See note on dates, Columns A and C, Table 7-2.*

Plants and algae remove DIN from the water and use it (via photosynthesis) to build new organic matter. I estimated the amount of carbon in the new organic matter created by the Estuary's uptake of nutrient nitrogen using the modelers' formula, namely the amount of Carbon in new organic stuff is the amount of Nutrient Nitrogen taken up multiplied by 7 (Ahmed and Pelletier, 2014). In the following, "new TOC calculated from DIN uptake" (as in Column J, Table 7-3) is abbreviated as "DIN-C."

For example on February 19, algae in the water of the imagined estuary removed 0.01 mg of N from every liter of water (Column I Table 7-3, row Feb. 19). The amount of carbon built into new organic matter by this uptake would be 7 x 0.01 = 0.07 (mg C/L). If *all* of this new carbon-containing organic material ended up suspended or dissolved in the water, the newly manufactured carbon present as TOC (= "DIN-C") on that day would be 0.07 mg C/L (Column J Table 7-3, row Feb. 19).

The new TOC that would be created by the uptake of NN from the estuary water each day is shown in Column J of Table 7-3. The total TOC to be expected at the dam site is the new "DIN-C" plus the existing "River TOC" (Columns B+J, Table 7-3). These totals are shown in Column JJ, Table 7-3.

It is likely that River water would pass through the estuary in a single day if there were no dam to retard its flow. Because it takes 15 days for river water to pass through the Lake however (TMDL Report p. 13), a different procedure was used for the Lake case. For each observation date (Column A Table 7-2) I calculated a "lag date" 15 days after the observation date (Column K Table 7-4). I estimated from scale measurements in Figure 7-3b (x-axis to top of green graph) the amount of DIN in the Lake water at the Bridge site on each lag date (Column L Table 7-4). For each DIN measurement, that is the amount of DIN still left in the water 15 days after the River water entered the other end of the Lake. To determine the uptake of DIN by plants during those 15 days, I subtracted the amount of DIN calculated to be present at the dam site on each lag date from the amount of DIN observed in the River 15 days earlier. (This subtraction is Column D minus Column L, Table 7-4.) The 15-day uptake values are shown in Column M, Table 7-4.

As in the Estuary case, the amount of carbon that would be incorporated into new organic biomass via DIN uptake was found from "New Carbon = 7 x DIN uptake." If *all* of this new carbon manufactured from DIN uptake became suspended as particles or dissolved as molecules in the water during the 15-day uptake period, this would be the amount of newly manufactured TOC predicted to appear at the dam site on each lag date. If some of the new "DIN-Carbon" remained in storage in the biomass of large plants, the TOC's appearing at the dam would be smaller – *much* smaller -- than these values.

The final step of the lake calculation requires estimating the amounts of TOC of River origin expected to be present on the lag dates. These values were found by interpolating between the observed River TOC values (Table 7-2 Column B) on the observation dates (Column A, Tables 7-2 and -4) just before and just after each lag date. These interpolated values are shown in Column O Table 7-4. The total TOC expected at the dam site on each lag date is shown in Column P, Table 7-4 (= Col. N + Col. O values).

I also calculated data estimates for the Lake scenario to see what would result if there were no 15-day lag between the entry of DIN from the river and the appearance of new TOC at the dam site. This calculation (not shown here) uses exactly the same procedure as for the Estuary case except using Lake data from Columns D and F, Table 7-2.

Lake Case.							
A	D	K	L	M	N (=DIN-C)	O	P
Date of Observation	DIN observed River mg N/L	*Lag Date 15 days later*	*DIN at dam on lag date (mg N/L)*	*DIN uptake (15 days; Cols. D-L) (mg N/L)*	*New TOC from DIN uptake (Col M x 7) mg C/L*	*River TOC interpolated values for lag dates mg C/L*	*Total TOC DIN-C + River TOC Cols. N + O*
Jan 25	-	*Feb 9*				*0.35*	
Jan 29	0.77	*Feb 13*	*0.58*	*0.19*	*1.32*	*0.35*	*1.67*
Feb 19	0.49	*Mar 6*	*0.62*	*-0.13*	*-0.88*	*0.33*	*-0.55*
Feb 27	0.75	*Mar 14*	*0.57*	*0.18*	*1.27*	*0.46*	*1.73*
Feb 27	0.68	*Mar 14*	*0.57*	*0.11*	*0.78*	*0.46*	*1.24*
Mar 19	0.55	*Apr 3*	*0.60*	*-0.05*	*-0.38*	*0.28*	*-0.10*
Mar 20	0.46	*Apr 4*	*0.57*	*-0.11*	*-0.75*	*0.31*	*-0.44*
Mar 28	0.72	*Apr 12*	*0.50*	*0.22*	*1.54*	*0.52*	*2.06*
Apr 1	0.59	*Apr 16*	*0.54*	*0.04*	*0.29*	*0.63*	*0.92*
Apr 16	0.56	*May 1*	*0.41*	*0.14*	*0.99*	*0.46*	*1.45*
May 1	0.59	*May 16*	*0.07*	*0.52*	*3.62*	*0.47*	*4.09*
May 7	0.48	*May 22*	*0.07*	*0.42*	*2.91*	*0.55*	*3.46*
May 28	0.59	*Jun 12*	*0.21*	*0.37*	*2.60*	*0.41*	*3.01*
May 29	0.56	*Jun 13*	*0.29*	*0.27*	*1.86*	*0.41*	*2.27*
Jun 11	0.59	*Jun 26*	*0.24*	*0.34*	*2.41*	*0.47*	*2.88*
Jun 26	0.59	*Jul 11*	*0.19*	*0.39*	*2.75*	*0.50*	*3.25*
Jul 2	0.59	*Jul 17*	*0.20*	*0.39*	*2.70*	*0.45*	*3.15*
Jul 22	0.66	*Aug 6*	*-0.01*	*0.66*	*4.64*	*0.35*	*4.99*
Jul 30	0.73	*Aug 14*	*0.00*	*0.73*	*5.09*	*0.40*	*5.49*
Aug 5	0.72	*Aug 20*	*0.00*	*0.72*	*5.02*	*0.40*	*5.42*
Aug 12	0.77	*Aug 27*	*0.06*	*0.71*	*4.94*	*0.40*	*5.34*
Aug 18	0.74	*Sep 2*	*0.03*	*0.70*	*4.92*	*0.40*	*5.32*
Aug 27	0.79	*Sep 11*	*0.06*	*0.73*	*5.08*		
Sep 9	0.73	*Sep 24*					

Table 7-4. Values of DIN in Lake water at the dam site (Column L) on the "lag" dates shown (Column K),

estimated from green graphs calculated by computer (in Figure 7-3b). Column M; estimated uptake of DIN during the 15 days in which the water flows from the River to the dam site (= Columns D – L). Column N; new carbon created by this uptake (= 7 x Column M). Column O; estimated River TOC values for the lag dates found by interpolation using values in Column B Table 7-2. Column P; total TOC to be expected at the dam site on each lag date (=Cols. N+O). Columns A and D are replicated from Table 7-2 for ease of visualization. See note in caption of Table 7-2 regarding dates of DIN observations (Column A). All italicized values are for the lag dates. *Values calculated by the Excel spreadsheet show 2nd decimal place numbers that differ slightly in some cases from those shown in Column N.*

7-5. Results. Estimating TOC from DIN Uptake.

The following graphs show the results of these calculations.

For the estuary case, Figure 7-4 shows how the levels of TOC that *must* be created by the daily uptakes of NN (that is, "DIN-TOC," Col. J Table 3-3) compare with the TOC values presented directly by the modelers in their graph (Figure 7-3a, estuary, blue). For the Lake case, Figure 7-5 shows how the levels of organic carbon created by 15-day uptakes of DIN (Col. N Table 7-4) compare with the TOC values presented by the modelers in their graph (Figure 7-3a). In both cases, the graphs shown by the modelers should "fit" between my uppermost and lowermost lines (purple and black respectively; see Figure captions).

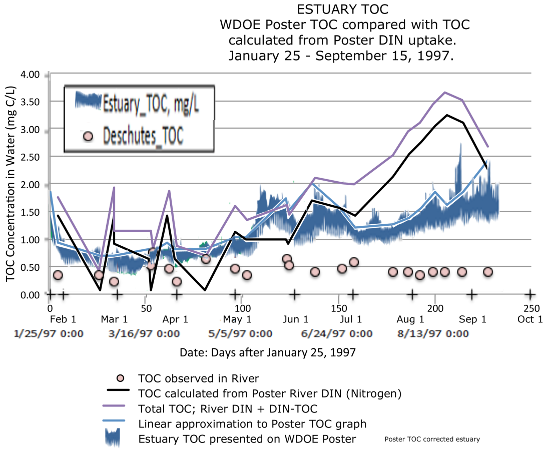	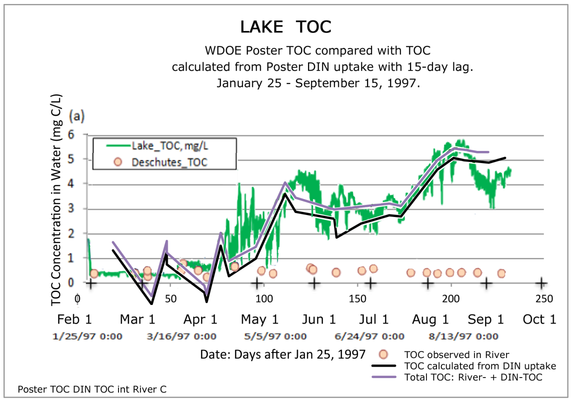
Figure 7-4. Estuary Case. Comparison of TOC calculated from DIN uptake with TOC presented by modelers. Data points show TOC observed in River (as in Figure 7-3a). Black line: DIN-TOC calculated from DIN uptakes (Col. J Table 7-3). Uppermost line; Total TOC in estuary (DIN-TOC + River TOC) at dam site (Col. JJ Table 7-3). Background blue graph: modelers' calculation of Estuary TOC at dam site (as in Figure 7-3a). [Narrow blue line – calibration confirmation, spurious, please ignore.]	*Figure 7-5. Lake Case. Comparison of TOC calculated from 15-day DIN uptakes with TOC presented by modelers. Data points show TOC observed in River (as in Figure 7-3a). Black line: DIN-TOC calculated from DIN uptakes (Col. N, Table 7-4). Uppermost line: Total TOC in lake (DIN-TOC + River TOC, Col. P, Table 7-4) at dam site. Background green graph: modelers' calculation of Lake TOC at Bridge site (as in Figure 7-3a).*

7-6. Errors in Ecology's Calculations and Interpretations.

The Ecology graphs used as "proof" of the "organic carbon" claim are deficient in these ways.

1) Ecology’s Lake TOC (green) graph correctly shows all of the organic carbon created in the Lake over the growing season. However, the only way that *all* of it could show up at the dam site would be if *all* of the growth was in the form of phytoplankton. For that to happen, *all* of the large plants that dominate the Lake would have to stop growing throughout the entire summer. That is impossible.

2) Ecology’s Estuary TOC (blue) graph fails to show about half of the new organic carbon that *must* be created in the estuary during the growing season from the known uptake of DIN. There is no ecologically realistic “hiding place” (= immobile reservoir) in a headward estuary into which the missing organic carbon can disappear. Either a modeling error has been made or the “missing carbon” has escaped to Budd Inlet.

3) The Lake has 15 days to trap incoming Deschutes River nitrogen, the estuary has only about one day. The Lake reduces the escape of DIN into Budd Inlet to near-zero by August (Fig. 7-3b), converting all that it captures into TOC shown in the green graph (Figure 7-3a). The DIN level “at the dam” in the Estuary case remains high and steady all summer. A torrent of DIN escapes into Budd Inlet beyond the dam before the headward estuary phytoplankters can capture it, all summer long. The TOC that it creates must be exactly the same as the total produced in the Lake, but almost all of the “Estuary TOC” is out in Budd Inlet where the Ecology graph doesn’t show it.

7-7. Waterborne TOC in Real Life.

As a reality check, Figure 7-6 compares Ecology’s Lake calculations with real-life observations.

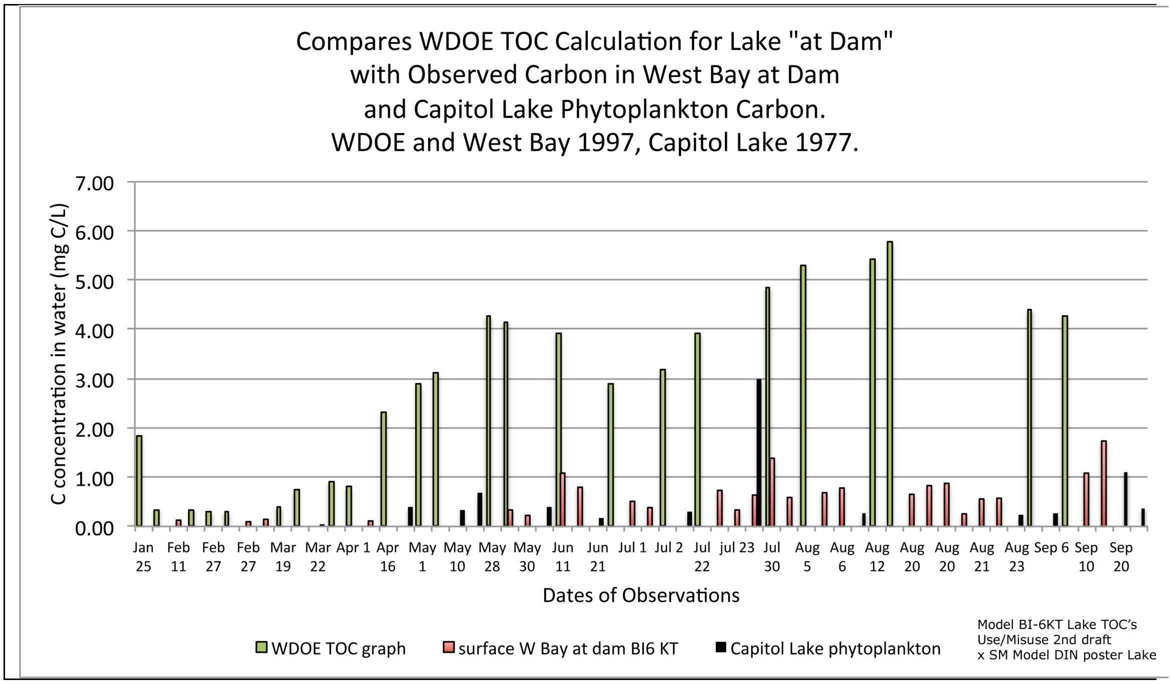

Figure7-6. Comparison of Ecology's calculated TOC levels in water near the dam site (estimated in Table 7-2 Column E, this Review) with nearby observed levels in salt water (BI-6 KT site) and Capitol Lake. BI-6 levels were calculated from measured chlorophyll levels (from Chlorophyll graph p. G2-3 TMDL Appendix G2) using modelers' "C=50xChl" conversion. Lake TOC levels estimated from phytoplankton volumes x 0.1 mg/mm^3 (gives phytoplankton dry weight) x 0.5 mg C/mg dry weight (gives carbon fraction of dry weight), Table 8 in CH2M-Hill 1978.

The tallest (green) bars are the levels of waterborne TOC calculated by Ecology (green graph in Fig. 7-3a) between January 25 and September 15, 1997, as estimated in Table 7-2, Column E. The small red bars show observed levels of organic carbon in phytoplankton in marine surface waters just beyond the dam (site BI-6). The small black bars are estimates of phytoplankton carbon in Capitol Lake, 1977. (In this compressed chart, only one observed bar [at July 30, Capitol Lake] is as tall as Ecology's calculated values.) Ecology's calculations show 4 to 5 times as much waterborne phytoplankton carbon as occurs in the two real-life situations.

7-8. Real Life Estuaries and Lakes.

The plants at the head of an estuary are mostly single-celled phytoplankton organisms or the cells of an algal mat on the intertidal mud. Although there can be tremendous production of new organic carbon by those organisms, there is not much capacity there for carbon "storage." In those communities, cells are eaten, oxygen is consumed, and nitrogen and carbon are recycled almost as fast as the algal cells grow. There can be no huge buildup of immobile new carbon-containing biomass. In the lake, the plants are mostly big rooted floating or submerged entities that can store the new carbon they create for a whole summer – or even for years. The DIN taken up disappears from the water, the newly created carbon compounds remain in the rooted plants where they are formed, and there the carbon stays out of circulation all summer long. Here there is a huge capacity for long-term carbon storage. Where that is the case, carbon simply "disappears" from the waterborne TOC calculation.

The modelers' calculations show exactly the opposite. A huge amount of new carbon seems to be stored out of circulation ("disappears") in the estuary case where one would expect no storage, and *none* of the newly created carbon disappears in the lake case (where one would expect huge storage) throughout most of the summer.

In addition to their enormous uptake of nutrient nitrogen (and that of the abundant algae attached to the huge surface area the plants provide), large plants create an unfavorable environment for phytoplankton in two ways. Floating and submerged leaves shade the water and reduce the sunlight available for phytoplankton. The large plants also provide cover from fish predation for the small zooplankton organisms that eat phytoplankton. If carbon production and storage by large plants and the carbon that ends up waterborne as TOC in the form of phytoplankton were properly modeled, the "Lake TOC" in Figure 7-3a would be smaller – *much* smaller – than that shown by the Department of Ecology.

7-9. Summary of Both Cases.

Figure 7-7 compares both cases. As before, the green and blue graphs show levels of "Lake TOC" and "Estuary TOC" at the dam site as calculated and presented by the modelers (Figure 7-3a above). The dark green- and blue- lines in Fig. 7-7 are the "Lake Corrected TOC" and "Estuary Corrected TOC" lines, same as the "Total TOC lines" in Figures 7-4 and 7-5 above (purple lines in those Figures), calculated by me.

The first thing to look at in this Figure is whether the modelers' graphs (green and blue ragged lines) fit my calculated ("corrected" green and blue lines, smooth and thin). After about May 1, when the growing season begins, my green "Lake Corrected TOC" line is a good fit to the modelers' green TOC graph. My "Estuary Corrected TOC" line, however, is at about twice the level of the modelers' blue TOC graph. More TOC was created from DIN uptake than the modelers' calculation shows, in the estuary case. That could happen if some of the new carbon was permanently removed from the water and stored in a reservoir, never to show up as TOC. An estuary has no such reservoirs, but it can happen in a lake where the "carbon storage reservoirs" are large plants.

The "Lake Corrected 50% Storage" line illustrates the following scenario. Suppose that roughly half of the new biomass created by all photosynthesizers during each 15-day interval (and therefore the carbon contained in it) remains in the large plants as new living stems, leaves, roots and flowers until after September 15. This would be "stored carbon," manufactured from DIN uptake but never appearing in the water as TOC. What would appear in the water in the form of phytoplankton is shown by the "50% Storage" line. Likewise the "90% Storage" scenario line shows TOC that would be present in the water if large plants stored 90% of all carbon in newly manufactured biomass and phytoplankton contained the remaining 10%.

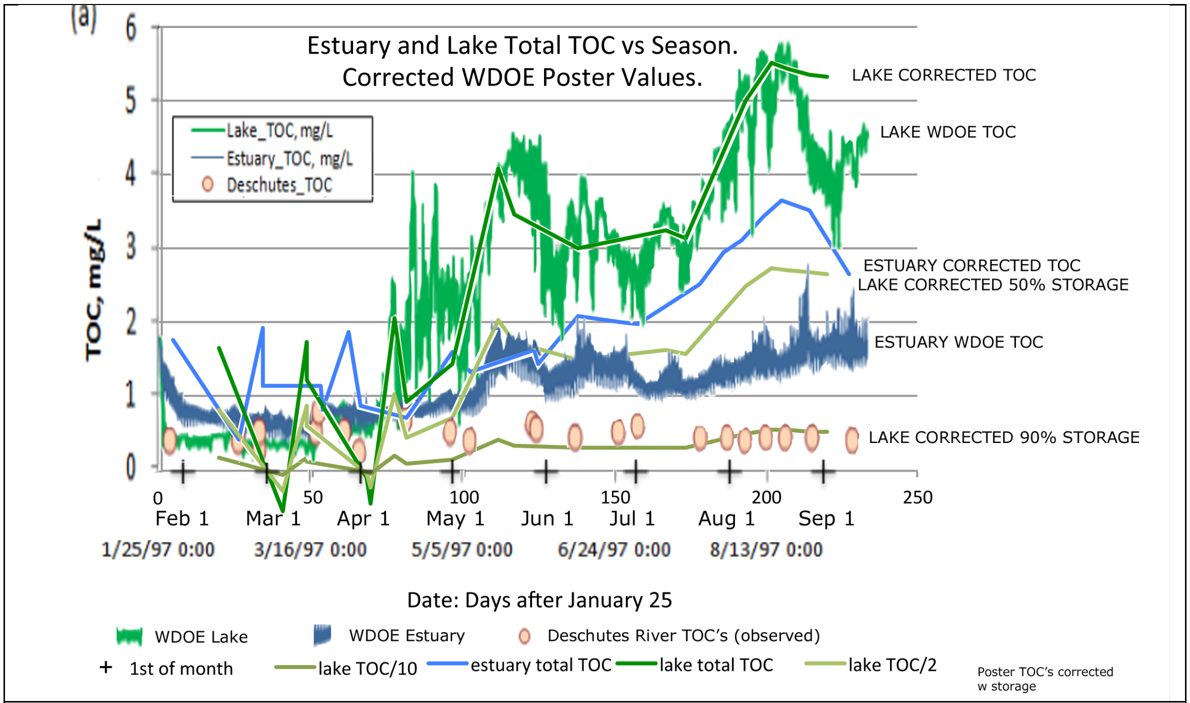

Figure 7-7. Summary. Ecology Poster TOC's compared with (my) corrected calculations. Data points for all Lake Corrected TOC's (points not shown but occurring at breaks in the dark- and light- green linear

graphs) are for dates 15 days after the observed River data dates, reflecting the 15-day passage of water through Capitol Lake. Data points for Estuary Corrected TOC's (blue line) are for the same dates as the observed River values, reflecting the one-day passage of water from the River through the estuary. Estuary and Lake corrected TOC's show the carbon calculated from DIN uptake ("DIN-C" in the text) with the river TOC's added (uppermost purple lines in Figures 7-4 and 7-5), present at the dam site. "Lake Corrected Storage" lines show phytoplankton TOC at the dam if the large plants create and store none (uppermost), 50% or 90% of the total new carbon produced.

If the large plants succeeded at capturing and storing even as little as 50% of all new carbon-containing biomass manufactured by photosynthesizers, the amount of TOC escaping from the Lake would be less than the amount of TOC in my calculated (corrected) Estuary scenario. My expectation is that the large plants would succeed at storing at least 90% of all carbon in newly manufactured biomass (the 90% scenario).

Ultimately the total TOC resulting from the Deschutes River DIN/NN input would be the same whether the plants and algae are freshwater or saltwater species. My "corrected" estuary calculation, while showing twice as much TOC as Ecology's graph admits, is still not as high on the scale as the uppermost Lake graph. That is probably because "the rest of the [estuary] story" is out in Budd Inlet beyond the dam site. Organic carbon in the Lake ending up at the dam site is the product of 15 days' photosynthesis; the lower amount from the estuary has formed only in the single day or so that it takes incoming river water to reach the dam site and exit this modeled part of the estuary. A torrent of DIN/NN continues past the dam site outward into Budd Inlet (see blue graph, right edge of Figure 7-3b) where the rest of the Deschutes River-driven organic carbon production (and oxygen depletion), not shown in the simulation, will run to completion. The estuary water will produce as much TOC as the lake water, with much of it farther out in West Bay than the dam site.

The bottom line is that the Lake allows near-zero nutrient nitrogen to escape to Budd Inlet (rightmost part of the green graph in Fig. 7-3b) and almost zero organic carbon (rightmost end of the light green "90% correction" line, Fig. 7-7) to escape to Budd Inlet. The estuary allows a summer-long gusher of nutrient nitrogen to escape past the dam into Budd Inlet (rightmost part of blue graph in Fig. 7-3b), an ongoing stream of TOC passing the dam as the modelers show it (rightmost part of blue graph, Fig. 7-7) and another stream of TOC about the same size as the one shown by the modelers disappearing in some unexplainable way (distance on the graph between my blue "Estuary Corrected Line" and the modelers' blue graph line, Fig. 7-7).

The true bottom, bottom line – data included by the modelers in their Fig. 7-3 show that the Lake would deliver much less nitrogen and much less TOC to Budd Inlet than would an estuary occupying the Lake Basin.

7-9. Why are the Modelers Fixated on Phytoplankton?

Phytoplankton cells are not much different from chemicals in a physical model of the movements of water. The water takes them wherever it goes, they interact with other chemicals (producing O_2 and consuming nutrients and CO_2, for example), interact with small swimming or drifting animals that can themselves be accommodated by a physical model, and differ from chemicals mainly in that they reproduce (and sink). The plants of a shallow freshwater ecosystem, on the other hand, are in a separate simulation universe that a physical model can't be tweaked to accommodate. They require a complex separate model that recognizes trophic levels, long lifetimes with little or no movement, many species with different ecological roles, competition, predation, and other complex features of their existences, all in addition to the chemistry and hydrology so familiar to physical modelers. In Budd Inlet, focus on the phytoplankton is the way to go; in a rich shallow lake filled with plants and animals, that is not enough. Unless the Budd Inlet model was grafted onto a whole different complex ecosystem model – which I expect it was not – there is little hope of it giving trustworthy insights into Lake processes.

If macroscopic plants were periodically harvested and removed from Capitol Lake, the effect would almost certainly be to strengthen the Lake's ability to capture NN and for that harvest to physically remove some nutrients from the Lake and Budd Inlet aquatic systems once and for all. A harvest program would almost certainly strengthen the Lake's ability to protect Puget Sound. *The most aggravating omission from the entire SM Report is the deliberate omission of simulation of a harvesting program.* The modelers tell us essentially that they already know that such a simulation would be unhelpful and, based on their guesses about phosphorus, phytoplankton, the tonnage required, and the like, they declined to do it (p. 69, SM Report). To the contrary, it would show that *exploiting this rare opportunity to physically remove nutrient nitrogen from the water would relieve the pressure on dissolved oxygen in Budd Inlet* – a beneficial effect of the Lake that Ecology seems strangely anxious to avoid publicizing.

In a meeting on November 12, 2013 one of the modelers was asked whether harvesting the plants in Capitol Lake could be an effective way of preventing nutrient nitrogen from reaching Budd Inlet. Her reply – "It is unrealistic to harvest the phytoplankton because it is microscopic." -- an anecdotal incident that suggests that the modelers don't recognize the giant presence and ecological dominance of macrophyte plants in the Lake (Havens pers. comm., 2015).

7-10. How Would These Errors Affect Our View of Dissolved Oxygen in Budd Inlet?

Figure 16 in the SM Report "shows" the Lake creating lower DO levels in Budd Inlet bottom water than those that would be present if the dam were removed. That Figure is the result of the fatally flawed computer simulation and interpretations of its output described above. Ecology has got it backwards. *The Lake would have much less adverse impact on Budd Inlet than would the Estuary.*

The Department of Ecology's Supplemental Modeling Report.
A Critical Review.

8. THE LATE-SEASON DEPARTURE OF ORGANIC CARBON.

8-1. Ecology's "Organic Carbon" Hypothesis and the Real World Alternative.

After I (and others) suggested that Capitol Lake might be helping Budd Inlet resist low DO levels by removing Nutrient Nitrogen (NN) from the Deschutes River water, the Department of Ecology began looking for ways to downplay this positive feature of the Lake. The answer that they arrived at is this: "Yes, the Lake traps NN and stores it in plant biomass, but then the biomass itself immediately goes over the dam into Budd Inlet in the form of organic carbon, then decays and releases the trapped NN in the saltwater." Then, of course, marine phytoplankton growth would immediately follow in Budd Inlet with the sinking phytoplankton using up oxygen at the bottom as it decayed. In that scenario, the uptake of NN by the Lake would postpone oxygen depletion in Budd Inlet by only a few days – an insignificant protective effect. In all of their subsequent dealings, the code words "organic carbon" refer to this idea.

It is true that, sooner or later, some, most or even all of the new plant biomass formed each summer in the Lake must be eaten or break down and decay, releasing nutrients and using up oxygen in the process. The critical questions are "Where?" (in the Lake? Budd Inlet? both?) and "When?" ("sooner," during the summer growing season, or "later," after the growing season?)

The real-life story is that most of the organic carbon created in the Lake during summers either decomposes there or, if it leaves the Lake, does so after the main growing season, when its oxygen-consuming decomposition in Budd Inlet can do no harm. That is, most of the organic matter that escapes from the Lake does so "later," not "sooner" as in Ecology's claim. The following describes that real-life phenomenon.

8-2. Seasonal Change in Capitol Lake.

To people who visit Capitol Lake, the most familiar fact is that the whole Middle Basin and parts of the North Basin fill up with "weeds" every summer. The weeds' growth is made possible by the vast quantities of NN delivered to them daily by the Deschutes River. Those plants are the base of a food web that includes ducks, insects, and a few other animals that eat certain plants directly. When the plant parts break off, sink, and decay, they support legions of clams, worms, insects, snails, crustaceans, and bacteria, many of whom become food for fishes, otters, waterfowl, and even for bats and swallows. These other organisms capture and store some of the NN originally trapped by the plants – for the durations of their entire lifetimes or until they themselves are eaten.

The same tonnage of plants would be created and would decay if the Deschutes River nutrient nitrogen went directly into Budd Inlet. The effect of its decay or consumption in the Lake is to prevent that consumption from occurring in Budd Inlet.

All of the organisms that respire in the Lake water prevent oxygen consumption in Budd Inlet. But their eventual deaths and decay then release the NN contained in them. In the slow-moving Lake water, that released NN can be immediately recaptured by other plants and phytoplankton and again held for a long or short time in the Lake. A few such re-cycles of the NN, especially if the NN is taken up by large plants, can long delay or even prevent its eventual escape from the Lake.

The NN from the Deschutes River enters the Middle Basin at its farthest point from Budd Inlet. That Basin is a long water body shallow enough (average depth about 9 feet) for sunlight to penetrate to the bottom and for rooted plants to grow virtually everywhere.

The giant submerged "forest" of plants in the Middle Basin seems to be invisible to the Ecology modelers. Their attention is focused on phytoplankton – the small drifting single plant cells that are the mainstay of photosynthesis in most of the ocean and in some lakes. Figure 8-1 (upper graph, green line) shows Ecology's calculation of the amount of organic carbon produced in the Lake each year by plants *and released to Budd Inlet*. To arrive at that answer they must assume that *all plant growth in the Lake is by phytoplankton* – there can be no growth at all of large plants. The upper green graph accurately portrays the amount of organic carbon production – *but in real life the amount escaping to Budd would be so small that that line would be at the very bottom of their graph*. (This unrealistic Figure, shown here for reader recognition, is analyzed in depth in Chapter 7.)

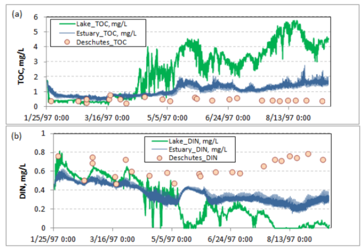

Figure 11. a) Total organic carbon (TOC) and b) dissolved inorganic nitrogen (DIN) concentrations at the location of the Capitol Lake dam under Lake (with the dam) and Estuary (without the dam) scenarios compared with concentrations in the Deschutes River at E Street.

Poster graph Grab2 > Figures

Figure 8-1. Ecology's calculations of organic carbon and nutrient nitrogen production in Capitol Lake or an estuary in the Lake basin. See Chapter 7.

The most abundant plants in Capitol Lake are a leafy submerged native species (*Elodea canadensis*) that grows attached to the bottom. Also abundant are native species of *Potamogeton*, rooted plants with flat oval or strap-shaped leaves that float at the surface (TMDL Appendix C, 2012). These and a few others (eg. introduced water lilies) make the water very unfavorable for phytoplankton in two ways. They shade the water beneath them (reducing the light available for phytoplankton growth) and they provide cover from predatory fish for zooplankters – copepods, rotifers, cladocerans and other tiny swimming animals that eat phytoplankton.

The rooted plants can only enter Budd Inlet if and when they break up and drift to the dam – in late summer. While growing, they "snag" floating masses of algae and duckweed and anchor them in the Lake until late summer as well.

The biomass of the rooted plants in Capitol Lake is at least 50 times that of the phytoplankton. (That calculation is shown in an Optional Technical Note section at the end of this Chapter.) In addition to their overwhelming biomass abundance, the rooted plants act as "platforms" for fuzzy blankets of tiny algal filaments that grow attached to the stems and leaves. Given this real-world ecology, *it is likely that phytoplankton make up*

2% or less of the plant production in the Lake. On Ecology's graph (Figure 8-1), that would be a green line so close to the bottom of the graph that it would be invisible.

With over 50 times the biomass of the phytoplankton, the large plants and their algal overgrowths get "first dibs" on the NN in the river water moving through the Middle Basin and take up about 58% of all of the NN delivered by the Deschutes River. The North Basin takes up some of the NN that escapes from the Middle Basin, removing by itself nearly 25% of the total NN delivered by the Deschutes River (Figure 34, CH2M-Hill 1978).

Figure 8-2. Floating plants and algal mats pushed toward and into the Middle Basin (behind the RR bridge) by wind from the north. The Middle Basin has surface plant mats piled by the wind and/or growing along its south shore in the distance. August 19, 2015.

"Delay" is the name of the game. If the Lake plants can delay the escape to Budd Inlet of the nutrient nitrogen that they capture each summer (or the new organic carbon that they manufacture) until October or later, they can prevent those materials from depleting oxygen in Budd Inlet during September (the critical growing season). And several factors do indeed delay the escape of the Lake's new plant biomass each summer.

The rooted plants stay put, except for pieces that break off and drift around. These pieces and floating algal mats are confined to the Middle Basin by three factors; partial blockage of the Basin's outflow by a railroad bridge at its north end, prevailing summer breezes from the north that confine the floating plants and algae to the south side of that bridge, and the anchoring effect of the rooted plants where the floating masses tangle with the surface leaves and stems. The deeper North Basin's plants are confined to that Basin's shores and shallow water. As in the Middle Basin, floating algal and plant masses are pushed southward by the prevailing summer breezes from the north, with the result that they accumulate along the shore farthest from Budd Inlet or are even pushed back southward under the railroad bridge into the Middle Basin (Figure 8-2). Occasional summer breezes blowing northward push floating algae (and trash) into an embayment at Heritage Park on the northeast shore, where this floating debris remains all summer long. These effects of the wind and Lake topography keep most of each summer's newly formed plant biomass in Capitol Lake until about October or later. In autumn the winds switch to their winter pattern (blowing regularly from the south) and begin to push floating Lake material toward Budd Inlet.

Figure 8-3. Floating plant matter trapped in the Heritage Park embayment where it remains all summer long. August 20, 2015.

Ecological processes contribute to the delay of NN passing through. Oxygen is consumed in the Lake – not Budd Inlet – whenever the newly created plant biomass is eaten or decays.[1] When that happens, the NN captured by the plants is released back into the water. The "residence time" of water in the Lake – the time elapsed between its entry from the Deschutes River at the south end and its departure to Budd Inlet at the north end -- is about 15 - 20 days. During that passage time the released NN can be taken up again by plants and again stored in new biomass. Cycling thus in the Lake much NN can reside there in plants throughout most or all of the summer growing season. Its best opportunity to move into Budd Inlet is after September. In late October uptake by plants stops and NN, now delayed in its journey to the sea by weeks or months, finally escapes from the Lake either dissolved in the water or in the biomass of senescent plants. (This cessation of uptake is shown in Figure 7-1 in Chapter 7 and also in Figure 8-5 below.)

Once the plant matter from Capitol Lake reaches Budd Inlet, there is one last mechanism of delay before it can start using up oxygen. Freshwater plant material is rich in cellulose, one of the most indigestible carbon compounds in nature. The plant biomass can drift for a long time and distance – perhaps entirely out of Budd Inlet -- before finally succumbing to the (mostly bacterial) processes that decay it.

Once the growing season is over, floating masses of plants begin to appear at the dam and go down the fish ladder into Puget Sound (Figure 8-4). Such sights are seen regularly during the fall, but only occasionally during the summer.

This scenario is described in a consultants' report on results of a Lake drawdown in 1997 (Entranco, 1997). The authors' expectations are that "… decay of the plants and algae occurs over a 60-day period at the end of the growing season, and … 100 percent of the nitrogen and phosphorus contained in plant tissue is contributed to the water column at that time …".

It is impossible to learn anything about this phenomenon from the Budd Inlet Model. The model's calculations stop on September 15 (Figure 8-5). The uptake of NN by the Lake via new plant growth continues until well into October, "beyond the edge of the universe" from the model's perspective. We must look to real, observed data for insight on this.

Figure 8-4. Floating mats of Capitol Lake plants at the dam exiting to Budd Inlet. October 28, 2015.

If "delayed release" of most of Capitol Lake's decaying

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[1] Massive oxygen consumption in the Lake water can *never* deplete the DO level there, for reasons explained in Chapter 9.

plant material really occurs, one would expect large-scale consumption of dissolved oxygen in Budd Inlet during October and November when the main mass of dead plant matter surges out of Capitol Lake and into the Inlet. In fact, there is an observed overall decline in DO through early fall culminating in levels below the water quality standards in the central and outer Inlet by late November at all depths, with recovery in December. Figure 8-6 shows this phenomenon during Fall 1996 at station BC-3 near the west-side Tykle Cove shore (BISS, 1998).

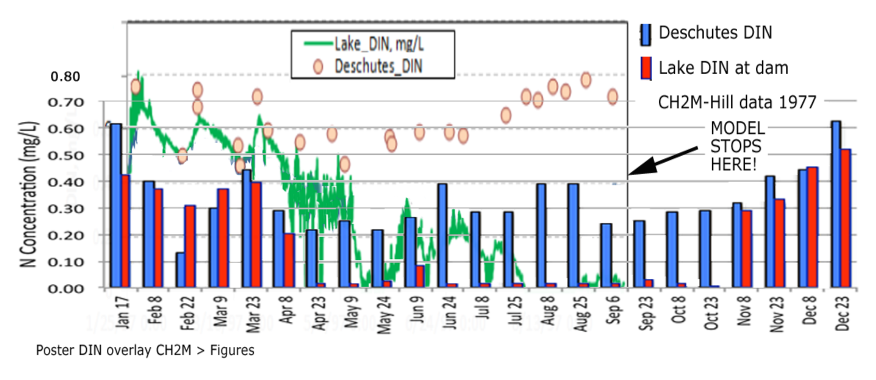

Figure 8-5. Budd Inlet Model prediction of Dissolved Inorganic Nitrogen (DIN) in Capitol Lake compared with observed data. The Model simulation ends while DIN uptake in the Lake is still continuing through mid-September and October. Superposition of Figures 7-1 (1977 data, CH2M-Hill) and 7-3b (1997 Poster- and SM Report - data and graph in Organic Carbon section, Chapter 7. The green graph is that in Fig. 8-1b above.) CH2M-Hill data (bars) are from 1977, SM graph and data points are from 1997.

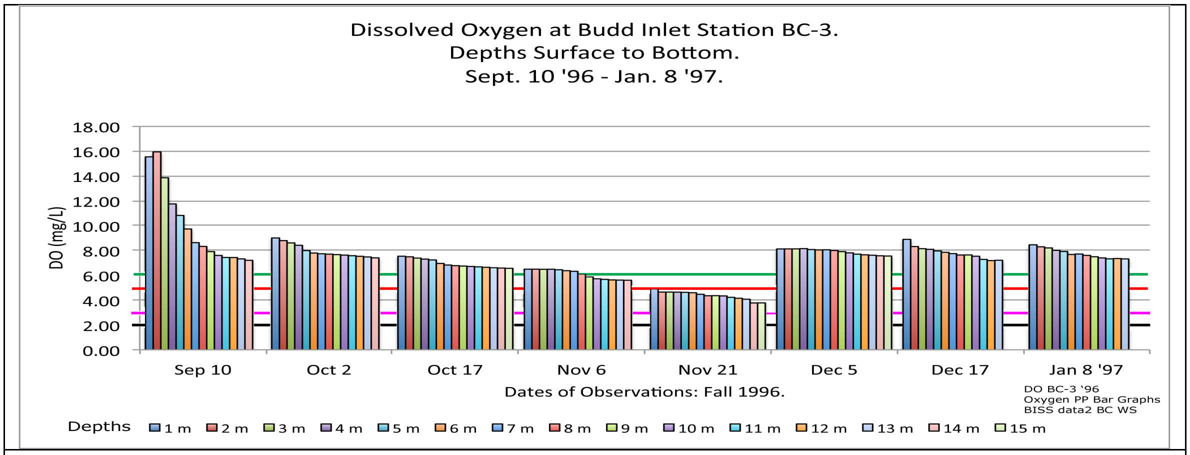

Figure 8-6. Dissolved oxygen vs. depth at station BC-3, central Budd Inlet, September 10 1996 – January 8 1997. In each group surface DO is leftmost bar, bottom DO is rightmost bar. Lines are 6.0- and 5.0-mg/L (green and red, DO standards), 3.0 mg/L (purple, low DO stress level), and 2.0 mg/L (black, low DO acute stress level). Source: BISS 1998.

This effect can be seen at stations in Budd Inlet from BF-3 near Boston Harbor to BB-1 opposite Priest Point Park. It is not detectable from the BA stations inward to the heads of East and West Bay.

This pattern is what we might expect if the DO drop is due to the decay of escaped Lake vegetation in late Fall. That is when Lake plant uptake of nitrogen nutrients and growth ceases for the year (see Figure 8-5 above) and when mats of vegetation break loose and drift to and over the dam. The Lake plants, unlike phytoplankton, are composed of decay-resistant cellulose and would not be expected to start depleting the Inlet's oxygen in the inner harbor immediately after entry. The following analyzes this possibility.

8-3. Background for Understanding the Late Fall Decline in Dissolved Oxygen in Budd Inlet.

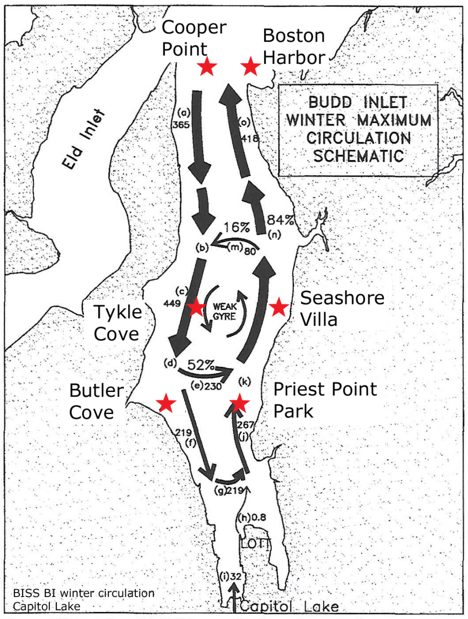

Figure 8-7. Circulation of water in Budd Inlet. Winter. Widths of arrows show sizes of flows. Stars show stations discussed in the text. Source: BISS 1998.

To investigate the late Fall drop in Budd Inlet's dissolved oxygen levels, I examined DO data collected during the BISS research conducted during fall and early winter of 1996. (The BISS study ended in September 1997, hence the need to look at 1996 fall data.)

Figure 8-7 shows the winter circulation pattern of water in Budd Inlet. (Summer circulation is the same, but the numbers are slightly different.) A massive stream of water enters the Inlet along the western shore. Mostly hugging the bottom, it heads southward, then turns and crosses Budd Inlet north of the Port Peninsula. That stream then heads northward along the eastern shore, now nearer to (or at) the surface. Some of it turns and re-enters the incoming stream, but the rest (some 80+ %) exits Budd Inlet at Boston Harbor. This is the "estuarine circulation," entirely independent of the tides, described in Chapter 1.

The "residence time" – that is, the average amount of time during which incoming water remains in the Inlet before leaving again – is about 8 days in winter and 12 days in summer (BISS, 1998). The BISS authors describe this non-stop year-round flow as "strong circulation."

The incoming salt water has characteristics acquired in Puget Sound outside Budd Inlet. While it is in the Inlet, Capitol Lake impresses it, more or less, with its own fresh water "signature." The BISS stations are numbered such that the "3's" are along the west shore, influenced by the incoming stream; the "1's" are along the east shore, influenced by the outgoing stream (the "2's" are in the center; see Figure 2-2 Chapter 2). Thus station BC-3 (Figure 8-7, Tykle Cove) is near the west shore and is more heavily influenced by water entering Budd Inlet than by water exiting the Inlet. By comparing the west shore and east shore stations, we can try to detect Capitol Lake's "signature" in the Inlet water.

8-4. Incoming and Outgoing Water; The Fall Seasonal Effect on Dissolved Oxygen.

Figure 8-8 compares stations DO levels at BC-3 (west shore) and BC-1 (east shore).

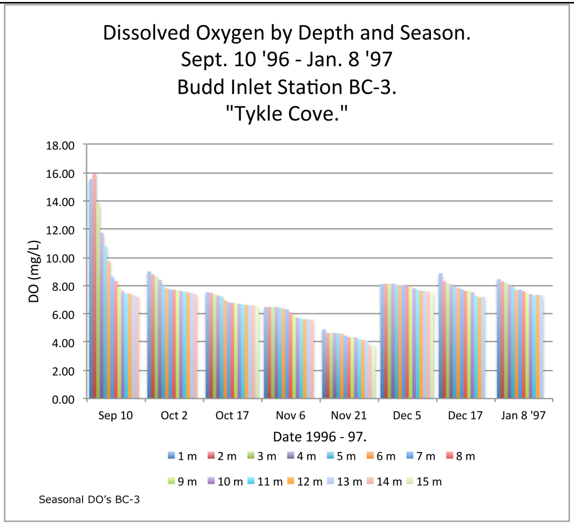

Figure 8-8a. Oxygen levels in incoming water at the position of Tykle Cove, west shore of Budd Inlet. Each group of bars shows DO's ranging from the surface (leftmost bar of group) to the bottom (rightmost bar) on each date. Source: BISS spreadsheet 1998. [This repeats Figure 8-6 above.]

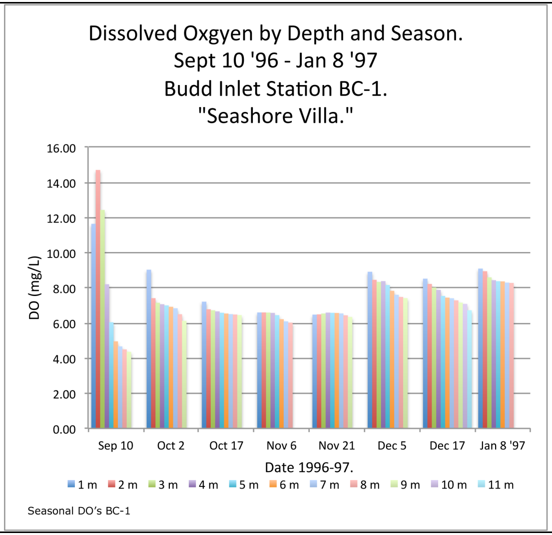

Figure 8-8b. Oxygen levels in outgoing water at the position of Seashore Villa, east shore of Budd Inlet opposite Tykle Cove. Format as in Figure 8-8a. Source: BISS spreadsheet 1998.

During September, DO levels are lower – *much* lower at the bottom -- in the outgoing water than in the incoming water (respectively BC-1, Fig. 8-8b and BC-3, Fig. 8-8a). During its passage, processes that deplete oxygen in innermost Budd Inlet remove DO from the incoming water before the flow takes it back outward. From October through early November, DO's are about the same in the outgoing water as in the incoming water, gradually declining along the incoming (west) shore while holding steady along the outgoing (east) shore. In November, the DO in the incoming water reaches the lowest point in its decline, but is dramatically restored by the time it begins its exit via BC-1. After November the incoming and outgoing waters have roughly the same amounts of dissolved oxygen.

That pattern suggests that something is reducing DO outside Budd Inlet. The "something" may be decaying Lake vegetation – but it almost certainly includes a much greater regional effect of decaying terrestrial leaves entering the water everywhere around Puget Sound on a grand scale at this time of year (Figure 8-9).

Figure 8-9. Autumn leaves with Lake vegetation mat near dam. Nov. 1, 2015.

Figure 8-10 shows a composite view of this oxygen pattern as the water passes through Budd Inlet. In that Figure, the DO at each depth at BC-3 (Tykle Cove) has been subtracted from the DO at the same depth at BC-1 (Seashore Villa) to show the change in DO as the water passes from BC-3 (inbound) to BC-1 (outbound). Where the result is negative, the water has lost oxygen during its passage from the west side around to the east side. Where the result is positive, the water has gained oxygen. The late-summer removal of oxygen from the water is very strong in September. A startling recharge occurs in November. These changes, *both* occurring *at all depths* are the most prominent features of this pattern.[2]

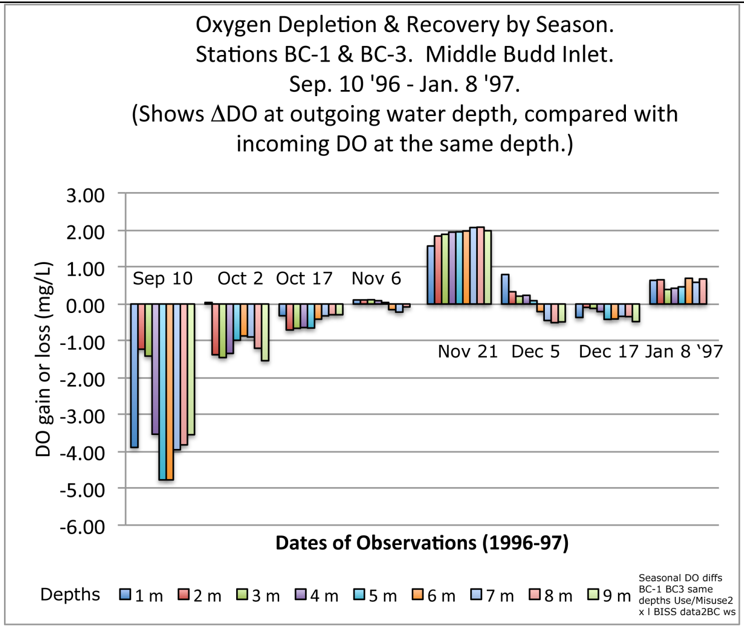

Figure 8-10. Changes in oxygen levels in water at all depths between entry to Budd Inlet (BC-3, Tykle Cove) and exit from Budd Inlet (BC-1, Seashore Villa). Bars show (DO at BC-1) minus (DO at BC-3) for water of the same depth, both stations. Negative values show loss of oxygen from water, positive values show gain of oxygen by water. Data for these subtractions are shown, bar by bar, in Fig. 8-8 above. Rightmost bar of each group shows the bottom water of the shallowest station, each comparison.

Comparisons between stations BB-1 and BB-3 (Priest Point area) and BF-1 and BF-3 (Boston Harbor area), not shown here, show the same patterns. This appears to be a general pattern of oxygen exchange throughout Central Budd Inlet.

Figure 8-11 shows the changes in water density with depth and season at station BC-1 (Seashore Villa) in Fall 1996. The water is strongly stratified in September and even more so in early October (“bent” curves) due to reduced salinity and residual summer high temperatures at the surface. The effect is to isolate deeper water from contact with the atmosphere, preventing atmospheric oxygen from replenishing oxygen consumed by processes near the bottom. By November 6, stratification has mostly disappeared (“straightening” the curves, due to cooling at the surface) and the water begins to mix from surface to near-bottom.

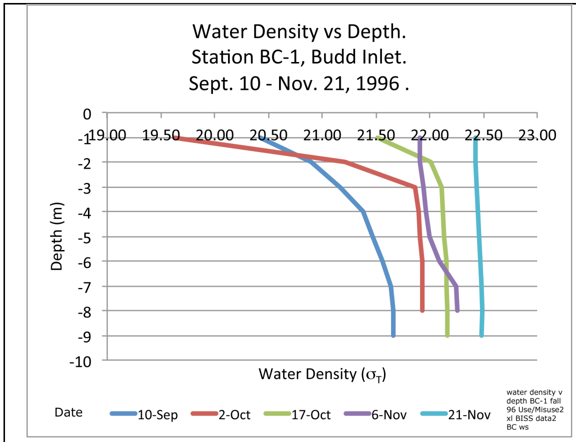

Figure 8-11. Density of water vs. depth at Budd Inlet station BC-1, Sept. 10 – Nov. 21 1996. Source: BISS spreadsheet 1998. [Density = $(\sigma_T/1000) +1$ g/mL.]

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[2] Bottom water rises, some of it all the way to the surface, as it penetrates farther into Budd Inlet. An alternative Figure comparing incoming water with outgoing water shallower by 1 meter (not shown) is almost identical to this one (Fig. 8-10) comparing DO’s at the same depths.

The effect is to expose the whole water column to the full blast of oxygen uptake from the atmosphere. Even if there is massive consumption of oxygen by decomposition of organic matter from Capitol Lake and autumn leaf-fall at this time, this huge seasonal re-oxygenation of water from the atmosphere would overwhelm it. If that is the case, then Capitol Lake may release its decaying vegetation at exactly the right time to have zero effect on Puget Sound.

8-5. Summary. The Search for a Late-Season Lake Effect.

Several real-life phenomena support the idea that decay of plants from the Lake does not cause oxygen depletion in Budd Inlet during the growing season. These are:

1) The Lake plants continue to take up nitrogen from the Deschutes River water (and thus continue to grow) until late October (Fig. 8-5);

2) Most of the plant biomass in the Lake is rich in cellulose, a material that does not decay quickly and hence has time to drift out of Budd Inlet before decaying;

3) Mats of uprooted or detached Lake plants can often be seen drifting over the dam in fall but seldom in summer (Fig. 8-4);

4) Seasonal winds blow drifting surface plants (detached algae and larger plants, duckweed, etc.) southward away from the dam during the summer and concentrate them in the Middle Basin, along the south shore of the North Basin, and in the northeast shore entrapment area of the North Basin (Figs. 8-2, 8-3);

5) Persistent low and decreasing levels of dissolved oxygen develop after the growing season throughout central and outer Budd Inlet, at a time and location where one would expect the Lake vegetation to begin to decay after its escape to the Inlet.

Items 1- 4 are not in doubt. The late-season depletion of oxygen in the outer Inlet mentioned in Item 5 is, however, likely due to the decay of terrestrial vegetation (including fallen autumn leaves) from everywhere around South Puget Sound. The stream of external water entering Budd Inlet (volume 219 m^3/sec) is nearly seven times the size of the stream exiting the Lake (23 m^3/sec, Fig. 8-7); this could dilute any Lake effect beyond recognition in the BISS data.

The only way to test this alternative hypothesis is by way of a year-long program of field observations in which organic carbon in floating biomass, phytoplankton, and dead particulate/dissolved material is directly measured. It is impossible for the Budd Inlet model to evaluate this hypothesis. The findings of a field study would be decisive for determining whether organic matter from Capitol Lake is – or is not – having an adverse impact on Budd Inlet.

8-6. Optional Technical End Note: Ratio of Biomass Between Macrophyte (Large) Plants and Phytoplankton.

The ratio "macrophyte carbon/particulate organic carbon" was calculated by me from Lake data for September 2004. Particulate Organic Carbon (POC) values in mg/L concentrations were taken from Figures H13 - H14, TMDL Appendix H, by scale measurement and interpolation. (Appendix H's misprinted "Matlab" graph scale is actually mg POC/L; Kolosseus, pers. comm.)

The average mg/L value for the whole lake in September was multiplied by the volume of the Lake to obtain total mass of POC in the Lake. September macrophyte dry weights in gm dry weight/m^2 were obtained from Figure H11, Appendix H, also by scale measurement and interpolation.

The total dry weight for the whole Lake was obtained by multiplying the average gdw/m^2 by the area of the Lake. The ratio "macrophyte dry weight/POC" is 56:1 by this calculation.

Since the carbon in living phytoplankton is only a fraction of the total POC (say half, usually less), the ratio of macrophyte- to phytoplankton carbon is probably even greater; say about 100:1.

The Department of Ecology's Supplemental Modeling Report.
A Critical Review.

9. CAPITOL LAKE: ERRORS AND FALSE CLAIMS.

Page 58 of the SM Report begins a short, error-filled section on Capitol Lake itself. A key image repeated three times in that section is reproduced here (Figure 9-1). The first appearance of this image was in 2012 in the TMDL Report, there shown as Figure 92. Wherever it appears in the SM Report, the caption refers to "oxygen depletion" in Capitol Lake. In real life, there is *never* any meaningful, real-life oxygen depletion in Capitol Lake, and the theoretical "depletions" shown in this image are grotesquely in error. If you see it in any Ecology presentation, know that whatever the speaker is saying about it is wrong.

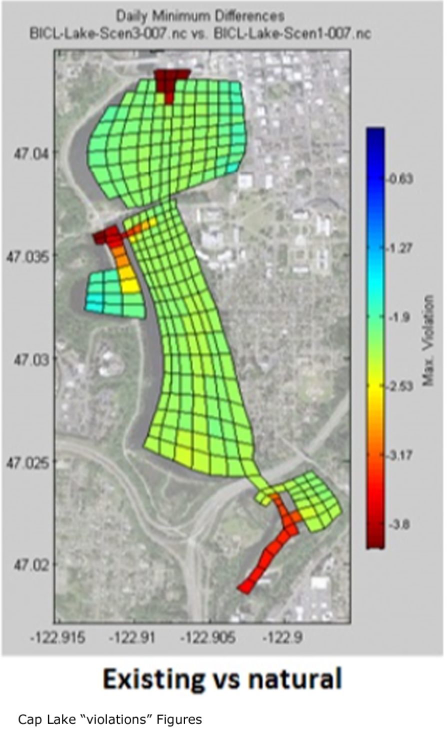

Figure 9-1. Output of the Ecology computer model that portrays all of Capitol Lake in "violation" of some dissolved oxygen water quality standard. Source: SM Report Fig. 35, p. 60.

This Chapter analyzes this worst-of-all-Ecology-modeling-failures. The findings in summary:

1) The modelers ran the simulation that produced this result with demonstrably wrong initial input data;

2) The modelers have wasted near-endless time, energy, and simulation focus on their mistaken view that phosphorus controls the Lake's ecology (it doesn't …);

3) The modelers have overlooked the critical role of nitrogen nutrients in Capitol Lake.

A few introductory words on how lakes and marine waters become oxygen-depleted and why that doesn't happen in Capitol Lake are as follows.

9-1. There is *No* Real-Life "Oxygen Depletion" in Capitol Lake.

The oxygen depletion story begins with the addition of excess nutrients (usually nitrogen and phosphorus) to the water. There they fuel the growth of plants and phytoplankton, which eventually sink to the bottom and decay. The decay (by bacteria) uses up oxygen. If there is enough sunken plant material, its decay can use up virtually all of the dissolved oxygen (DO) in the bottom water.

This process is well known to aquatic ecologists. An example is shown in Figure 9-2, which depicts a vertical DO profile in Hicks Lake in Thurston County. On June 20, 2011, the amount of oxygen in the water declined from a high level at the surface to zero at the bottom, almost certainly as the result of decay by bacteria of sinking plant matter.

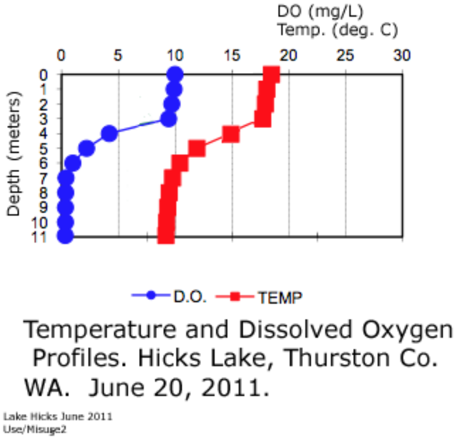

Figure 9-2. Change in dissolved oxygen and temperature with depth, Hicks Lake, Thurston County, June 20 2011. Source: Thurston County Water Resources Report 2012. (The TCPHSS original Figure has been simplified by removal of vertical profiles of pH and conductivity.)

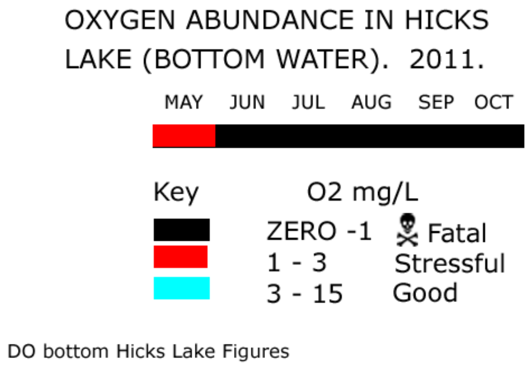

Figure 9-3. Dissolved oxygen in the bottom water of Hicks Lake, growing season May – October 2011. Source: TCPHSS 2012.

Figure 9-3, constructed from all of the monthly vertical profiles presented in TCPHSS Report 2012, shows that Hicks Lake's bottom water was devoid of oxygen from June through October, 2011. Similar constructions for all of the lakes monitored by the Thurston County Health Department (Figure 9-4) show that *all* of the county's monitored lakes experience severe oxygen depletion at their bottoms … except one.

The exception is Capitol Lake. There, the North and Middle Basins *never* became fully or even partially DO-depleted at the bottom in 2011 (and in 2005, included to show that the data gaps for 2011 weren't hiding DO problems).

Why is Capitol Lake the exception, despite the enormous load of nutrient nitrogen and phosphorus dumped into it daily by the Deschutes River? The River itself is the answer.

Unlike the other lakes, which are enclosed basins, Capitol Lake is a flow-through ecosystem that is constantly refreshed by the entry of river water at its southern end. The river water is supercharged with oxygen by its passage over Tumwater Falls. The result is that *the water entering Capitol Lake is always as high in dissolved oxygen as it can naturally get* (100% saturated) without the additional help of plant photosynthesis. *Always*. Because it is almost always cooler than the Lake water, the river flows along the bottom, slowly upwelling as it goes. The result is that the bottom water of Capitol Lake (and all of the rest of the water as well) *never* runs out of oxygen no matter how much decay of sunken plant matter takes place. In this regard Capitol Lake is an "oxygen superpower," an "oxygen blast furnace" unlike every other lake almost everywhere else and unlike the marine water just beyond the dam.

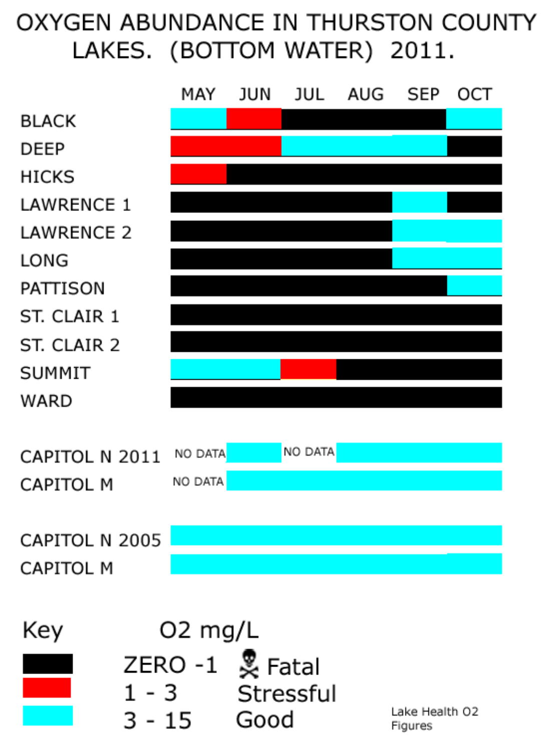

Figure 9-4. Seasonal bottom water DO concentrations in 10 monitored Lakes in Thurston County in 2011. Source: TCPHSS Report 2010-12.

Figure 9-5 shows dissolved oxygen levels in the Middle Basin of Capitol Lake during the 2014 growing season. The Basin's DO levels remain at values classified as "extraordinary" all season long, never dropping to the level of the standard for the lower Deschutes River (8.0 mg/L).

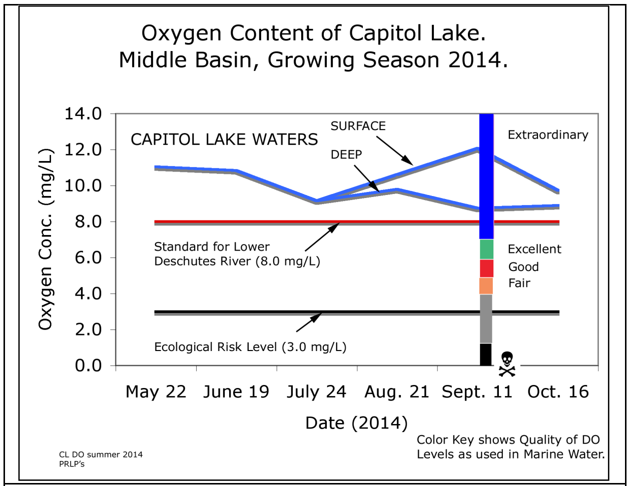

Figure 9-5. Capitol Lake dissolved oxygen levels, 2014. Measured DO levels of Capitol Lake (upper lines), May – October 2014, Middle Basin. Water quality standards for the lower Deschutes River (8.0 mg/L) and low-DO ecological risk level (3.0 mg/L) are also shown. Water quality labels used to describe DO levels of various amounts are shown on the colored scale. Sources: TCPHSS 2012-14; Ahmed et al 2013; Vaquer-Sunyer and Duarte 2000.

There is *never* a real-world problem with "oxygen depletion" in Capitol Lake.

9-2. Ecology's "Dissolved Oxygen Deficiencies" in Capitol Lake Were Calculated Incorrectly.

9-2a. Background for the Correct Calculation.

Repeated mention is made *ad nauseam* of "DO depletion" in Capitol Lake throughout the "Capitol Lake Scenarios" section of the SM Report. In real life the oxygen levels in the Lake are always at the "extraordinary" highest level of classification at all depths (Figure 9-5). What DO standards could possibly be violated in a Lake that is always extraordinarily high in dissolved oxygen? The answer is that the "DO depletions" (violations) are not in the real world; they exist only in computer "cyber space;" a simulation of the "natural conditions" of a "natural" water body compared with its simulated modern conditions.

The "violations" obtained by the Model from the comparison with "natural" water are gigantic – fully 4 mg/L in the parts of the Lake closest to the Deschutes River, Percival Creek, and the dam (red zones, Figure 9-1). How does this relate to the Lake that we know? A few explanations and reminders are in order here.

Lakes do not have set numerical water quality standards (TMDL Report, pp. 19-20). Instead, the method used to determine whether a lake's waters are degraded is to compare its condition in modern times with its condition in some pre-modern era when it was "natural" and to declare a DO Standards Violation if the modern water is 0.2 mg/L (or more) below that bygone "natural DO level." As always, the challenge is to determine what the "natural" DO levels actually were in the Lake before the modern era. In this case, a "natural" Lake didn't exist in pre-modern times, but it is easy to envision a similar natural impoundment (say, fresh water dammed by a rock barrier as seen in some coastal British Columbia estuaries) and proceed from there.

There is a second difficulty, namely; "Should the 'natural' Capitol Lake be considered a lake, or simply a slow-moving part of the 'natural' Deschutes River?" If it were considered a slow-moving river, the standard for the lower Deschutes River (8.0 mg/L) would be used and the 'natural' lake DO would need to drop below that value before its DO content could be used for finding "violations." It never does that. That would be the complete, final and definitive end of the computer modeling story. Indeed there would be no computer modeling at all -- the case would be closed; "no violations."

However, a dammed reservoir can be defined as a "lake" in this way (used by the modelers). Divide the reservoir's volume by the lowest average 30-day river flow of the past 10 years and if the answer (= residence time of the water in the basin) is greater than 15.0 days, the dammed reservoir is considered a "lake," not a slow-moving "river." The modelers did so, using a low flow value apparently obtained by word of mouth,[1] and found that the residence time of water in the lake at this low flow rate is 15.2 days – just long enough to qualify as a "lake."[2]

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[1] They cite "D. Kresch, personal communication 2003", p. 13 TMDL Report, not cited in their references.

[2] In doing so, the modelers are simply following legal guidelines for defining lakes and for examining best-guess 'natural' conditions to advise on modern water quality. I have used this "flow through" procedure to calculate low-flow residence times and find that, in some summer months of some years, the residence times can be as high as 20 days. Orsborn and others (1975) show that such residence times would have been expected only once in every 47 years, back in the era before widespread awareness of climate change. This frequently recurring modern condition is now only tentatively comparable with typical past 'natural' conditions (Orsborn and others, p. 45).

With that definition the 8.0 mg/L DO standard for rivers goes out the window and the modelers are free to use the 'natural' DO levels calculated for some theoretical Lake-of-the-Past as the moving, changing, unknowable standard against which modern levels can be compared. Since there are no modern standards for lakes, any modern DO levels that are lower than their calculated counterpart 'natural' levels in Capitol Lake by 0.2 mg/L or more result in "violation" labels for their locations in the Lake. Figure 9-1 above, showing virtually every location in this modern observable high-oxygen Lake plastered with large "violations," is the result of that process.

When I first saw this Figure in the TMDL Report, I found it so contrary to expectation and common sense that I wondered whether it really showed something else; namely how much more oxygen would be present in the Lake water than in an estuary's water if the estuary replaced the Lake. I asked the modelers how they obtained such results. Their answer (long delayed) was that they considered the 'natural' Deschutes River to be 3° C colder than the modern river, thanks to global warming. Since cold water holds more oxygen than warm water, the violations shown resulted from that assumption.[3]

This assumption was a trade secret. Nowhere in the entire SM Report, or in any other Ecology publication, is the reader informed that this underlying assumption about the "natural" conditions of the past is the basis for the Capitol Lake simulation.

The critical drawback of using 'natural' conditions to find DO "depletions" in modern water is that it is almost always impossible for others to check up on the calculated findings. To do so one would need to know all of the 'natural' DO's calculated by the computer for every depth, every location, every 6 minutes, from January 25 to September 15, then all of the same values as calculated for modern waters. The Capitol Lake case provides a rare exception. Here, for some of the grid cells, we can "know" what the natural values must have been, assuming that the river was 3°C colder in the past.

The exceptional circumstance that makes a checkup possible is that the water entering the south end of Capitol Lake must always be 100% saturated with oxygen from its passage over Tumwater Falls. Whatever its DO level was when it started over the Falls, that churning tumbling exposure to the atmosphere will always "re-set" it to 100%. That knowledge enables us to calculate the 'natural' DO levels at the south end of the Lake

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[3] The relevant part of the modelers' answer to my question is as follows: "The other change reflected in the model is the Deschutes River temperature that would occur under natural conditions. We consulted the river projections for temperature, which would be over 3°C cooler under natural conditions. Cooler water holds more oxygen at saturation, so the river would also have higher oxygen concentrations. The differences between natural and existing oxygen concentrations predicted in the south basin of Capitol Lake mostly reflect the river temperature and dissolved oxygen differences. This effect is limited to the south basin, however (red cells in [TMDL's] Figure 92). Oxygen levels in the middle and north basins reflect productivity within the lake." (Ahmed et al, 2014).)

(the “red zone,” Figure 9-1) back when the river is said to have been 3^{o}C cooler and compare them with the modelers’ grotesquely mistaken findings.

That calculation, for readers interested in checking up on it, is shown in the following Optional sections. (To skip it, go to section 9-3 below.)

9-2b. Optional: Checking The Dissolved Oxygen Calculation.

Figure 9-6 is a “nomograph” that was used in the pre-computer era for fresh-water dissolved oxygen calculations. It is a diagram with three carefully arranged scales that show the following (top to bottom); (1) water temperature; (2) per cent DO saturation of the water; and (3) DO level in mg/L. If you know any two of those quantities, you can use the nomograph to find the value of the third.

The nomograph is used by placing a straight-edge (ruler) on the diagram aligned so that it crosses two of the scales at the known values, then finding the third value by seeing where the straight edge crosses the third scale. For example, if you know that the water temperature is, say, 8.64^{o}C and its per cent saturation with oxygen is 100%, a ruler placed at these values on the upper two scales crosses the lower (DO) scale at 11.35 mg/L. That is the amount of oxygen that fresh water will contain after prolonged contact with the atmosphere if its temperature is 8.64^{o}C to become 100% saturated.

I used the nomograph to calculate the sizes of the “violations” of DO standards for five dates in the river’s ‘natural’ past. Table 9-1 illustrates the procedure and the values obtained.

The calculation begins with observed modern water temperatures and DO’s for the river water as measured at Tumwater Falls Park, a location just above the Falls (Cols. A, B and C, Table 9-1; 2010 data TCPHSS 2012). I used the nomograph to determine that the water there is just below saturation (values in the high 90’s, Col. D). Using the nomograph, I found the DO levels that would occur in the water at 100% saturation below the Falls (Col. E). That is marginally the southernmost part of Capitol Lake. Column F shows the ‘natural’ temperatures that the modelers would assign to the pre-modern era water, namely temperatures 3^{o}C lower than those in Column B. Column G shows the dissolved oxygen levels that would have been present if the water were 100% saturated with oxygen at those ‘natural’ temperatures. (Because of the colder ‘natural’ water, these levels are higher than the modern levels.) The differences are shown in Column H. A “violation” is declared if that difference is greater than 0.2 mg/L. The amount of difference in excess of 0.2 mg/L – that is, the size of the ‘violation’ – is shown in Column I.

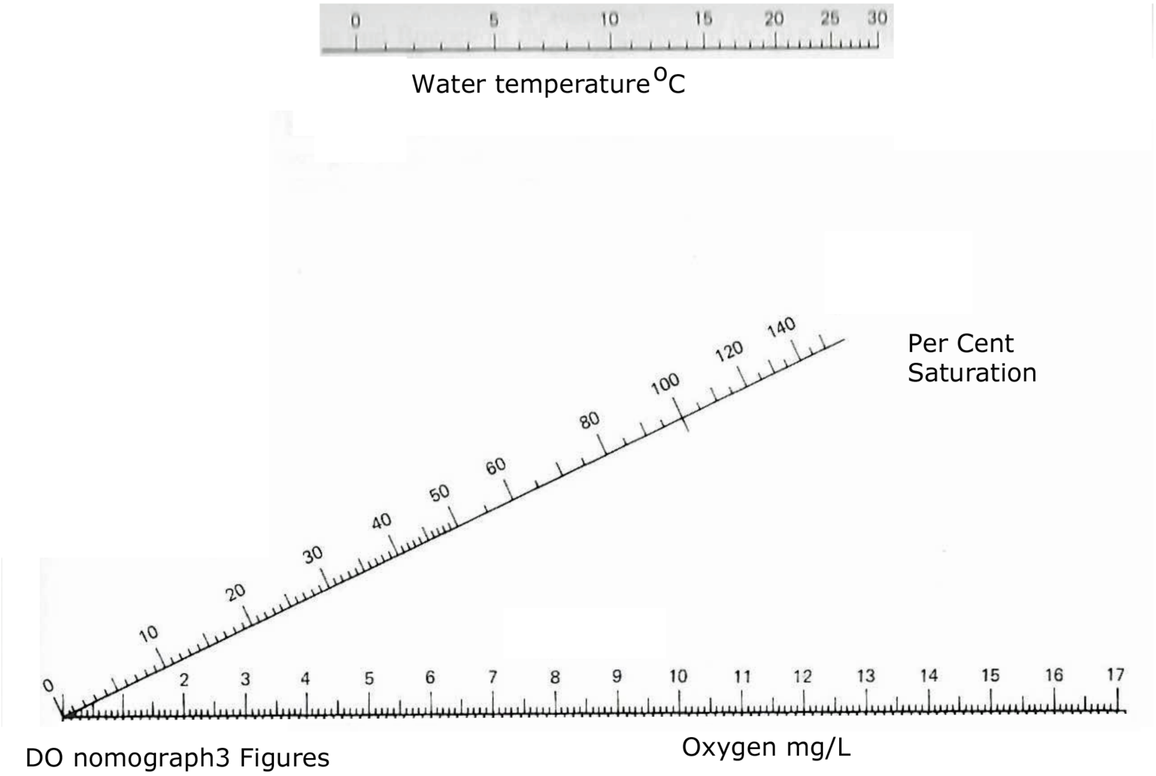


Figure 9-6. Nomograph for determining the amount of dissolved oxygen in fresh water at full (100%) saturation, using the temperature of the water (at sea level atmospheric pressure). Full (100%) saturation is the amount that the water acquires via contact with the atmosphere with no additions from plant photosynthesis or subtractions via respiration or chemical contamination. Source: Horne and Goldman, 1994. The original nomograph's corrections for lakes at high altitude are not shown.

A	B	C	D	E	F	G	H	I
--	observed	observed	nom	nom	(= B-3)	(nom)	(= G-E)	(= H - 0.2)
Date	Temp	DO	% Sat.	DO at	Temp.	DO 100% sat.	Δ DO natl.	violation
				100% sat.	"natural"	natural Temp	- modern	
(2010)	(°C)	(mg/L)	(% sat)	(mg/L)	(°C)	(mg/L)	(mg/L)	(mg/L)
Apr 19	11.64	10.24	98	10.55	8.64	11.35	0.80	0.60
May 10	11.64	10.18	97	10.55	8.64	11.35	0.80	0.60
Jun 15	11.92	10.37	99	10.50	8.92	11.30	0.80	0.60
Aug 16	16.58	9.31	98	9.50	13.58	10.10	0.60	0.40
Sep 13	13.27	9.52	95	10.20	10.27	10.90	0.70	0.50

Table 9-1. Calculation of the DO levels that would exist in the Deschutes River and southernmost Capitol Lake if the 'natural' River were 3°C cooler than at present. Columns A, B and C; dates and observed data for Tumwater Falls Park, 2010, above the falls. (Source: TCPHSS 2012.) Column D; percent DO saturations of observed waters (using Cols B & C & nomograph). Column E; DO of water of temperatures in Col. B at 100% saturation below the falls (from nomograph). Column F; 'natural' water temperatures (Col. B values minus 3°C). Column G; DO's at 100% saturation at 'natural' temperatures in Col. F (from nomograph). Column H; 'natural' DO's minus modern DO's (Col. G values – Col. E values). Column I; sizes of the DO "violations" (Col. H values – 0.2 mg/L). Grey headings show nomograph calculations.

9-2c. Optional: The Corrected Dissolved Oxygen Calculations.

Column H of Table 9-1 shows that the largest difference between the DO levels of modern waters and 'natural' waters at 100% DO saturation would be about 0.80 mg/L, using 2010 observed water temperatures and DO's. The theoretical water quality "violation" on that date would be about 0.60 mg/L (Column I). The modelers' depiction of Capitol Lake (Figure 9-1) shows "violations" of about 4 mg/L in the 100%-saturated area – more than six times the size of the one calculated here. Their calculation is wildly wrong for the south end of the Lake.

There is a "modern" way of performing this calculation. That is to go to the USGS website and use the "DOTABLES" tool (USGS DO Tables, 2018). That calculation tool uses additional data, namely the electrical conductivity of the water due to the lake's (greatly diminished, nearly zero) "salinity." The "violations" calculated (shown in Table 9- 2) are almost identical to those calculated from the nomograph (Table 9-1). A complete USGS-derived table analogous to the nomograph table is shown in an optional section near the end of this Chapter as Table 9-3.)

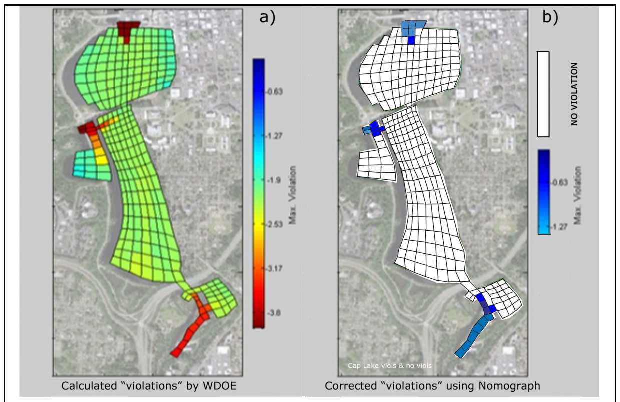
A	*C-1	I	*I
--	Conductivity	nom.	DOTABLES
Date	(observed)	violation	violation
	μmho/cm		
(2010)	[= μS/cm]	(mg/L)	(mg/L)
Apr 19	101	0.60	0.60
May 10	105	0.60	0.60
Jun 15	103	0.60	0.59
Aug 16	136	0.40	0.45
Sep 13	147	0.50	0.54

*Table 9-2. "Violations" of DO water quality standards in modern Capitol Lake obtained via nomograph and USGS calculation tool "DO TABLES" (Tables 9-1 and 9-3, this Review). Column *C-1; additional data used by DO TABLES but not the nomograph. Sources: TCPHSS 2012, USGS DO Tables 2018.*

9-3. The Lake's Calculated Water Quality Violations are Tiny or Nonexistent.

Ecology's DO level "violations" in the southernmost stretch of Capitol Lake (the Deschutes River "red zone," Figure 9-1) are grotesquely in error. What about the rest of the Lake?

The modelers' depiction of DO "violations" (Figure 9-1) shows two other "red zones" (at the outlet of Percival Creek and at the dam) in addition to that in the southernmost Lake. Percival Creek, like the Deschutes River, experiences aeration from the rush of its water over a cataract just north of the Highway 101 bridge (at the Auto Mall). I expect that the theoretical violations at the Percival Creek outlet arise from the same computer error as in the Deschutes River case. The "red zone" at the dam is probably traceable to the inability of the salt water ponded there in a deep hole in the bottom to hold as much DO as the fresh water overlying it, compounded by the modelers' mistaken assumptions about past river temperatures.



Calculated "violations" by WDOE

Corrected "violations" using Nomograph

Figure 9-7. Water Quality standards violations in Capitol Lake as calculated by Ecology's computer model (left) and as recalculated by the author (right) using a nomograph and an on-line USGS tool. The value in each "blue zone" (right) is the violation calculated in Table 9-1. The "red zone" (left) violations are in error by about 3 mg/L. All other calculated violations shown in mid-Lake are about 2 mg/L or less. If they were also overestimated by 3 mg/L, the corrected Capitol Lake map (right) would show no significant violations at all.

Throughout the rest of the Lake, the green areas (Figure 9-1) show the success of plants at raising the water's dissolved oxygen level and reducing the sizes of the 'violations' shown by the modelers where water enters the Lake. There the percent saturation of the water is unknown and unknowable and the nomograph and USGS's corrections can't be applied.

The violations shown by the modelers in the red zones are some 3+ mg/L higher than are indicated by the nomograph calculations. Errors of the same size (that is, 3 mg/L higher than "real" or "likely" over most of the Lake) probably characterize the whole green zone. If calculated correctly, the "violations" of cyberspace water quality would appear as shown in Figure 9-7b.

The modelers tell us almost nothing about how they adapted the Budd Inlet Model to simulate Capitol Lake. They divided it up into 280 grid squares (nearly twice as many as for all of Budd Inlet), apparently lumped all large plants (macrophytes), the small plants that grow on them (epiphytes), and "attached algae" into one category, and concentrated on phytoplankton and phosphorus (see below) for calculating oxygen levels (see their one-sentence description in the TMDL Report, p. 188). It would not be surprising if this approximation to the complex reality of a rich freshwater ecosystem resulted in large errors of estimation of its real-world conditions.

Common sense and familiarity with real-world dissolved oxygen levels and changes should have prompted the modelers to take a second look at the enormous DO changes calculated by their model. Apparently they never did so. The result was a depiction of Capitol Lake, now widely disseminated, that has mislead everyone who has taken it at face value into believing that Capitol Lake has serious dissolved oxygen depletion conditions.

Modern reality is that Capitol Lake's dissolved oxygen levels are always higher than the standard for the Deschutes River, (almost always) higher than the adjacent salt water DO levels at their highest, and <u>never</u> "depleted."

9-4. The Phosphorus Wild Goose Chase.

Figure 9-8 is from Ecology's TMDL Report of 2012 (their Figures 23 & 24, pp. 79-80). It shows the measured concentrations of phosphorus and nitrogen nutrients at points along the Deschutes River and at two points in Capitol Lake (the two leftmost "boxes," each graph). Aquatic ecologists will recognize that they show unequivocal evidence that nitrogen is the "limiting nutrient" in Capitol Lake – not phosphorus. No one in the then-TMDL-Advisory-Group or on the computer modeling team appears to have ever noticed that.

The "limiting nutrient" in an aquatic ecosystem is the one that the plants and phytoplankton completely use up. They take up all of it; the amount left in the water is zero. From then on, it doesn't matter how much of the other nutrients are present; the plants can no longer use those others and their growth stops.

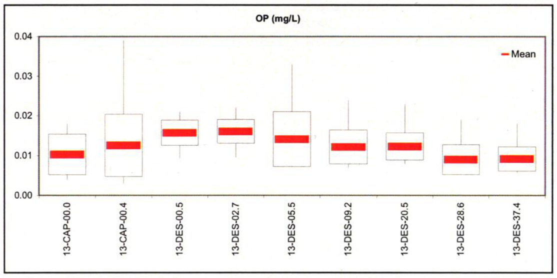


Figure 24. Longitudinal variation in monthly and twice-monthly phosphorus concentrations from the 1000 Road to the E Street bridge.

N limiting not P CL '04
Use/Misuse 2

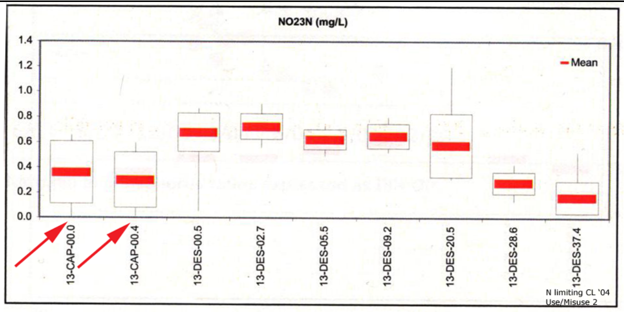


Figure 9-8. Phosphorus (upper) and Nitrogen (lower) concentrations in Capitol Lake (leftmost two boxes) and the Deschutes River (rightmost 7 boxes). Source: TMDL Report Figs. 23 and 24 in part, pp. 79, 80. The year represented is 2004.

In lakes, the limiting nutrient is almost always phosphorus. In the coastal ocean, it is almost always nitrogen. Capitol Lake is the glaring exception to the usual lake condition; there the limiting nutrient during the growing season is nitrogen (CH2M-Hill 1978).

"Box plot" graphs like Figure 9-8 confirm this. Each "box" spans the range of the middle 50% of measured concentration values. The "whiskers" at the tops and bottoms of the boxes span the highest 25% and the lowest 25% of values, respectively, with the ends of the whiskers showing the extreme highest and lowest values of all. For the limiting nutrient, *the lowest value is zero* (arrows, Figure 9-8). For all other nutrients, the lowest value is never zero. The extreme low end of the whisker shows no hint of how often that extreme value occurred. If the "zero" value shown in the nitrogen graph occurred just once (1% of all measurements) or in fully 25% of all measurements, the box plot would look the same. As is clearly shown in that Figure, nitrogen – not phosphorus – is the limiting nutrient in Capitol Lake.

Despite that, the Ecology modelers mistakenly think that phosphorus is the limiting nutrient in Capitol Lake. They've expended endless effort simulating the effect on water quality of reducing phosphorus levels in the Deschutes River and Capitol Lake (for example, Figure 9-9). The model keeps telling them (accurately) that that will make no difference whatsoever toward changing DO levels in the Lake water. Fully 10 pages of text, tables and figures of the 80 pages in the SM Report are devoted to "phosphorus".

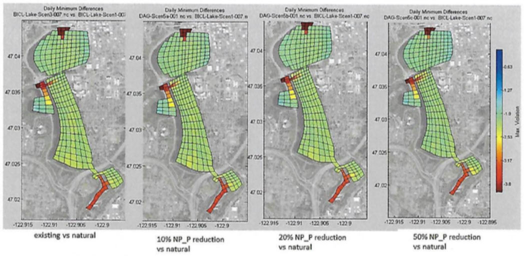


Figure 34. Predicted DO depletion (mg/L) from various assumed reductions in nonpoint phosphorus loading to Capitol Lake.

N not P CL analysis
Use/Misuse 2

Figure 9-9. Ecology's analysis showing that even a 50% reduction in phosphorus doesn't eliminate the [bogus, see above] "oxygen depletion" calculated for Capitol Lake. SM Report Fig. 34 p. 59.

This amusing wild goose chase would be of no real consequence, except for one thing; the modelers use the "no improvement" results to constantly browbeat the public with the idea that there's nothing we can do (except remove the dam, of course) that can make any positive difference in DO levels in Capitol Lake and Budd Inlet.

9-5. The Eutrophic "Hopeless Phosphorus Red Herring" and the 303-d Listing.

Figure 9-10 from the SM Report is another way of showing the public that "phosphorus-control-is-hopeless-therefore-our-only-recourse-is-to-remove-the-dam." This one appears regularly in the agency's public presentations. The graph's scales are the amount of phosphorus entering lakes in general (from stream flow, local fertilizer use, etc, vertical axis) vs. the mean depths of lakes (horizontal axis). Capitol Lake's annual average position is shown by the black dot at the extreme top, its average position during the growing season is the green square below the dot.[5]

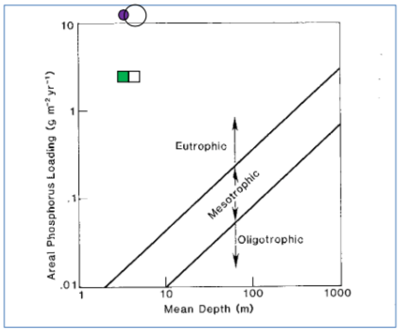


Figure 37. Vollenweider's (1968) phosphorus loading plot showing areal loading vs. mean depth, with the expected trophic state.

Eutrophic hopeless #1
Use/Misuse 2

Figure 9-10. Diagram used by Ecology to show the hopelessness of improving Capitol Lake by manipulating phosphorus levels. Source: SM Report Figure 37 p. 65.

This particular graph shows the simulated change in the phosphorus situation that would result from dredging the Lake. The open circle (top) and square (below) show the tiny shift in position of Capitol Lake's status that would result from dredging. To "cure" the Lake's phosphorus "problem" would require that the shift move the Lake's position sideways all the way over to the uppermost diagonal line (labeled "Eutrophic") on the graph. (That is, dredge the Lake to a depth of 1000 meters or so …) Clearly dredging the Lake would be utterly hopeless as a way of "curing" its "phosphorus problem."

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[5] The dot and square show that the annual and summer phosphorus entries to Capitol Lake are about 11- and 4 grams P per square meter per year vs. the mean depth of the Lake, about 3-4 meters.

What is “eutrophic?” That term refers to water bodies with very high biological productivity, visible as lush growth of aquatic plants and/or phytoplankton. Such waters often have low or zero dissolved oxygen near the bottom, a consequence of sinking and decay of the plants from the surface. Because of this, the term “eutrophic” has a second, negative connotation in addition to its primary definition; that is, “having impaired water quality.” Capitol Lake is indeed eutrophic but it has high oxygen levels at the bottom all year round – a fact never mentioned by the modelers when showing Figure 9-10.

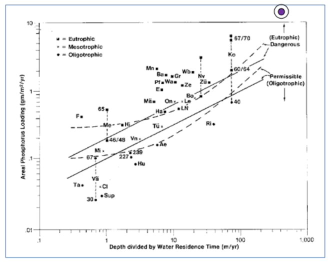

Figure 38. Vollenweider’s (1975) phosphorus loading plot to include the residence time with trophic state.

Eutrophic hopeless #2. Use/Misuse 2

Figure 9-11. A second way of showing Capitol Lake as resistant to improvement by dredging for phosphorus control. Source: SM Report Fig. 38 p. 66.

Figure 9-11 is a warmed-over version of Figure 9-10 used by Ecology in the same way for the same purpose. With their log scales, their technical terms, references to scientific experts, the out-of-the-ballpark positions of Capitol Lake, and their diversion of public attention to something that is not really a problem in the Lake, they are ideal for advancing the idea that removing the dam is the only feasible alternative for “improving” that water body.

Ecology uses phosphorus to perpetrate another negative image of Capitol Lake; namely keeping the Lake on the EPA’s “303-d” (“Clean Water Violation”) list on account of its high phosphorus levels. Four other Thurston County lakes are also listed as high-phosphorus violators.[6] As typical eutrophic lakes, unlike Capitol Lake, their phosphorus loads really do reduce their bottom water DO levels to zero. That critical ecological difference apparently doesn’t qualify Capitol Lake for “escape” from the list.

9-6. Nutrient Nitrogen – Seldom Mentioned, Never Simulated.

Figures in Ecology’s own TMDL Report show that various forms of nitrogen are the key nutrients in Capitol Lake (their Figures 24 and 25, shown as Fig. 9-8 above). But the modelers have studiously avoided simulating its effects on Capitol Lake and Budd Inlet, focusing instead on the irrelevant phosphorus situation. A section at the end of the SM Report (p. 68) goes so far as to mention scenarios that have *not* been simulated – “solar powered aeration,” “back-flush the lake,” and “harvest lake macrophytes,” – but doesn’t mention “simulating nutrient nitrogen effects.” That avoidance (as well as of the macrophyte harvest scenario, which would physically remove nutrient nitrogen from the water) seems intended to obscure public understanding of the Lake’s critical role as a protector of Puget Sound. That understanding is crucial to making the best decisions regarding the Lake’s future. Ecology’s efforts have thus far prevented that understanding.

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[6] The other four listed lakes are Black, Lawrence, Long, and Pattison Lakes.

9-7. Optional. The DO TABLES Calculations.

Table 9-3 shows the complete calculation of DO “violations” in Capitol Lake making use of the USGS “DOTABLES” tool (USGS DO Tables, 2018).

A	B	C	C-1*	C-2	C-3	F	G	H	I
						= B - 3.0		= G - C3	= H - 0.2
Date	Temp	DO	Cond.	% sat	DO 100% sat	Temp natural	DO 100% sat	Δ DO natl.	violation
	obs.	obs.	observed		modern		at Temp F	- modern	
2010	(°C)	mg/L	μmho/cm	%	mg/L	°C	mg/L	mg/L	mg/L
			[μS/cm]		[=100@T=B]			(G - C-3)	
Apr 19	11.64	10.24	101	94.29	10.86	8.64	11.66	0.80	0.60
May 10	11.64	10.18	105	93.74	10.86	8.64	11.66	0.80	0.60
Jun 15	11.92	10.37	103	96.11	10.79	8.92	11.58	0.79	0.59
Aug 16	16.58	9.31	136	95.49	9.75	13.58	10.40	0.65	0.45
Sep 13	13.27	9.52	147	90.93	10.47	10.27	11.21	0.74	0.54

Table 9-3. Use of the USGS “DOTABLES” tool to calculate DO “violations” in Capitol Lake, using knowledge that the South Basin Water would have been 100% saturated in pre-modern (“natural”) times. Columns A, B, C and C-1; observations in 2010 of Deschutes River water above Tumwater Falls. (Cols. A, B, C same as in Table 9-1; data in C-1 were not used in that (nomograph) calculation.) Column C-2; % DO saturation of the above-falls water using the DOTABLES tool with data from Cols. B, C, & C-1. Column C-3; DO of the water at 100% saturation after passage over the falls, using the DOTABLES tool. Column F; “natural” Deschutes River temperatures = modern temps in Col. B minus 3 degrees. Column G; DO of 100% saturated water at “natural” temperatures in Col. F, using the DOTABLES tool. Column H; difference between DO of “natural” 100% saturated water [Col. G] and modern 100% saturated water [Col. C-3]. Column I; size of violation = values in Col H. minus 0.20. Grey headings show values obtained by DOTABLES tool. Sources: TCPHSS 2012, USGS DO Tables 2018.

These calculations avoid the “fit by eye” uncertainty inherent in the nomograph calculation and by virtue of using more data probably give the more accurate results of the two methods.

9-8. Not Optional. The Bottom Line. Capitol Lake is NOT “Oxygen Depleted.” ECOLOGY STOP SAYING THAT IT IS!

The subtitle says it all.

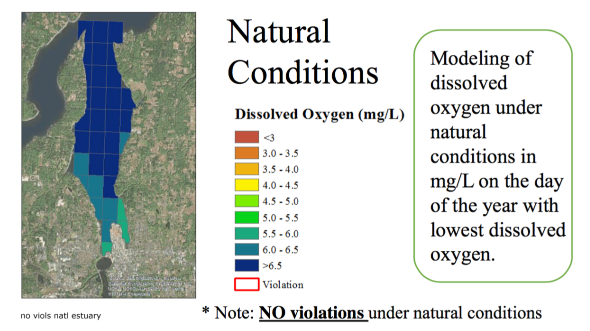
10. LOW DISSOLVED OXYGEN IN NATURAL ESTUARIES.

10-1. The Drive to Sanitize Natural Estuaries.

"Eld Inlet has no dam and never has any low oxygen problems."

These words, spoken as "proof" that Budd Inlet's seasonal low oxygen levels were due to the dam that impounds Capitol Lake, were by a "Remove The Dam" advocate, a worker at the Thurston County Department of Health (Havens, pers. comm. 2013).

She couldn't have been wronger. Her mistaken view is that of many estuary advocates, who consider that "natural" is always better than "human impacted." In fact dissolved oxygen levels in undammed Eld Inlet are worse than those in modern Budd Inlet.



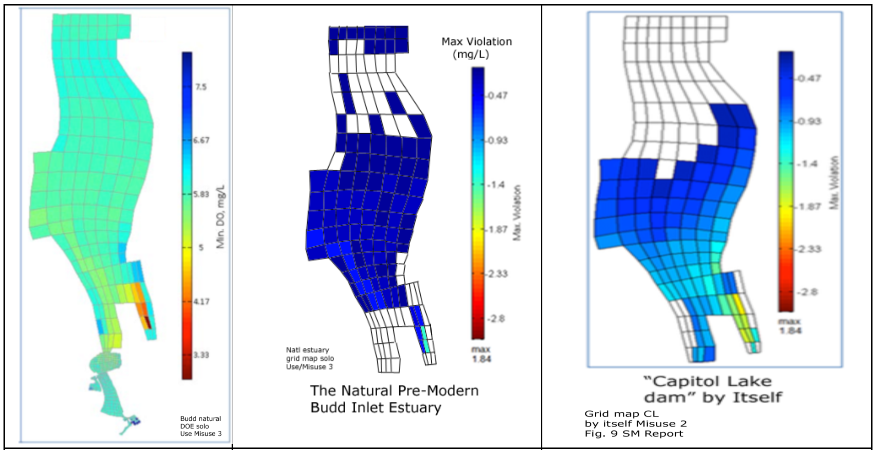
Natural Conditions

Modeling of dissolved oxygen under natural conditions in mg/L on the day of the year with lowest dissolved oxygen.

* Note: **NO violations** under natural conditions

Figure 10-1. Slide from an Ecology presentation showing ***NO violations*** *[Ecology's emphasis] in the simulated pre-modern "natural" Budd Inlet. Source: Weiss, 2017.*

The Department of Ecology's Budd Inlet modelers have recently modified their computer model to "show" that "natural" (= pre-modern) Budd Inlet had no low oxygen episodes that would violate modern water quality standards (Figure 10-1). This is an example of their standard practice of revising the model to try, try again whenever it obstinately shows that Budd Inlet is improved by the presence of Capitol Lake. In this latest case, I expect that the revision of the model stems from its demonstration that pre-modern ("natural") Budd Inlet is about as plastered with water quality violations as is modern Budd Inlet with the dam (Figure 10-2).



a) The natural Budd Inlet. Ecology's portrayal.

b) The natural Budd Inlet. Conventional grid map portrayal of violations.

c) The modern Budd Inlet showing calculated violations "caused" by the dam.

Figure 10-2c seems to show that modern Budd Inlet with Capitol Lake is not much worse off than the Inlet was in pre-modern times with no dam (Fig. 10-2b), a sign that addition of the dam has actually prevented deterioration of the oxygen situation in modern times.

Figure 10-2. "Natural" Budd Inlet (a and b) and modern Budd Inlet (c) showing calculated violations of modern dissolved oxygen standards. a) Natural Inlet violations shown by Ecology in an opaque non-standard format; b) Natural Inlet violations converted to a standard grid map format (see Chapter 4); c) Modern Inlet violations shown by Ecology in the standard grid map format. Sources: a) SM Report's Fig. 7b, p. 32; b) derived from 10-2a in Chapter 4, this Review; c) SM Report's Fig. 9, p. 34.

Given the forces at work in estuaries – in particular those bearing down on East Bay (see Chapter 6) -- it is very unlikely that those water bodies went through the seasons in pre-modern times without ever experiencing DO levels lower than modern water quality standards.

This Chapter assesses what we can know about estuarine DO conditions in pre-modern times, using Eld Inlet as a specific example and all of Puget Sound as portrayed by another one of Ecology's computer models.

10-2. Eld Inlet – A Modern "Natural" Estuary?

Figure 10-3. Eld and Budd Inlets. (Source: Google Earth Image June 24 2017.)

Figure 10-3 shows Eld and Budd Inlets with a few important labeled features. The main streams driving Eld Inlet's estuarine circulation are the (very small) Perry and McLane Creeks. Their combined volumes in September, 2009, at 3.7 cfs were only 4% that of Budd Inlet's Deschutes River (TCPHSS 2010). Their low stream flows are probably the reason for the inlet's frequent low oxygen episodes.

Eld Inlet is closer to its pre-modern condition than Budd Inlet in the following ways:

1) The watersheds of its two main creeks are rural, forested, and non-urbanized;

2) Its shores are lined by residences and residential activities, not urban structures and activities;

3) The nutrient nitrogen levels in the creeks entering the inlet are very low – among the lowest of all South Sound streams;

4) It has not been dammed;

5) It is not extensively used for recreational boating or commercial shipping;

6) It does not receive treated wastewater from any (significant) WWTP's.

Eld Inlet differs from Budd Inlet in one way that is a departure from the "natural" condition; it is extensively farmed for shellfish. Budd Inlet has no such aquaculture.

10-3. Low Oxygen Levels in Modern Eld Inlet.

During the late 1990's, shellfish growers became concerned about the deaths of oysters planted in upper Eld Inlet. They began a research project, assisted and supported by the Department of Ecology, focused on the oxygen content of the water. A permanent measuring device ("probe") was established on the intertidal mud at the +1 foot >MLLW tide level (Figure 10-4, also Figure 10-3). Except for times when the tide dropped below that level (thus exposing the probe to air), *the device made DO measurements every 15 minutes throughout the whole summer seasons* of years 1998, 1999, and 2000.

Figure 10-4. Location of the Eld Inlet Dissolved Oxygen Probe at the +1' tide level. (See also Figure 10-3.) Google Earth Image provided by Pacific Shellfish Institute.

These probe data were graciously made available to me in the form of a spreadsheet (Pac. Shellfish Inst. Spreadsheet, 2000).

An example of the probe's DO measurements between 7:45 PM June 18 and 3:45 PM June 19 (1999) with the tide levels at those times is shown in Figure 10-5. In this example, the DO level was below 3.0 mg/L for the whole time shown and below 1.0 mg/L for most of that time – a deadly "worst case scenario" for marine life.

A "low-DO episode" as defined in this example is the length of time between the first decline of the dissolved oxygen level to below 5.0 mg/L and its first return back to that level or higher. The durations of the episodes in the Eld Inlet record that I have assessed range from 15 minutes to several days. Figure 10-6 shows the durations of 24 episodes of DO lower than a DO standard (5.0 mg/L) during July 1998, the last episode of which continued into August. Figure 10-6 also shows the lowest DO levels reached in each of these episodes. Early in the month the episodes are brief 15- or 30-minute "dips" below the DO standard, all higher than 4.0 mg/L, then they begin to last longer and show more drastic drops to stress-causing levels as the season advances.[1] (The Budd Inlet model, with its iteration interval of six minutes, is capable of detecting such dips.)

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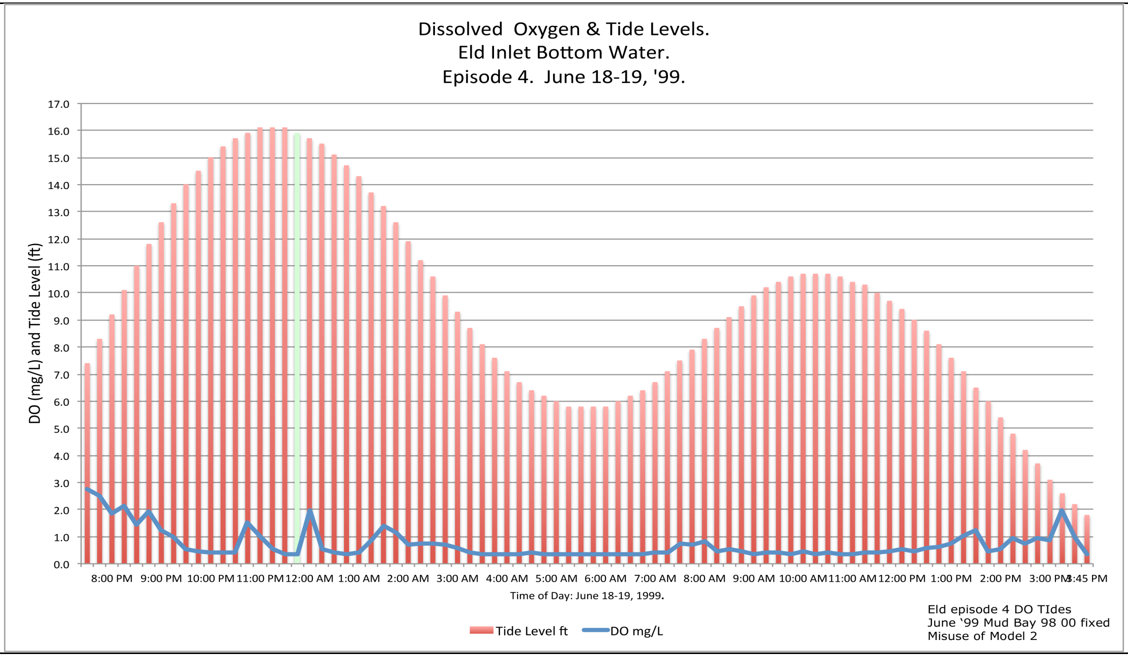
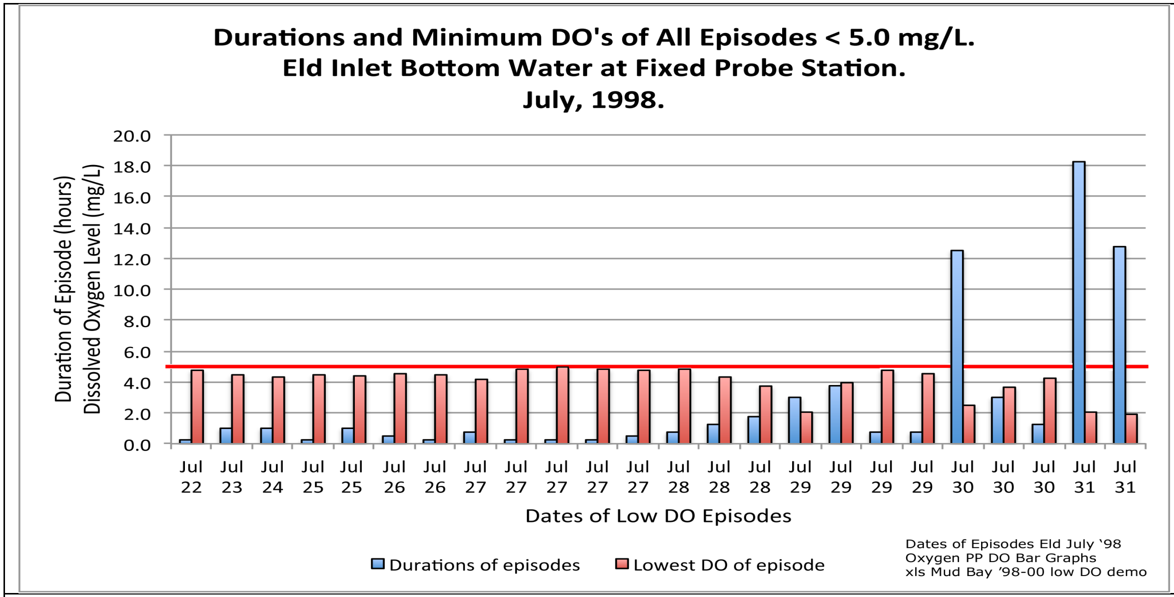
[1] A DO level of 3.0 mg/L is stressful for most marine organisms. Mild distress for the most sensitive species starts at about 4.5 mg/L and acute distress is experienced by almost all of them at about 2.0 mg/L. See Vaquer-Sunyer and Duarte, 2008 in References.

It is worth noting that the probe and the extreme low DO levels it measured were in a part of Eld Inlet that is comparable to the Budd Inlet headwaters that would be created if estuarine tidal marine water was returned to the Capitol Lake basin by dam removal.


Dissolved Oxygen & Tide Levels.
Eld Inlet Bottom Water.
Episode 4. June 18-19, '99.

Eld episode 4 DO TIdes
June '99 Mud Bay 98 00 fixed
Misuse of Model 2

Figure 10-5. DO levels measured by the Eld Inlet bottom probe 7:45 PM June 18 to 3:45 PM June 19 1999 throughout low-DO episode 4. Dissolved Oxygen levels are shown by the graph, tide heights are shown by vertical bars. (The green vertical bar is at midnight.) This episode ended when the receding tide exposed the probe to air (far right of graph). Source: Pac. Shellfish Inst. DO spreadsheet.


Durations and Minimum DO's of All Episodes < 5.0 mg/L.
Eld Inlet Bottom Water at Fixed Probe Station.
July, 1998.

Dates of Episodes Eld July '98
Oxygen PP DO Bar Graphs
xls Mud Bay '98-00 low DO demo

Figure 10-6. Dates of onset of low-dissolved-oxygen episodes (<5.0 mg/L) at the probe site in Eld Inlet, with their durations and lowest DO levels observed during each episode. Red line (5.0 mg/L) is the DO water quality standard in the comparable Budd Inlet Harbor area. Source: Pac. Shellfish Inst. DO spreadsheet.

The measurements made by the probe are always right at the bottom, no matter what the water depth may be. Its "last" measurement however, just before the falling tide drops below the probe's +1' level and leaves it "high and dry" is also at the surface. Similarly the probe's first measurement during a rising tide event is at the surface, when the rising water reaches its level and it begins to make measurements. It is possible to convert these bottom (and occasional surface) water measurements, made over many hours, into a "vertical profile" comparable to the more conventional measurements made by lowering a DO probe from a boat and obtaining all of the top-to-bottom readings within a few minutes.

To maintain continuity here, the method for converting the Eld probe's measurements into a "vertical profile" is described in the next-to-last (Optional) section of this chapter for interested readers. A profile so obtained is shown here in Figure 10-7 and is compared with one from Budd Inlet (station BI-5 opposite the Port dock).

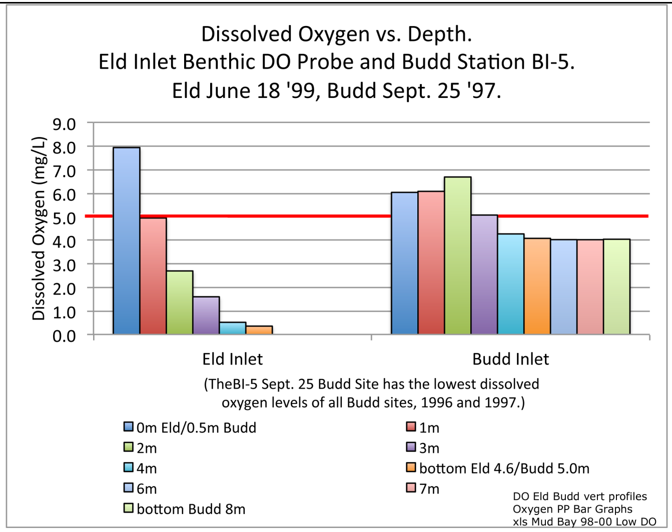


Figure 10-7. Dissolved oxygen vs depth at the Eld Inlet probe site and the Budd Inlet BISS site BI-5 (June 18 '99 and September 25 '97). The red line shows the DO standard (= 5.0 mg/L) at BI-5). Sources: Pacific Shellfish & BISS spreadsheets.

The Budd Inlet measurements at site BI-5 (opposite the Port of Olympia in West Bay) shown in Fig. 10-7 are the worst (lowest) DO's observed from all of Budd Inlet in the entire year from September 10, 1996, to September 25, 1997.[2] I did not search the Eld Inlet data for the "worst case" example there; the one shown was selected for relative ease of converting the probe measurements to this format (see section 10-5).

Whether we accept Eld Inlet as a modern example of a natural inlet with low DO's or not, it is clear that that inlet had far worse low DO episodes than did Budd Inlet during the late 1990's, probably more frequently and definitely beginning much earlier in each year.

10-4. Eld Inlet with "Natural" Low DO's; a Second Line of Evidence.

The modelers' interest in natural pre-modern water quality (and other objectives) led to simulations of the whole body of Puget Sound using a regional-scale model like the Budd

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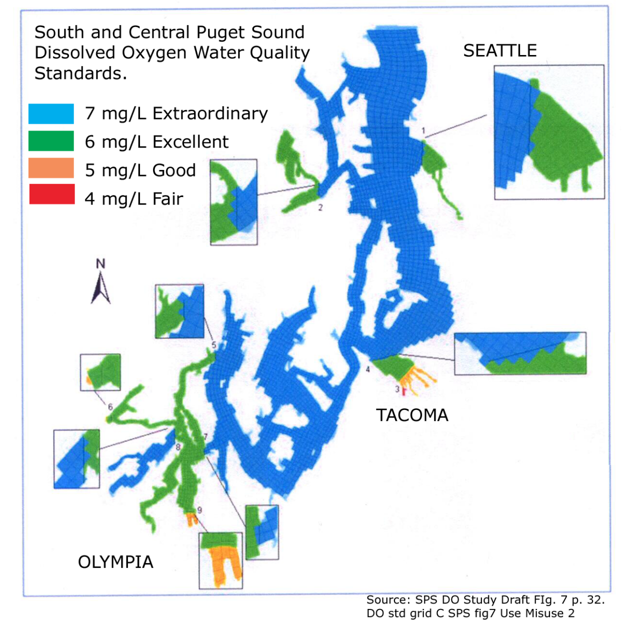
[2] DO measurements lower than 4.0 mg/L are shown in the BISS spreadsheet. These are all flagged as errors in the spreadsheet error pages. Lower short-lived DO's were also measured in Budd Inlet near the dam during an experimental sudden release of all of the water in Capitol Lake (July 22 – August 4 1997). Such low levels were never seen in the Inlet during normal operation of the dam.

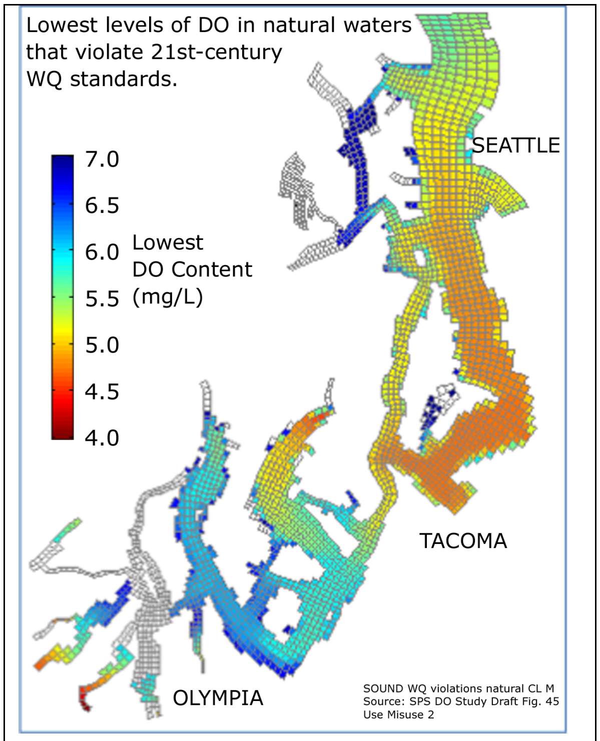
Inlet model. Figure 10-8 shows the modern water quality standards overlaid on a grid map of Puget Sound produced by that model. (Budd and Eld Inlets are the lowermost estuaries in that Figure.) In Budd Inlet the standard is 6.0 mg/L from Boston Harbor to Priest Point Park (green on the key) and 5.0 mg/L in East and West Bays and vicinity (orange on the key). In Eld Inlet the standard is 6.0 mg/L (green; "excellent") from the entrance to the landward head of the estuary. Most Puget Sound DO levels are classified as "extraordinary" – 7.0 mg/L or higher.



Source: SPS DO Study Draft FIg. 7 p. 32.
DO std grid C SPS fig7 Use Misuse 2

Figure 10-8. Water quality standards for all of Puget Sound from Olympia to Edmonds. Source: SPSDOS 2013 draft, p. 87.

In the next Figure (10-9) each colored grid square is a location where the standard for that location was "violated" in pre-modern "natural" Puget Sound. The size of each violation itself is not shown – the colors show instead the calculated DO level in each grid square at the time when the largest calculated violation occurred. Uncolored regions had no calculated violations during pre-modern times. Regions that remain dark blue had very small violations even though their calculated levels were below the modern standard.



SOUND WQ violations natural CL M
Source: SPS DO Study Draft Fig. 45
Use Misuse 2

Figure 10-9. Dissolved oxygen levels at sites in pre-modern Puget Sound at the times when the model calculated their largest "violations" of modern

<u>Almost all</u> of pre-modern "natural" Puget Sound is shown by this computer simulation to have had violations of modern water quality standards at one time or another.

In Budd Inlet, a patch of water between southern Priest Point Park and the opposite shore shows where this model found pre-modern DO's lower than the modern standard (6.0 mg/L). The rest of Budd Inlet with adjoining waters is the largest contiguous body of water in all of Puget Sound that was entirely free of DO standards violations in its pre-modern condition.

Nearby Eld Inlet, by contrast, has the lowest calculated DO's in its natural state of any region *in all of Puget Sound*.

water quality standards. Uncolored sites had no violations. Dark blue sites had excellent DO levels even though small violations occurred there. SPSDOS draft p. 87.

The modelers used these pre-modern DO levels as the standards to meet when assessing impacts of modern human-caused- inputs to Puget Sound that deplete oxygen. *They found that they could not eliminate low DO levels in Eld Inlet even by eliminating 75% of all human-caused sources of oxygen depletion everywhere throughout Puget Sound from Eld Inlet to Edmonds.* That supports the idea that Eld Inlet's modern low DO levels are, at least in part, of "natural" origin.[3]

10-5. Optional: How the Eld Inlet Profile was Constructed from the Probe Data.

Table 10-1 shows the data from which the tide graph and low DO levels plotted in Figure 10-7 were taken. These (Column B) are the readings made every 15 minutes (Column A) by the Eld Inlet probe between the low tide at 17:30 (5:30 PM) June 18 1999 to just past the high tide at 23:30 (11:30 PM).

A	B	C	D	E	F	G
Date/Time	DO mg/L	Tide ht (m)	Tide ht (ft)	probe depth (m)	graph depth (m)	graph DO (mg/L)
6/18/99 17:30	7.94	0.31	1.00	0.00	0.00	7.94
6/18/99 17:45	7.65	0.49	1.60	0.18		
6/18/99 18:00	2.98	0.70	2.30	0.40		
6/18/99 18:15	4.20	0.92	3.00	0.61		
6/18/99 18:30	5.02	1.16	3.80	0.85		
6/18/99 18:45	4.90	1.40	4.60	1.10	1.00	4.95
6/18/99 19:00	3.97	1.68	5.50	1.37		
6/18/99 19:15	3.91	1.98	6.50	1.68		
6/18/99 19:30	2.74	2.26	7.40	1.95		
6/18/99 19:45	2.51	2.53	8.31	2.23	2.00	2.70
6/18/99 20:00	1.87	2.81	9.21	2.50		
6/18/99 20:15	2.16	3.08	10.11	2.78		
6/18/99 20:30	1.46	3.36	11.01	3.05	3.00	1.59
6/18/99 20:45	1.93	3.60	11.81	3.29		
6/18/99 21:00	1.23	3.84	12.61	3.54		
6/18/99 21:15	0.99	4.06	13.31	3.75		
6/18/99 21:30	0.53	4.27	14.01	3.97		
6/18/99 21:45	0.47	4.42	14.51	4.12	4.00	0.51
6/18/99 22:00	0.41	4.58	15.01	4.27		
6/18/99 22:15	0.41	4.70	15.41	4.39		
6/18/99 22:30	0.41	4.79	15.71	4.48		
6/18/99 22:45	1.52	4.85	15.91	4.54		
6/18/99 23:00	0.99	4.91	16.11	4.61		
6/18/99 23:15	0.53	4.91	16.11	4.61		
6/18/99 23:30	0.35	4.91	16.11	4.61	4.61	0.35
6/18/99 23:45	0.35	4.85	15.91	4.54		
6/19/99 0:00	1.99	4.79	15.71	4.48		
6/19/99 0:15	0.53	4.73	15.51	4.42		

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[3] Eld Inlet was the most resistant to improvement by reducing human impacts. The second most resistant water body was Budd Inlet. Source: SPSDOS 2013 draft.

Table 10-1. Method of obtaining a “vertical profile” of dissolved oxygen in water (as in Figure 10-7 above) using data from a probe fixed at the +1.0 ft > MLLW tide level. Column A; times of day when DO measurements were made (June 18-19 1999); Col. B; DO value measured by probe at that time; Cols. C and D tide heights in meters & feet respectively at that time; Col. E; depth of probe beneath water surface (m); Col. F; standard depths (m) for graphing; Col. G calculated DO levels at the standard depths. Col. G values calculated by interpolation between shaded depth and DO values in Cols. E and B.

Columns A-D show observed data, E-G show my calculations.

This tidal change event began with the low tide at +1.0 ft > MLLW (Col. D, first row). That is exactly the level of the probe. The “depth below the surface” of the probe was zero at that moment (Col. E, first row). The tide height in meters at that moment (Col. C) was 0.31 m. Fifteen minutes later, the height of the tide is 0.49 m (Col. C row 2). That is (0.49 – 0.31 =) 0.18 meters above the top of the probe; the probe is now at depth 0.18 m (Col. E). Proceeding in this way the depth of the probe in meters can be calculated at each time (Col. E). To estimate DO at the standard depths of 1, 2, 3, and 4 meters, the DO values in the pairs of green-shaded cells (Col. B) were interpolated between the green-shaded depth values (which enclose the standard depth values) in the same pairs of rows. The depths and DO values used in Figure 10-7 (the Eld vertical profile) are in Columns F and G.

In most modern vertical profiles of DO (as at BI-5 in Figure 10-7) the measurements were collected by a device lowered from the surface, all within a few minutes of each other. In the Eld profile constructed as above, the deepest reading was obtained six hours after the surface reading – a drawback we just have to live with, as there is no other way to construct a vertical profile from the fixed probe data.

10-6. Where Will They Go From Here?

The widespread DO violations shown in the “natural estuary” grid map (Figure 10-2b) complicate Ecology’s efforts to “prove” that “the dam” has a damaging effect on Budd Inlet’s dissolved oxygen levels. The “violations” blamed on “the dam” (Fig. 10-2c), mostly calculated by comparing modern Budd Inlet with its own “natural” condition (Fig. 2-10b), are microscopic and, if anything, less widespread than they were in pre-modern times. It would better serve Ecology’s purpose (and also correspond with the notion that “natural is always better”) if they could contrive to show that Budd Inlet in its pre-modern condition had no DO standards violations at all.

It appears that the Department of Ecology has succeeded at this by trying yet another approach. That is to drastically reduce the number of grid squares shown in their map printouts in such a way that (they say) the Natural Budd Inlet had no water quality standards violations at all (see Fig. 10-1)!! Another “fix” is to adopt the disingenuous impossible-to-read format of Figure 10-2a, using subtle color gradations to show total dissolved oxygen instead of their standard format easy-to-read grid-map depictions of DO violations as in Figure 10-2b.[4]

If the model obstinately refuses to change its behavior in response to these latest "up-dates" and keeps showing that Capitol Lake has prevented Budd Inlet from slipping into worse water quality than prevailed in pre-modern times, I expect that Ecology will stop using grid maps entirely and will instead resort to obtuse difficult-to-track graphs like Figure 10-2a to "prove" its point. It will eventually become impossible for skeptics with limited time, no staff, and few resources to dispute their claims.

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[4] I note that this latest format adoption also appears to be impossible to analyze by the Photoshop technique I used to convert Ecology's "natural" estuary to a standard format grid map, described in detail in Chapter 5.

The Department of Ecology's Supplemental Modeling Report.
A Critical Review.

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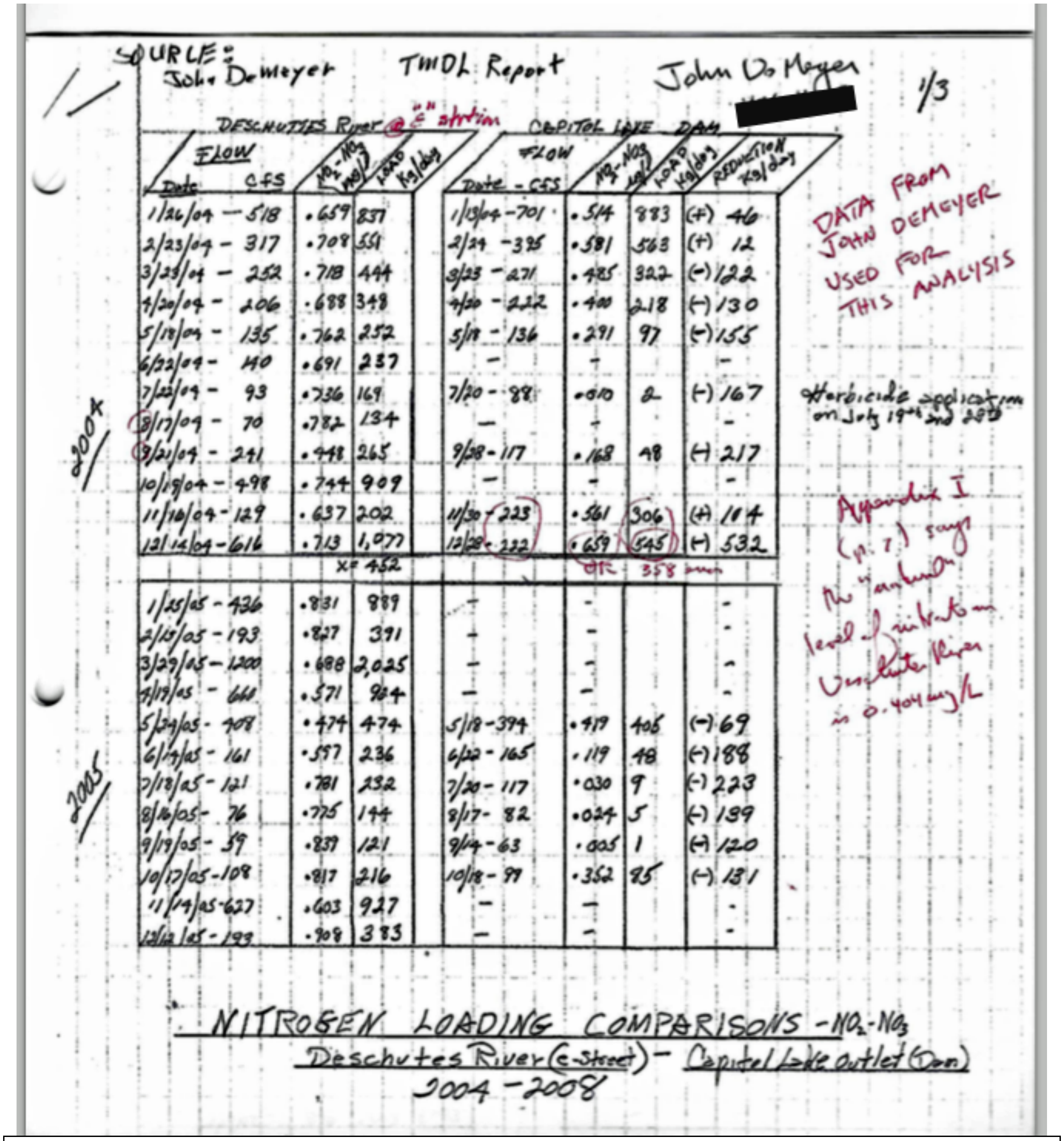
The Department of Ecology's Supplemental Modeling Report.
A Critical Review.

12. APPENDIX A.

The "DeMeyer data" used in this Review (see Chapter 7).



SOURCE:
John DeMeyer

TMDL Report

John DeMeyer [redacted]

1/3

Deschutes River @ "E" station			Capitol Lake Dam			
Flow Date – CFS	NO_2-NO_3 mg/L	Load kg/day	Flow Date – CFS	NO_2-NO_3 mg/L	Load kg/day	Reduction kg/day
1/26/04 – 518	.659	837	1/13/04 – 701	.514	883	(+) 46
2/23/04 – 317	.708	551	2/24 – 395	.581	563	(+) 12
3/23/04 – 252	.718	444	3/23 – 271	.485	322	(-) 122
4/20/04 – 206	.688	348	4/20 – 222	.400	218	(-) 130
5/18/04 – 135	.762	252	5/18 – 136	.291	97	(-) 155
6/22/04 – 140	.691	237	–	–		–
7/22/04 – 93	.736	169	7/20 – 88	.010	2	(-) 167
8/17/04 – 70	.782	134	–	–		–
9/21/04 – 241	.448	265	9/28 – 117	.168	48	(-) 217
10/19/04 – 498	.744	909	–	–		–
11/16/04 – 129	.637	202	11/30 – 223	.561	306	(+) 104
12/14/04 – 616	.713	1,077	12/28 – 232	.659	545	(-) 532
		x = 452		OR	358 mean	
1/25/05 – 436	.831	889	–	–		–
2/15/05 – 193	.827	391	–	–		–
3/29/05 – 1200	.688	2,025	–	–		–
4/19/05 – 661	.571	934	–	–		–
5/24/05 – 408	.474	474	5/18 – 394	.419	406	(-) 69
6/14/05 – 161	.557	236	6/22 – 165	.119	48	(-) 188
7/18/05 – 121	.781	232	7/20 – 117	.030	9	(-) 223
8/16/05 – 76	.775	144	8/17 – 82	.024	5	(-) 139
9/19/05 – 59	.839	121	9/14 – 63	.005	1	(-) 120
10/17/05 – 108	.817	216	10/18 – 99	.352	85	(-) 131
11/14/05 – 627	.603	927	–	–		–
12/12/05 – 193	.908	383	–	–		–

2004

2005

DATA FROM JOHN DEMEYER USED FOR THIS ANALYSIS

Herbicide application on July 19th and 28th

Appendix I (p. 7) says the "ambient" level of nitrate in Deschutes River is 0.404 mg/L

NITROGEN LOADING COMPARISONS – NO_2-NO_3
Deschutes River (E-Street) – Capitol Lake Outlet (Dam)
2004 – 2008

Page 1 of the "DeMeyer data" used in this Review. This is a data set provided to the author by Mr. John DeMeyer in 2013. He obtained it from a Department of Ecology website, which was posted upon his request. The data set consists of his penciled copies of the following; Section 1 Deschutes River data from E-Street bridge (Tumwater) with dates, river flows (cfs), nitrate+nitrite concentrations (mg/L), and load (kg/day). Section 2, Capitol Lake data at the dam; dates, flows (cfs) *through the dam*, nitrate + nitrite concentrations (mg/L), load (kg/day), and "Reduction (kg/day)" [The "Reduction" entry consists of his own calculations. Red annotations are my own.] The Ecology website showed data from 2004 through 2008. Data for 2004 (used in my Figure 7-1) showed the entire year's nitrogen entry and exit data; data for all other years showed only the summer patterns. (These summer patterns are all similar to that shown in Figure 7-1.)

After two weeks, the data unaccountably disappeared from the Ecology website. Neither he nor I can find it again. His notes include an entry on another page, "See p. 36 South Puget Sound Dissolved Oxygen Study." I find nothing pertaining to these data on that page or elsewhere in the SPSDOS reports.

These are the only data I've seen that report the actual flows of the Deschutes River and water exiting the Lake. All others show concentrations of nitrogen nutrients in the River water and the Lake water at the dam.

(Black bar obscures JDM's telephone number.)