Capitol Lake and Puget Sound.

An Analysis of the Use and Misuse of the Budd Inlet Model.

David H. Milne PhD
February, 2016.

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 recognized even 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 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 several 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 0.2 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) There is no Figure showing violations in the modern water if the dam were not present – a critical omission making it impossible to see whether that "estuary scenario" would be better or worse than the "lake scenario;"

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 might improve Inlet water quality;

11) The authors avoided simulating the Lake's effect on the Inlet if nutrient nitrogen levels in the Deschutes River were reduced, an option that might improve Inlet water quality;

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.

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Page # **OUTLINE AND INDEX.**

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1. INTRODUCTION.

In September 2015, the Washington Department of Ecology (WDOE) 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 various 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 theoretical water quality violations (specifically depleted dissolved oxygen) in adjacent Budd Inlet and discounts or fails to mention several other possible causes.

In brief, the Report appears to be hastily written with many significant and insignificant errors, flaws, and oversights. Significant errors include a misleading miscalculation of "oxygen depletion" in Capitol Lake. Additional likely errors include calculations that appear to 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 a plethora of data in their own Report that strongly suggests the opposite.* In the following, I discuss and analyze the SM Report.

I have written 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 have used 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 refer readers to that earlier document.) The References Section gives the full documentation,

[1] This "Budd Inlet Model" is described in WDOE's report of June 2012. See "TMDL Report 2012" in the REFERENCES section.

both in my abbreviated forms and in scientific format. In the following I refer to my own (the present) document as an "Analysis" to distinguish it from WDOE 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, and have used the right technical language where that is essential.

I regret that my time for analyzing the SM Report was critically limited. It seemed likely, while I was doing it, that I would have to leave this project unfinished. To that end I wrote this paper by sections, each of which could stand alone if my departure was required. My time for research and writing did indeed run out; the following sections are the result.

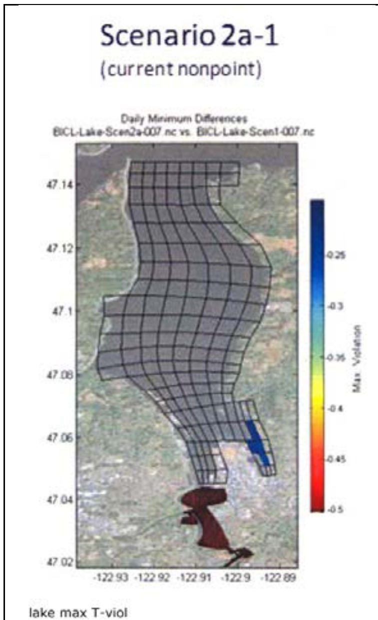

Figure 1-1. WDOE's depiction of the maximum theoretical impact of Capitol Lake and other non-point sources on dissolved oxygen conditions in Budd Inlet (TMDL Report, Figure 90a, p. 206). Fine print in the original at the top of chart reads "Daily Minimum (sic) Differences ECL-Lake-Scen2a-007 nc vs. BCL-Lake-Scen1-007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

I believe that the origin of the SM Report is traceable back to the image shown here in Figure 1-1. 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 by "non-point sources," mainly 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 grey areas in Budd Inlet are those where not even the tiniest of theoretical 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* theoretical 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.

In encounters with the WDOE 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

[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.)

effect of Capitol Lake on Budd Inlet, then in reality there is no problem whatsoever. That seems to have 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 SM Report that I review here is the latest result of that "alarmed scramble."

1a. The Budd Inlet Computer Model.

For persons who are not familiar with the Budd Inlet computer model, a few words of description are in order. The 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 1-1 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 its 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 [24-hour?] 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 1-1. The smallest low oxygen condition triggering a "violation" color is a DO level 0.2 mg/L below the standard – the blue top end of the scale in Figure 1-1. 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.

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[3] The number of grid squares is not always the same in WDOE reports. For example, two side-by-side grids on p. 32 of the SM Report (reproduced as Figure 2-7 below) 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 Section 2.

1b. 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 1-2. To date, this "Budd Inlet Scientific Study" (= BISS in the following) is the most detailed and reliable study of Budd Inlet ever made.

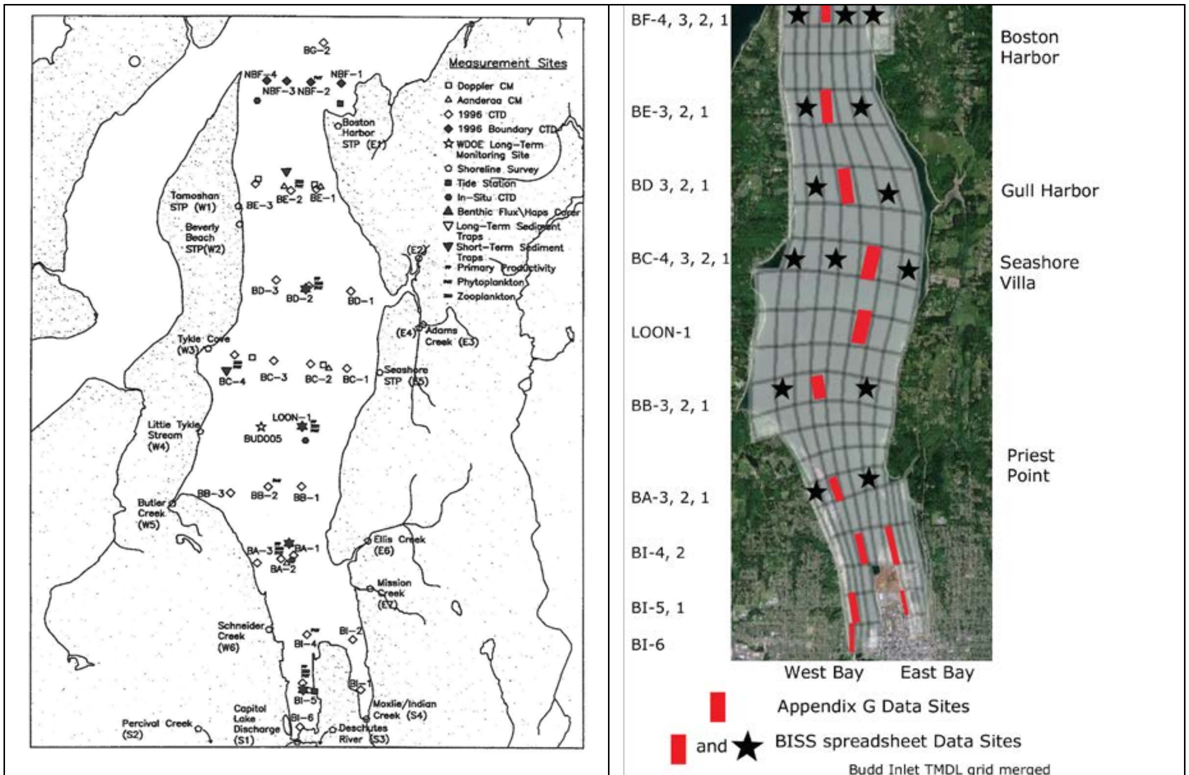

Figure 1-2. (Left) All BISS sample sites in Budd Inlet with a key to observations made at each site. Source: BISS Vol. 1 p. 59, 1998. Figure 1-2. (Right) Sites for which 1996-1997 data are available in Budd Inlet, referred to in this Report. Red bars; data available in TMDL Appendix G. Red bars and stars;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

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 1-1. 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 change) in increments of 0.5 meters.

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

The Budd Inlet computer model used by the WDOE 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,

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 1-1. 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 Notes); I Water Temperature °C; J Water Salinity ppt; K Water Density (σ_T); L Dissolved Oxygen Concentration (mg/L); M Chlorophyll Concentration υg/L); N Light level. This example shows bottom water at station BI-1 (head of East Bay, includes the colored squares of Figure I-1) on various dates (Jan. 22 – Sep. 24, 1997), depth 7.5 m below the surface, water temperatures ranging from 8+ to 15+ °C, salinities ranging from 26+ to 28+ parts per thousand, and DO's ranging from 8.00 to (critically low) 2.85 mg/L over these dates. Some data are rounded to two decimal places; in the spreadsheet they have more. Data under shaded headings are also contained in the TMDL Appendix. Notes: 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). "-999" indicates that data were lost or not taken on some occasions.

are shown in a WDOE Report that accompanies the 2012 TMDL Report – namely, the "TMDL Appendix." Here the data are mostly reported in the form of Figures comparing the computer's calculations (as a graph) with observed data (as points). The actual numerical values must be calculated by measurement of the graph scales and interpolation. Table 1-1 shows which data are presented in both the Appendix and in the Spreadsheet. The Appendix also includes graphs for data that are not in the BISS spreadsheet in my possession.

The Spreadsheet and the TMDL Appendix were my major sources 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 Section 2).

These sources are referenced here as "TMDL Appendix" and "BISS Report 1998."

<u>1c. Encounters with WDOE</u>.

I was invited to examine the claim that Capitol Lake degrades water quality in Budd Inlet in Autumn 2012 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 WDOE's "TMDL Advisory Group," a group of professionals, agency representatives, and members of various organizations that met monthly to advise WDOE on restoration of the Deschutes River. This group's agenda included the Lake/ Estuary question.

I quickly realized (from Figure 1-1 from the TMDL Report and others like it – Figure 1-3 below, 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 WDOE 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.

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's chapter 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 WDOE modeling staff members.

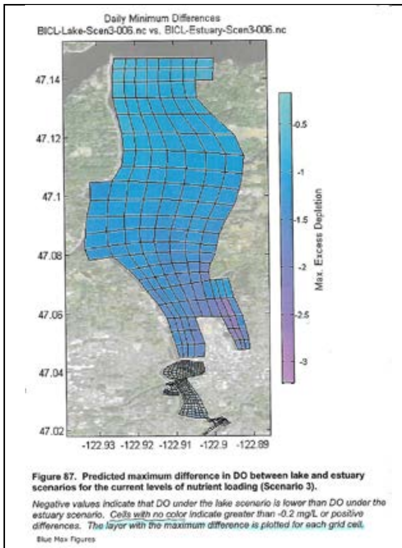

Figure 1-3. Budd Inlet purportedly with less dissolved oxygen everywhere "caused" by the Lake, compared with DO levels if an estuary were present. Source: Figure 87, TMDL Report. [7]

During the interim "waiting period," it was announced by the WDOE 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 Section 3.) The effect of this change was to make Budd Inlet appear to be far more degraded by Capitol Lake than is shown in Figure 1-1 and elsewhere in the TMDL Report.

I met with the WDOE 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 July 17, 2014 (AHSS, 2014). At that time I gave a Power Point presentation correcting

[7] My detailed response to the WDOE 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 – while overlooking the near-inevitable detrimental consequence of that, namely DO depletion at the bottom.

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 (included at the end of this entire Analysis as an Appendix), 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 realizations 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 WDOE 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 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" and addresses 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 WDOE; the SM Report's References section makes no mention of any of my written or presented contributions.

Two special features of the modelers' effort and interpretations are mentioned here. One is their apparent lack of appreciation of certain vast differences between the Capitol Lake and Budd Inlet systems. The other is their apparent oversight of an important natural estuarine phenomenon, namely the seasonal formation of "null zones."

1d. The Special Case of Capitol Lake.

To include Capitol Lake in their simulations, the modelers devised a clone of the existing Budd Inlet Model, using the same principles of calculation, and fitted it to Capitol Lake. If surface area alone were a main criterion, the tiny Lake would merit about 16 grid squares (using the same scale as in Budd Inlet). Surprisingly, the modelers divided it into 280 squares, nearly twice the number used for all of Budd Inlet. No mention of the reason for this is made in the TMDL Report and its Appendix, where sections are devoted to changes made in the Budd Inlet model to extend it to Capitol Lake (TMDL Report, pages 187 – 197; TMDL Appendix H). Likewise no mention is made of the number of depths needed in the Capitol Lake part of the extended model. The TMDL Appendix states that the shallow water in the Lake is so homogeneous that one hardly need bother at all about differences between depths – that is, that the water column as a whole under each grid square can be treated as a single "cube." Whether or not the modelers do so is not stated.

The real difficulty with trying to drag Capitol Lake into a simulation devised for Budd Inlet is that the Lake's ecosystem is vastly different from that of Puget Sound. The large plants and other biota of the Lake constitute a vast nutrient-collection- and carbon-storage- system on a scale unlike anything in southernmost Budd Inlet. The carbon compounds formed by plant photosynthesis are stored for days, weeks, months or years in the structures (roots, stems, leaves) of the plants and the organisms that eat them or their decaying byproducts (clams, fish, birds, insects, snails, worms). Many of these organisms have long lifetimes and can store carbon and nutrients in their bodies for a year or more. This huge rich complex ecosystem intervenes between the input of high-nutrient water from the Deschutes River and the output of "lake-treated" water at the dam. Simulation of its effects on the water would require creation of a whole additional ecosystem model tracing the uptake of nutrients, their storage in plant biomass, their transfers to animals via herbivory and detritivore feeding, and processes such as predation, competition, and "leakage" of materials back into the water with consequent continued recycling. There are also significant differences in the species makeup, characteristics, and life cycles of freshwater- and marine- phytoplankton organisms and the small animals that eat them to be considered. The freshwater biotic community is a system that the Budd Inlet model was never constructed to emulate; a once-over-lightly extension created by the modelers cannot possibly cover it accurately.

The modelers' only significant statement on how the Lake's biota were simulated is a single sentence describing a new subroutine added to the Budd Inlet model, namely "Water Quality Additional Model (WQADD) can simulate a combined bottom plant community of macrophytes, epiphytes, and attached algae *as a lumped variable*"[8] (TMDL Report, p. 188). The results – and absence of results – of their attempt to force-fit the Lake ecosystem into a model designed for an estuary system are evident in the pages of the SM Report (see Section 3, this Analysis).

[8] … emphasis added …

1e. The Natural Null Zones of Estuaries.

In addition to what appears to be inadequate appreciation of the special complexities of freshwater ecosystems, the modelers appear to be unaware of one of the most important natural features of estuaries. That feature is the "null zone," a pocket of low dissolved oxygen that develops in late summer at the heads of most estuaries, arising from entirely natural causes. Figure 1-1 above shows an example of a null zone, this one the colored region of exaggerated low DO in East Bay caused by Moxlie Creek. Again and again throughout the SM Report, East Bay's DO null zone can be seen, markedly more oxygen-depleted than any other locale in Budd Inlet. The modelers seem to regard such zones as phenomena caused entirely by human activities. Regardless of interpretation, if interactions between fresh and salt water at the point where they meet were accurately simulated when the model was constructed, the Budd Inlet model would show those zones. As shown in many of the Figures in the following sections, it seems to do so consistently.

An example of the modelers' interpretation of null zones can be seen in WDOE's South Puget Sound Dissolved Oxygen Study Report (SPSDOS 2013). The model used in that Report operates on the same principle as the Budd Inlet model but has been expanded to include all of Puget Sound south of Edmonds. In the Figures generated by that model, the head of Eld Inlet -- an estuary with no dam, no urbanization, and a rural/forested stream drainage basin – obstinately continues to show low DO's below modern water quality standard levels even after the modelers have reduced human O_2-depleting sources by 75% throughout all of Puget Sound (see Figure 51 p. 96, SPSDOS 2013).[9]

In the Eld Inlet case, the modelers attribute the low oxygen phenomenon to "poor circulation." That is mistaken. The "null zone" forms in the small restricted region where the incoming saltwater at the bottom of an estuary collides with the incoming freshwater from the river at the head. Here dissolved organic matter in both incoming streams is chemically and physically converted to colloidal (small) particles by the abrupt change in salinity and other changes in the water chemistry. Where the waters collide, the net horizontal velocity drops to zero and the newly mixed waters rise. In this zone of slower water movement, the newly formed colloids accumulate, aggregate, and sink. Their decay causes a low DO condition at the bottom in this small region at the head of every estuary.

Understanding and recognition of this estuarine phenomenon is not widespread. An excellent detailed description of it is provided by Mann (1982).

I mentioned this phenomenon during the March 2014 meeting with WDOE staff. Tiny Moxlie Creek at the head of East Bay has one of the highest nitrogen nutrient concentrations in its waters to be found anywhere among all South Puget Sound streams

[9] Eld Inlet is the most resistant of all estuaries to simulated efforts to eliminate its null zone by curtailing human activities. The second most obstinate inlet in that regard is the null zone in East Bay in Budd Inlet, still showing DO depletion below the level of water quality standards despite a simulated 50% reduction in human impact.

(SPSDOS 2011, Figure F-2 p. 124). It is at least possible that that small stream (with adjacent high-nitrogen streams, Mission and Ellis Creeks) is responsible for the chronic low DO excursions (that is, the null zone) seen in East Bay and would cause that condition even if there were no human activity at all.

I learned during the March meeting that Moxlie Creek could not (at that time) be simulated separately from the other small creeks around Budd Inlet (at Gull Harbor, Priest Point, Butler Cove and elsewhere). All creeks rimming the Inlet were treated as a single "watershed source." I suggested that it was important to try to isolate Moxlie Creek as a nutrient source to determine whether it was playing a role in the persistent dissolved oxygen depletions seen in East Bay, but have seen no subsequent evidence that the modelers actually did so.

<u>1f. The Analysis That Follows</u>.

In the following, 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. As noted, I believe that the Model falls short in that it has been poorly adapted to mimic the ecology and hydrology of Capitol Lake. I also have reason to believe (and have never been corrected on this by the modelers) that the WDOE staff consider every single one of the model's thousands of projections 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 theoretical water quality standards violation. All such calculated theoretical violations are invariably reported by them as "real."

Wherever possible throughout the following, 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 is definitive. Where the computer calculates theoretical water quality standards violations, that is suggestive and instructive – but not evidence of real-world violations.

In addition to this Introduction (Section 1), the rest of this Report is divided into six sections. These are …

2. The Mistaken Assumption of Model Infallibility.
3. The Real and Calculated Role of Organic Carbon.
4. [Blank pages]
5. Miscellaneous Mistaken Assumptions and Presentation Errors.
6. The Mistaken Calculation of Theoretical Water Quality Violations in Capitol Lake.
7. References and Notes.
8. Appendices.

2. THE COMPUTER GETS MANY WRONG ANSWERS.

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 G stations highlighted in Figure 1-2, portraying observed and calculated conditions at the surface, bottom, and a depth midway between surface and bottom. Figure 2-1 shows a typical example, this one for the dissolved oxygen levels in the bottom water at station BI-6 in West Bay (the station nearest the dam). These pages enable us to estimate how many of the calculations were dead-on accurate.

Two features are evident. First is that the computer's graph (dark line) follows the general trend of the observed data (open circles) quite faithfully between January 25 and September 15, 1997. Second, if every calculation were accurate, the graph would go through every one of the open circles. It does not. It "misses the mark" by a wide margin in some cases, by a narrow margin in others, and in some cases (where it touches the circles) it is accurate.

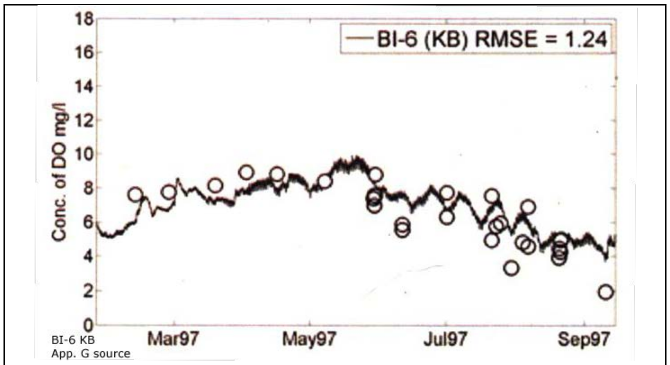

Figure 2-1. Observed dissolved oxygen levels (circles) and Budd Inlet model's calculations (graph line) of those levels near the head of West Bay (station BI-6), in water at the bottom. January 25 – September 10 1997. Source: Appendix G2 TMDL Report, page 1.

That is the fact to always bear in mind; *the computer often gets wrong answers.*

I used the following method to estimate the overall accuracy of the Budd Inlet Model's calculations.

<u>2a. Methods. Counting Right Answers.</u>

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 value (0.2 mg/L) used in judging whether a water quality standards violation has been detected, in many cases.

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 was scored as a "miss;" the graph was close in that case but the top or bottom (over the center) of the data circle was not in contact with the graph on the date of the observation. An example is shown in Figure 2-2 for station BF-3 surface water (near Boston Harbor).

2b. Results. "Hits and Misses."

Figure 2-3 shows the pattern of computer "hits" and "misses" at all stations, three depths per station. At best over all, the computer's calculations matched observed DO's about 80% of the time in bottom water at sites BI-4 (mouth of 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.

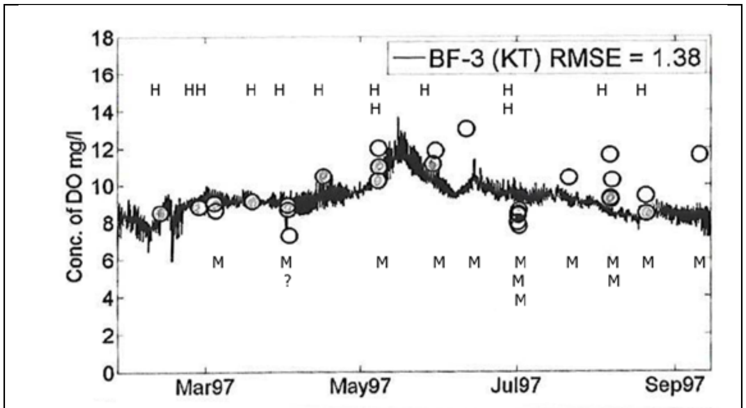

Figure 2-2. Assessment of calculated "hits" and "misses" of observed data circles by the Budd Inlet Model for dissolved oxgyen concentrations in surface water at station BF-3 (near Boston Harbor) by the method described in the text. Hits ("H" in upper row), misses and undeterminables ("M" and "?" in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

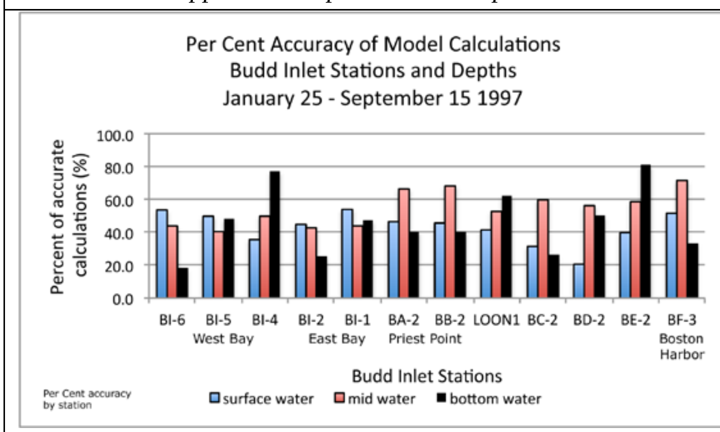

Figure 2-3. Accuracy of the Budd Inlet model. Bars show the per cent of calculations that correctly identified observed DO values (counting all "indeterminable" scores as "hits") by stations from south to north in Budd Inlet. Data from graphs in Appendix G2 TMDL Report.

2c. Discussion. Hits and Misses.

As a tool for showing broad trends, the Budd Inlet Model is useful. It is not capable of telling us, however, the exact value of every dissolved oxygen level – every depth, every six minutes[1], every location – for half a year. Yet the modelers base their most important claims on an apparent assumption that it is really that accurate. For example, if the computer finds that a calculated DO level is only 0.2 mg/L below the standard of 6.0 mg/L that prevails over most of Budd Inlet, the real-life water at that site is said by the modelers to be "in violation" of that standard. This must stem from their assumption that the computer really does "get it

[1] Iteration interval given on p. 187 TMDL Report.

right” in every last calculation. (This is also based on their assumption that a theoretical number from their computer is as valid as a measured “violation” in the water.)

In the above analysis, 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 2-4 provides an example. That Figure (same as Figure 2-1 above) shows the bottom water at station BI-6 with an 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).

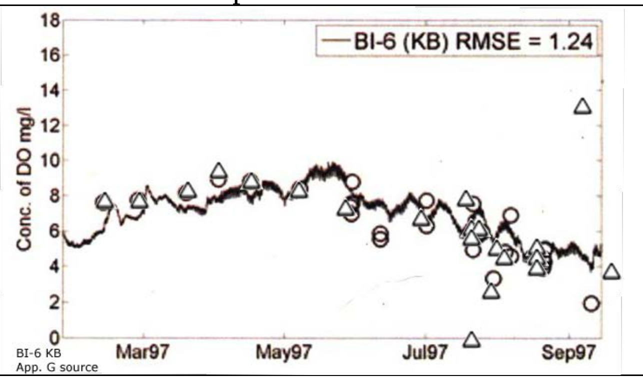

Figure 2-4. Figure from the TMDL Appendix with an overlay of data from the BISS research (triangles). The rightmost triangle is on September 24, a few days after the end of the computer simulation. Source: BISS spreadsheet.

Table 2-1 compares all of the bottom water DO data from East and West Bay stations for September, 1997 as reported in the Appendix G2 pages and in the BISS spreadsheet data. The correspondence is loose, at best. I haven’t attempted to reconcile the two data sources and have taken both at face value throughout this Analysis.

	Appendix G2 data		BISS data			
Station	Date	Bottom DO (mg/L)	Date	Time	Depth to Bottom (m)	Bottom DO (mg/L)
BI-6	~Sept 10	2.0	Sept 10	12:44	9.0	12.53
			Sept 24	12:28	10.0	3.59
BI-5	~Sept 10	2.5	Sept 10	12:58	13.5	2.16
	next day?	3.5	Sept 24	12:44	13.0	3.83
			Sept 25	8:58	8.5	4.09
BI-4	~Sept 10	9.5	Sept 10	13:13	13.5	4.29
			Sept 24	12:57	14.0	3.91
BI-2	--	ND	Sept 10	13:29	5.5	13.51
			Sept 24	13:13	9.0	4.10
BI-1	~Sept 10	13.5	Sept 10	8:44	4.0	3.47
			Sept 10	13:43	6.0	13.53
			Sept 24	13:26	7.5	2.84

Table 2-1. Data for all observed bottom water dissolved oxygen levels during September, 1997, at all West and East Bay stations. Appendix DO’s and date(s) were estimated from the graphs. BISS data were taken from the BISS spreadsheet. Appendix data don’t show depth to bottom or sample times. Depths to bottom vary in the BISS data due to tide changes. BISS observations extend past the September 15 end date of the computer simulation interval.

The September 10 BISS value (12.53 mg/L) is startlingly high for bottom water in late summer. Nevertheless it is real. It is not cited in the BISS spreadsheet's "errors" section and similar high bottom- (and midwater- and surface-) values are seen on the same date at East Bay sites BI-2 and BI-1. If the computer were always accurate, it would have "noticed" this high value whether it was portrayed on a graph or not. (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, alerting the modelers to something special happening there.) As we see, the computer "missed by a mile."

The lowest graph value calculated by the computer should have branded the BI-6 site as "in theoretical violation of water quality standards" on September 10 – but it did not.[2] Ironically, an accurate calculation would also have shown (as did the actual measurement) that the bottom water also experienced the highest DO water quality of the entire year for that site -- on that same day.

Figure 2-5 shows an instance in Eld Inlet where the bottom water was dangerously low in oxygen at 2 AM (less than 2.0 mg/L) then astoundingly high in DO (more than 10 mg/L) one hour later. In this case, there is a simple tidal explanation. For a computer making calculations every six minutes and programmed to keep its eye on layers of water (so to speak), this would be easy to detect and report. Station BI-1 in Budd Inlet, comparable in shallow depth and position in the estuary to the Eld Inlet station, shows something similar – a jump from 3.47 to 13.53 mg/L over a period of 5 hours (Table 2-1). The underlying cause at BI-1 in Budd Inlet may be ecological rather than tidal. If so, a more sophisticated simulation than the Budd Inlet Model would be needed to track it.

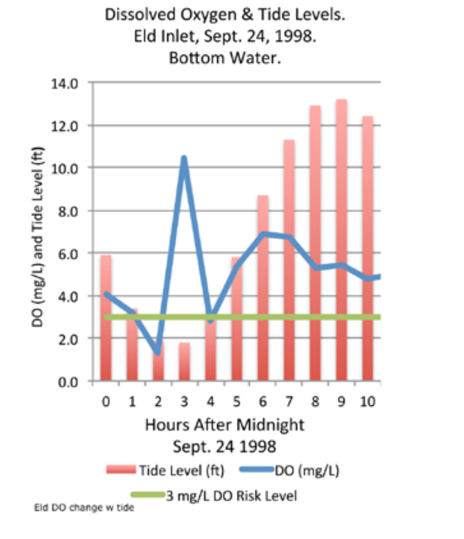

Figure 2-5. Oxygen levels in Eld Inlet bottom water during morning hours, Sept. 24 1998, showing a dramatic rise from < 2 mg/L to > 10 mg/L within one hour. Source: Eld Inlet Spreadsheet.

<u>2d. Statistics could play a role</u>.

As mentioned, graphic comparisons of the computer's calculations with real observed DO data are presented in Appendix G2 for the surface, bottom and a middle depth at the BISS stations considered by the modelers. Each of these graphs has a box in the upper right corner with the label "RMSE"and a number in it (example; Figure 2-4 above). The number is the "Root Mean Square Error," which is essentially the average distance by which the computer's calculations "miss the mark." In an analogy with bullets fired at a conventional circular target, the RMSE is an approximation of the average distance of all bullet holes from the exact center of the bullseye.

[2] The modelers did not show station BI-6 in violation of water quality standards at any depth on any date (see TMDL Figure 90 and Figure 1-1, Section 1 of this Analysis). A staff member expressed surprise when I pointed that out.

In the DO situation as used by the modelers, the size (radius) of the bullseye is always 0.2 mg/L or more, even though the number at the exact center is not always the same. The average “miss” by the computer (that is, the RMSE) is always larger than 0.52 mg/L at every depth and station, ranging from 0.52 mg/L to 4.72 mg/L (BB-2 and BE-2 surfaces, respectively). This does not mean that *all* “shots” miss the “bullseye” – but where the RMSE is large, half or more of them miss the mark by an amount that obscures the true value of the “target” whose size we would like to estimate. This was the subject of my presentation to the modelers and others on November 14, 2014 (Power Point OK2, 2014).

Statisticians have perfected many reliable tools for overcoming the “misses” in calculations derived from sample measurements and for having confidence that data show (or don’t show) what you want to know. One such practice uses “confidence limits” calculated from the data. Here I present an example without burdening unwilling readers with the details.

Figure 2-6 shows a sample of observed DO data obtained in West Bay during a total drainage of Capitol Lake, and two pairs of confidence limits (CL’s) that were calculated from that sample. The two sets of CL’s are shown at the right edge of the Figure. Each consists of a “data point” linked to 2 horizontal bars (the CL’s) above and below it.

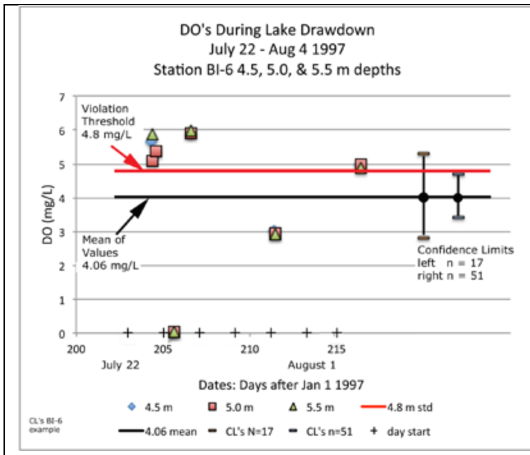

Figure 2-6. Example of using confidence limits for greater confidence in identifying WQ standards violations. DO data points (17 total) are from depths 4.5, 5.0, and 5.5 m at station BI-6 near the dam on dates when the Lake was drained. (Some points are hidden behind others.) Mean of the data is 4.06 mg/L (black line), WQ violations threshold is 4.8 mg/L (red line). Confidence limits for 17 observations include values above the threshold; for the data shown we can’t conclude with 95% confidence that the mean of the DO’s is below 4.8 mg/L. Also shown; the confidence limits if the sample had included 51 observations, also with mean 4.06 mg/L. (That sample obtained artificially by tripling the 17 value observed data set.)

Speaking non-statistically, CL’s “trap” unknown numbers. Even if you can’t know or calculate their exact values, you can still be “pretty sure” that the numbers you’re interested in are somewhere between the two CL’s. You find CL’s by first finding the average of a sample of several measurements (or calculations), then (speaking non-statistically) “take it from there.”[3]

In Figure 2-6, what we’d like to know is whether the average real-life DO at that site was low enough to qualify as a Water Quality Standards Violation. The violation threshold is 4.80 mg/L (red line), the average of 17 measurements is 4.06 mg/L – black data point and line – well below the threshold.

[3] The CL’s were calculated from 4.06 +/- std dev (of array of 17 values) x $T_{(.95,\ df=15,)}$/sqr root (17). See Keller, 2001.

Because of the vagaries of sampling (or the hit-or-miss nature of the computer's calculations) 4.06 mg/L may or may not be the "real" (= real-life, "population") average DO of the water. But even if it isn't, we can be "pretty sure" ("95% confident," speaking statistically) that the real life average, whatever it is, lies between the CL's.

For the sample of 17 measurements, the upper CL is higher than the 4.8 mg/L cutoff threshold. The "real mean," whatever it is, occurs somewhere between the two CL's. If it is in the upper end of this range, it could be above the threshold. We can't be "pretty sure" (that is, "95% confident") with only 17 measurements that a violation really exists.

The way to shrink the CL range is to take more measurements (or include more computer calculations). Figure 2-6 shows the CL range if our sample had 51 measurements (and the same average, 4.06 mg/L). In that case the upper CL would be less than 4.8 mg/L and we could be "95% confident" that the unknown average DO, whether it is really 4.06 or something different, violates the Water Quality Standard.

Caution: the data obtained by the computer do not consist of independent measurements. Each calculated DO value is partially pre-determined by ("dependent upon") its value just a few minutes earlier. That may also be true of measured data, in this instance. That is a complication that introductory statistics are not prepared to deal with. Simple CL's like those for the sample of 17 real-world measurements probably aren't appropriate for data of this kind. *Only a professional statistician can advise on ways of having confidence in calculated answers in such situations*.

If something less complicated than CL's be needed, one possibility might be a simple "rule of thumb" like the one that I suggested to the modelers on November 3, 2014. That is, subtract the RMSE from the WQ standard and compare every calculated DO value with the number thus obtained. If the calculated value is lower, the likelihood is high – maybe 84%?[4] – that a real violation occurred at that time, depth and place indicated. Figure 2-7 from my presentation illustrates the difference that this rule of thumb would make in understanding Budd

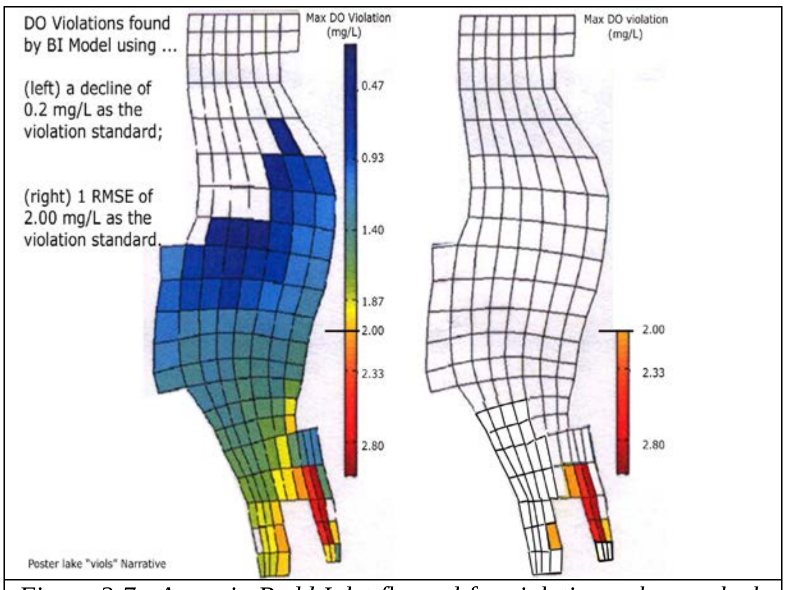

Figure 2-7. Areas in Budd Inlet flagged for violations where calculated values are (a, left) 0.2 mg/L below the standard or (b, right) one RMSE (in this example, 2.0 mg/L) below the standard. Here the modelers' colored scale (a) shows the amount by which each colored square is in theoretical violation, not the minimum DO of each square. Source: a) Poster 2014; b) Power Point OK2, 2014.

[4] The amount of "confidence" in this "simple" case is beyond the author's statistical comfort level and would need to be calculated by a professional statistician.

Inlet. That is, fewer theoretical violations would be found, but we could have confidence that they really do occur, when and where they are found in this way.

The modelers heard these suggestions in my presentation to them on November 3, 2014. They appear to have taken some notice of it and mention confidence limits in the new SM Report (pp. 27-28). Although their explanation is not easy to follow, they appear to compare the computer's calculations in one scenario ("natural") with its calculations in another ("current conditions") and concentrate on the variability in differences between the corresponding calculations. They find that if there is a difference between a calculated estuary number and the corresponding calculated lake number, that difference is likely to be "real." Nothing appears to be said about comparing the computer's calculations with real data. A better explanation of what they are referring to is needed before knowledgeable readers can evaluate their claims here.

The modelers are not inclined to use averages of DO calculations in their search for theoretical violations. Elsewhere (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 briefly below the WQ standard for that area. Their preference is to take each individual calculation at face value and assume that it is accurate enough for real-life policy decisions.

Expressing doubt about the alleged dead-on accuracy of every calculation, personnel of the HDR consulting firm asked the modelers precisely that question 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).

2e. Hiding the Search for Violations.

One place where the hit-or-miss accuracy of the model makes a huge difference arises from the question: "Did the water quality of Budd Inlet meet modern standards, even in its 'natural' state before human activity began to modify it?" The consequences of that question are explored in this subsection, centering upon the pair of illustrations in the SM Report reproduced here as Figure 2-8.

Figure 2-8a shows the part of Budd Inlet for which the modern water quality standard is 6.0 mg/L (green) and the part where the standard is 5.0 mg/L (orange). If the natural water of times past had DO's that were always higher than these values, then the computer could look for violations of the standards in modern waters by simply comparing the modern waters' DO's with 6.0 or 5.0 mg/L in each grid cell. If the "natural" waters would have violated these standards, however, then the search for violations in modern water becomes very complex. The challenge is to learn or estimate what the DO's in the natural waters of times past really were, to determine the method by which violations are sought in modern waters.

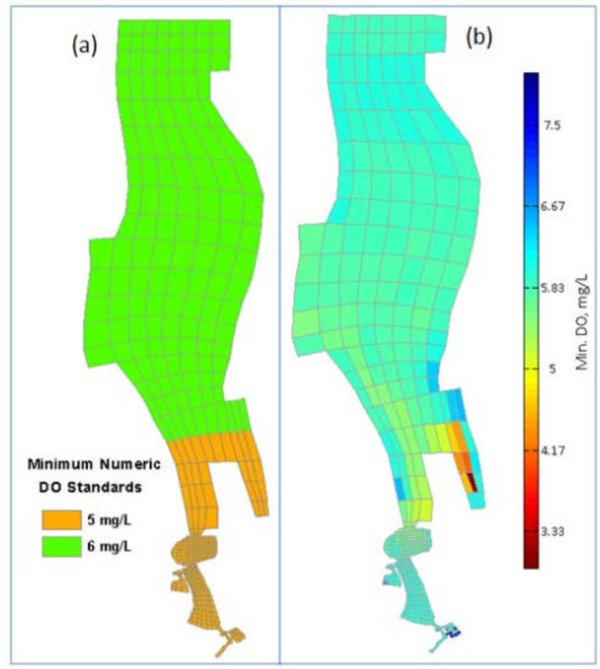

Figure 2-8(a). Modern water quality standards that apply to Budd Inlet. (b) Minimum dissolved oxygen levels in Budd Inlet as calculated by the modelers for 'natural' waters before they were altered by human activity. ("Capitol Lake" in Fig. 2-8b is an estuarine extension of Budd Inlet, not a dammed impoundment.) Source: Both images make up Figure 7 (p. 32) in the SM Report.

Absent observed data, one way of doing this would be to run the Budd Inlet model with pre-modern conditions of the past – differences in weather, river runoff, and inputs from the Pacific Ocean to the extent that those can be known or estimated. No dam or impounded Lake would be present. What about tides? Use 1997 tides or those of some year of the past? The modelers are not clear about how they do this.[5]

In any event, the modelers run the model with settings for presumed pre-modern conditions, calculate the DO at every depth underneath every grid location in Budd Inlet every six minutes for 9 months, while comparing each calculation with 6.0 or 5.0 mg/L depending upon the location. Figure 2-8b presents their findings. Rather than show readers the grid cells in which the "natural" waters violate a modern water quality standard, they paint each grid square with a color that represents the lowest DO that they found there during the 9 simulated months.

Are those DO levels above or below the modern standards? It is possible to see that East Bay has several cells clearly in violation, as heads of estuaries naturally do in late

[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 Section 7, this Analysis). As another example of their typical indifference to consistency and detail, the grid above has three top tiers at Boston Harbor in Figure 2-8a, two in Figure 2-8b.

summers, but aside from there, Figure 2-8b leaves readers no clue. In the following I show how Figure 2-8b can be compared with Figure 2-8a and relate the result to the implications of claiming that every number calculated by the computer is accurate.

<u>2f. Methods. Finding the Water Quality Standards Violations in the Pre-Modern ('Natural') Estuary</u>.

Figure 2-8b can be analyzed using Photoshop Elements 12 software. Using that software, I first added a readable DO scale to the Figure for determining which colors showed DO's less than 5.8 mg/L for the central part of Budd Inlet and which colors showed DO's less than 4.8 mg/L for the southernmost part. (These DO levels are 0.2 mg/L below the respective modern standards. Any DO reading below these levels qualifies as a WQ standard violation.)

I then selected the interiors of various grid squares in Figure 2-8b using Photoshop's "polygonal lasso" tool and clicked "Similar" in the Selection menu. This function identifies every part of Figure 2-8b that has the same color as the selected square. *It also identifies the part of the modelers' scale that has the same color.* By comparing the colors selected on the modelers' color scale with my more readable scale, it was possible to see whether the 'natural waters' in each selected area of Budd Inlet were calculated to be in violation of modern WQ standards. I assigned every grid square that was in theoretical violation – whether the calculated "violation" was large or small – a grey color and left the squares that were not in violation in the green or orange colors that show the standards. (A detailed description of this technique is in Section 5.)

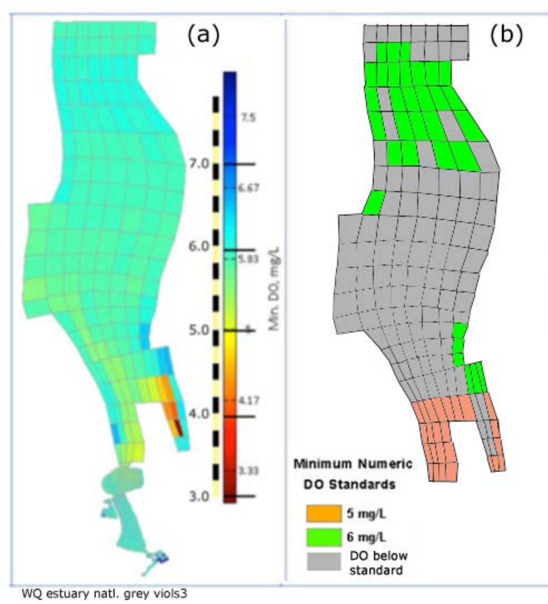

Figure 2-9. (a) "Minimum DO" data provided by the modelers for the pre-modern estuary, from which Figure 2-9b was determined (same as Figure 2-8b above with a readable DO scale added by me. (b) Grey areas show where pre-modern ('natural') waters had DO levels 0.2 mg/L or lower below modern water quality standards, as calculated by the Budd Inlet model.

<u>2g. Results. Most of the 'Natural' Estuary Violates Modern Water Quality Standards.</u>

Figure 2-9b shows the result of this exercise. The grey areas in Budd Inlet show locations where the 'natural' waters of some time in the past experienced DO levels lower than the modern standards at least once during the interval January 25 – September 15. Only 57 of the grid locations out of 160 total had 'natural' waters that *always* contained more than 6 (or 5) mg/L of dissolved oxygen. Those grid squares in modern waters can be judged by the 6.0 or 5.0 mg/L standards. In the other 103 squares, theoretical modern water quality violations must be calculated by the more complex method.

2h. Discussion. It is Impossible to Check the Calculations when the 'Natural' Estuary is used as the Water Quality Standard.

Once the areas where the "natural" waters violate modern standards are identified (grey grid cells, Figure 2-9b), the modelers use a complex method for those areas to "find" theoretical violations in modern waters. For each grid square, at times when the 'natural' waters have DO's higher than the standards shown in Figure 2-8a, those numerical standards (6.0 or 5.0 mg/L) are used for the modern waters. But at times when the DO's of 'natural' waters are lower than the modern standard, then the DO of the 'natural' water itself is used as the standard.

The grey areas are veritable Happy Hunting Grounds for finding theoretical violations in modern waters. There, compared with calculated DO's of the past whose real values or times of occurrence we can never know, the modelers can assure us that modern-day "violations" of as little as 0.2 mg/L have been identified. The foundation of this assurance is the assumption that the model gets the exact right answers 100% of the time – first when it calculates the DO's of the "natural waters," then again when it compares the calculated modern DO's with those "natural" DO's.

The modelers have implied elsewhere (SPSDOS 2013, p. 87) that all that is needed to declare a location (= grid square) in violation of modern water quality standards is a single computer calculation of a DO level that is slightly lower than the DO of the mythical 'natural water' at that time and place. An example described by them (obtained from a model similar to the BI model but expanded to Central and South Puget Sound) is a location with a modern WQ standard of 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 that model.* The whole grid square was flagged as "in violation."[6] That is, the 'natural' water's DO fell below 5.0 mg/L just once by an amount so small – 0.05 mg/L -- that it is well-nigh undetectable in real life – an illustration of confidence with which the modelers regard their calculations – namely that they are always dead-on accurate to the second decimal place.

A drawback of the grey zones of Budd Inlet (Figure 2-9b) is that it is impossible for anyone to check up on the numbers used to assign violations to the modern waters in those zones. The violations originate from the supposed waters of the past, whose exact DO levels we can never know. If the observed BISS data show "no violations" at the times and places when measurements were made, that reality can always be dismissed by saying "yes, but the computer detected theoretical violations at times other than those hours during which the BISS observers were actually observing."

Despite the impossibility of checking up on the model's calculations over most of Budd Inlet, it is still possible to do so in those few areas in the remaining green and orange zones of Figure 2-9b. There we know that the DO levels with which the modern water

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[6] In this case the "violation" – 4.95 mg/L – is only 0.05 mg/L below the standard. I don't get it. The violation threshold is supposed to be 0.20 mg/L lower in all other applications. Why this exception?

must be compared to find WQ violations are always 6.0 and 5.0 mg/L, not some unknown/unknowable theoretical DO level of waters past. There are at least two instances in which WQ violations occurring in real life were not found and flagged by the computer. In the BISS data, these are West Bay sites BI-5 (observed DO levels 4.74 and 2.16 mg/L on June 12 and September 10 1997) and BI-6 (DO's of 3.83, 4.48 and 4.37 mg/L on August 20-21, 1997). The modelers, on the other hand, found "no violations" at these two sites (see Figures 2-9a and –b).

The modelers' portrayal of where Budd Inlet's modern waters are lower in DO than the 'natural' waters of times past is not credible at face value. It is based on the assumption that every last one of the calculations of DO's in "natural" waters is accurate, and then on the assumption that every one of the corresponding calculations of DO's in modern waters is also accurate, and that therefore the differences between every pair of numbers from the two calculations are also accurate.[7] Even though we can only examine the margins (BI-6 and BI-5) of the 'natural violations' zone, we can still recognize that the computer was in error some of the time. That is just one more illustration of the fact that its detailed projections are untrustworthy throughout all of the rest of time and space.

[7] Actually, where the DO's of the 'natural' waters are used as the standard, the calculated differences between the 'natural' and 'modern' calculated values are less likely to be accurate than is either individual calculation by itself. If, say the probabilities that the 'natural' and 'modern' values are accurate are (1/2) and (1/3) respectively, the probability that their difference is accurate is only (1/2) x (1/3) =1/6.

3. THE SIMULATED (AND REAL) ROLES OF ORGANIC CARBON.

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 (particularly the bottom 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 enters Budd Inlet and uses up oxygen in various ways. In this section, I analyze that claim.

I show in the following that the modelers are mistaken. In this section my conclusions are drawn from obvious calculation errors in the SM Report itself. I also hypothesize that the formation of organic carbon in the lake and its entry into the salt water differs from the mode claimed by the modelers in ways that are much more consistent with ecological reality.

For the benefit of readers who are not familiar with the Lake/Estuary conversation, I first present an overview as a reminder of the main facts and issues.

3a. Background.

During summers, Capitol Lake acts as a vast trap for nutrient nitrogen (NN [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 3-1 shows the NN trap process in action for year 1977 (data from Figure 34 p. 56, CH2M-Hill). The Lake's entrapment of NN can be seen in recent data, as well. Figure 3-2 shows similar uptake of NN by the Lake in 2004.

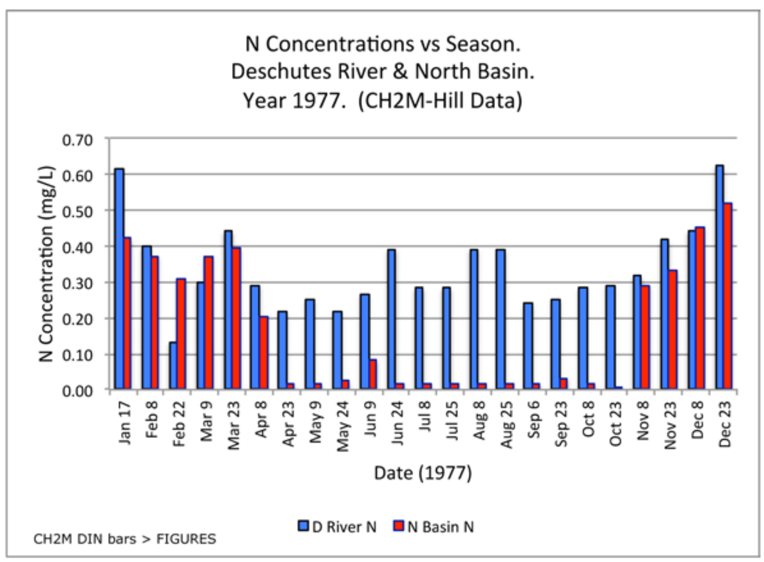

Figure 3-1. Nutrient nitrogen concentrations in the Deschutes River at the south end of Capitol Lake (blue bars) and in water in the North Basin near the dam (red bars), 1977. Differences in bar lengths show the uptake of N by the Lake during almost every time of year, most markedly during summer. (CH2M-Hill data.)

[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.

How does the Lake trap NN? The plants do it. They 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 that we see on the Lake's surface each summer are the reservoirs in which the trapped NN 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 (always "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.

There can be a "down side," however. 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]

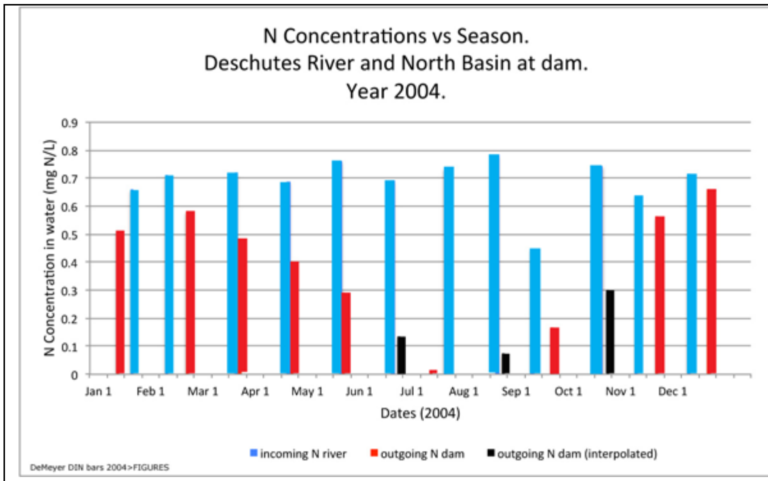

Figure 3-2. Nutrient nitrogen concentrations in the Deschutes River (blue bars) and in water exiting the Lake's North Basin over the dam (red bars), 2004. Same interpretation as Figure 3-1. Black bars are interpolated values for missing data. (DeMeyer data.)

The Deschutes River has a higher concentration of NN in its water than any other major stream entering Puget Sound south of the Narrows. These are compared with the NN contents of other South Sound streams in Table 3-1.

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
Nisqually River	0.20	199

Table 3-1. 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.

Because the Nisqually River has such a large volume of flow, that river delivers more total NN to Puget Sound than any other stream, despite its low NN concentration. (This is especially true when the

[2] This is *never* a problem in the deep water of Capitol Lake, where the oxygen supply is virtually inexhaustible.

whole year is considered.) 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 3-1 and 3-2). 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. Some 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 disastrous 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. However, that stream is always naturally low in dissolved oxygen to begin with. The result, during the warm, high-biomass days of September, is that the bottom waters of East and West Bays usually experience their lowest DO's of the year. The net effect of adding NN to the Sound, as the Deschutes River would do, is to ramp up plant growth in the sunlit surface water and, 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. In the months after I 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 Section: "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 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.

This is a valid scientific hypothesis. 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?) An alternative to the "sooner" hypothesis is presented and analyzed in Section 6. Here I examine the validity of WDOE's claim that, by this

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

[4] This includes the more-or-less permanent natural estuarine "null zone" introduced in Section 1, but it can be a more widespread phenomenon elsewhere throughout whole late-summer estuaries.

mechanism, the Lake lowers Budd Inlet oxygen more than an undammed estuary would do.

<u>3b. The Production of Organic Carbon by Lake and Estuary</u>.

The modelers support their claim (that Capitol Lake plant matter significantly decreases dissolved oxygen in Budd Inlet all summer) using the graphs shown in Figure 3-3. The upper graph (Fig 3-3a) shows “total organic carbon (= TOC)” levels in Capitol Lake or the estuary that would replace it if the Lake were missing, as calculated by their computer, day by day, from January 25 through September 15, 1997. The lower graph (Fig. 3-3b) shows levels of nutrient nitrogen (NN, called “DIN” by the modelers) in the water, also as calculated for both Lake and estuary for the same time period. The graphs show the Lake trapping more River DIN than would an estuary (Fig. 3-3b) but also releasing more TOC to Budd Inlet than would an estuary (Fig. 3-3a). Pink dots on both graphs show actual observed values of TOC and DIN on various dates.

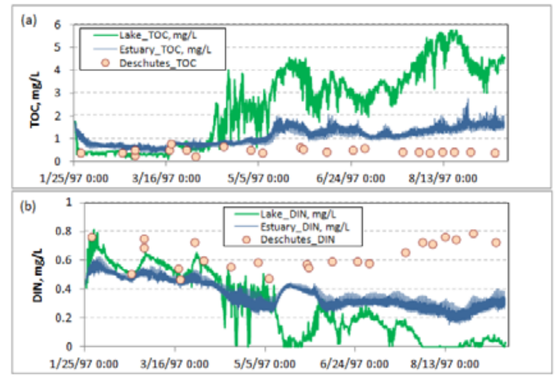

Figure 11. a) Total organic carbon (TOC) and b) dissolved inorganic nitrogen (DIN) concentrations at the location of the Capitol Lake dam under Lake (with the dam) and Estuary (without the dam) scenarios compared with concentrations in the Deschutes River at E Street.

Poster graph Grab2 > Figures

Figure 3-3. Fig.3-3a (Upper). “Total organic carbon” (TOC) in water at the position of the dam if the Lake is present (green graph) or if the Estuary were present (blue graph). Figure 3-3b. (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 Poster, 2014.

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

Both “TOC” and “DIN” as calculated by the modelers are reported in “milligrams per liter (mg/L).” By those units of measurement, the modelers inform us that they are calculating the amount of suspended and dissolved material in each liter of Lake or estuary water – not in solid parts of plants or biomass of animals.

These graphs provide a way of checking the computer’s calculations. In the lower Figure (3-3b) both Lake and Estuary DIN graphs are positioned lower on the Figure than are the observed 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 3-3a), one finds that *there are serious discrepancies in the modelers’ calculations.*

3c. Methods. Estimating TOC from DIN Uptake, using Figures 3-3a and 3-3b.

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 observations of River TOC and DIN values are shown in Table 3-2 (Columns A-D). I used the same technique to estimate the

Basic Data from the Poster Graphs (Figures 3-3a and 3-3b).							
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 from green graph, Fig 3-3a date in Column A mg C/L LAKE	DIN from green graph, Fig 3-3b date in Column C mg N/L LAKE	TOC from blue graph, Fig 3-3a date in Column A mg C/L ESTUARY	DIN from blue graph, Fig 3-3b 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
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 3-2. 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 3-3a (TOC's) and 3-3b (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 Analysis I have used the TOC dates in Column A for both TOC and DIN observations.

[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 unhelpful date scale provided on the x-axis by the modelers makes this near-impossible.

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 3-2 (Columns E-H).

For the estuary case, I assumed that the uptake of NN (= 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 Bridge site *at the end of the same day* (Columns D and H, Table 3-2). These uptake values are shown in Table 3-3 (Column I).

Estuary Case.						
A	B	D	H	I	J	JJ
Date	Amount of TOC observed (mg C/L) RIVER	DIN in River this date* (mg N/L) RIVER	DIN at Bridge 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 3-3. 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 3-2 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 Bridge site (Col. J + Col. B). (Rounding of products alters some 2nd place decimals). *See note on dates, Columns A and C, Table 3-2.*

Plants and algae remove DIN/NN 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 NN 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 3-3) 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 3-3, 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 3-3, row Feb. 19).

Proceeding in this way, 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 3-3. The total TOC to be expected at the Bridge site is the new "DIN-C" plus the existing "River TOC" (Columns B+J, Table 3-3). These totals are shown in Column JJ, Table 3-3.

It is likely that River water would pass through an 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 3-2) I calculated a "lag date" 15 days after the observation date (Column K Table 3-4). I estimated from scale measurements in Figure 3-3b (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 3-4). 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 Bridge 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 3-4.) The 15-day uptake values are shown in Column M, Table 3-4.

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 Bridge 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 Bridge 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 River TOC values observed (Table 3-2 Column B) on the observation dates (Column A, Tables 3-2 and -4) just before and just after each lag date. These interpolated values are shown in Column O Table 3-4. The total TOC expected at the Bridge Site is shown in Column P, Table 3-4 (= 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 Bridge 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 3-2.

Lake Case.							
A	D	K	L	M	N	O	P
Date of Observation	DIN observed River mg N/L	*Lag Date 15 days later*	*DIN in Lake 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 3-4. Values of DIN in Lake water at the Bridge site (Column L) on the "lag" dates shown (Column K), estimated from green graphs calculated by computer (in Figure 3-3b). Column M; estimated uptake of DIN during the 15 days in which the water flows from the River to the Bridge 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 3-2. Column P; total TOC to be expected at the Bridge site on each lag date (=Cols. N+O). Columns A and D are replicated from Table 3-2 for ease of visualization. See note in caption of Table 3-2 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.*

3d. Results. Estimating TOC from DIN Uptake.

The following graphs show data from these calculations.

For the estuary case, Figure 3-4 shows the amounts of NN observed in the river on the observation dates, the estimated levels of NN in the estuary as calculated by the computer, and the amounts of NN removed daily. Figure 3-5 shows how the levels of TOC that must be created by the daily uptakes of NN (that is, "DIN-TOC") compare with the TOC values presented directly by the modelers in their graph (Figure 3-3a). For the Lake case, Figure 3-6 shows how the levels of organic carbon created by 15-day uptakes of DIN compare with the TOC values presented by the modelers in their graph (Figure 3-3a). Figure 3-7 compares the modelers' graph with new organic carbon from DIN uptakes in the Lake with no 15-day lag.

In Figure 3-6 the upper line representing total TOC (DIN-C + River TOC) is the sum of values in Columns N and O, Table 3-4, for each lag date.

<u>3e. Discussion. TOC from DIN Uptake.</u>

The modelers have presented computer calculations of the nutrient N levels that would be present in the water at the Bridge Site for a Lake scenario and for an Estuary scenario (green and blue graphs respectively, Figure 3-3b). From that nutrient data I

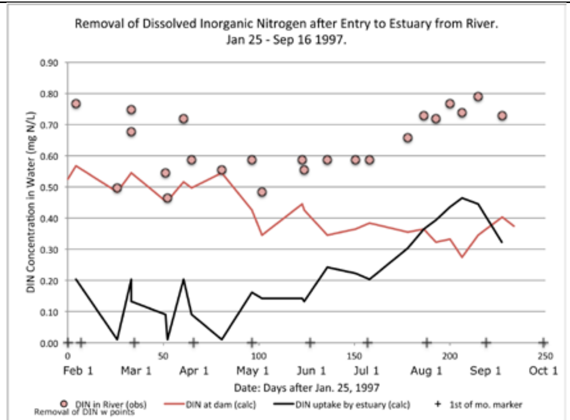

Figure 3-4. Estuary Case. Changes in Dissolved Inorganic Nitrogen, January 25 – September 9 1997. Data points are observed DIN values in the River (same as in Fig. 3-3b). Upper line is DIN in the estuary at the Bridge Site as calculated by computer (fits the blue graph in Figure 3-3b). Lower line is DIN removed from estuary on each date, found by subtracting the upper line value from the value of the data point directly above it. The lower line is DIN uptake, used to calculate DIN-C production.

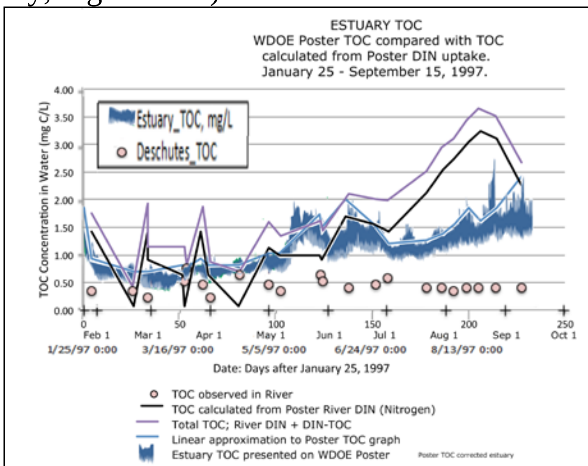

Figure 3-5. Estuary Case. Comparison of TOC created by DIN uptake with TOC presented by modelers. Data points show TOC observed in River (as in Figure 3-3a). Black line: DIN-TOC calculated from DIN uptakes (from Col. I Table 3-3, shown in Figure 3-4). Uppermost line; Total TOC in estuary (DIN-TOC + River TOC) at Bridge site. Background blue graph: modelers' calculation of Estuary TOC at Bridge site (as in Figure 3-3a).

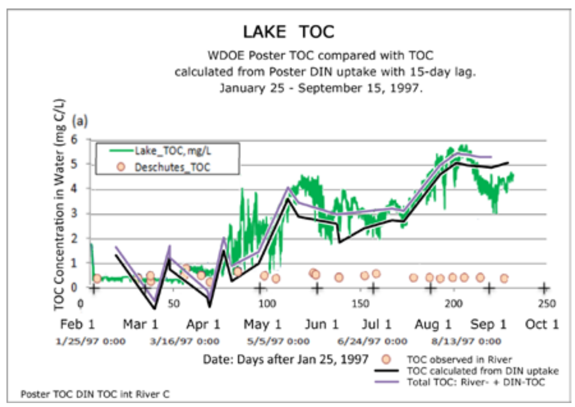

Figure 3-6. Lake Case. Comparison of TOC created by 15-day DIN uptakes with TOC presented by modelers. Data points show TOC observed in River (as in Figure 3-3a). Black line: DIN-TOC calculated from DIN uptakes (Col. N, Table 3-4). Uppermost line: Total TOC in lake (DIN-TOC + River TOC) at Bridge site. Background green graph: modelers' calculation of Lake TOC at Bridge site (as in Figure 3-3a).

have estimated the amounts of NN taken up by the plants in each ecosystem and hence the amount of carbon converted to new plant biomass for each scenario. In the estuary, the "plants" are either single-celled phytoplankton organisms or the cells of an alga mat on the intertidal mud. There is not much capacity there for carbon "storage." In those communities, cells are eaten and recycled almost as fast as they grow and there can be no huge buildup of immobile new carbon-containing biomass. In the lake, the plants are mostly big rooted floating entities that can store the new carbon they create for a whole summer – or even for years. Here, there is a huge capacity for carbon storage.

All of the new carbon created can be estimated from the uptake of DIN from the water in either ecosystem, no matter which types of plants are using it, from data taken from Figure 3-3b. When comparing that carbon creation with the values reported by the modelers in their separate calculation of TOC, strange discrepancies emerge. Those are, a huge amount of new carbon seems to be stored out of circulation in the estuary case (where one would expect none), and *none* of the newly created carbon seems to be stored in the lake case (where one would expect huge storage) throughout most of the summer. The following explores these findings.

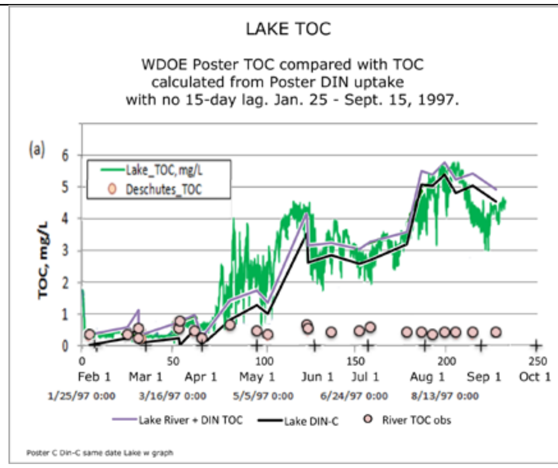

Figure 3-7. Lake case with no time lag. Comparison of TOC's created by DIN uptakes with TOC's presented by modelers. Same as Fig. 3-6 except that in this example there is no 15-day time lag between entry of DIN from the River and its appearance in the form of TOC at the Bridge site. The Total TOC line (upper, purple) differs in detail and position from its counterpart in Figure 3-6 because the two lines are calculated for different dates.

<u>1). Lake Case.</u> In Figure 3-6, the total amount of TOC that the uptake of nitrogen is capable of creating (black line) is less than the amounts shown by the modelers (green graph) during April and part of May. After that, the black line follows the green graph closely and the total TOC (purple line) fits the green graph even more closely. During the months of close fit, there is *no* storage of the newly created carbon compounds in the Lake. *All* of it shows up in the water as TOC.

Where the green graph is higher than the total (purple) line (mainly April and late May), the modelers' calculation shows more waterborne carbon-containing biomass (TOC) than capture of the waterborne nutrient nitrogen is capable of producing.

How can these fits and mis-fits be interpreted?

During the times when DIN-C + River TOC match the modelers' TOC graph (early May and again in June – August), *all* of the newly manufactured carbon that the captured DIN can produce ends up suspended or dissolved in the Lake water. There is none left over for long-term storage in large plants. To make that happen the modelers would have to assume that *all* uptake of NN in the Lake during that time is by phytoplankton, none is by large plants. In other words, the big plants simply don't grow during the summer. If their storage uptake were properly modeled and subtracted from the DIN-created amount of carbon that ends up as TOC, the "Lake TOC" in Figure 3-3a would be smaller – *much* smaller – than that shown by the modelers.

During April and part of May and also when the DIN-C values go briefly negative (parts of March, Fig. 3-6), the modelers' graph shows more TOC in the water than could be produced from the nutrient nitrogen consumed. Could this be TOC released from the early and late spring decay of overwintered material from large plants, produced and stored the year before? If so, one would expect, by way of compensation, less free-drifting TOC than could be created from the consumed nutrient nitrogen at some other time in the graph, when carbon storage occurs. In Figure 3-6 a hint of that "some other time" is seen in late August/early September, where the green graph drops below the black DIN-TOC line for the first time. Does the Lake begin to store new carbon-containing biomass at this time? (In a realistic scenario, storage would begin much sooner, probably before June 1.)

Unfortunately, the computer simulation stops at September 15. Nutrient nitrogen uptake, manufacture of carbon-containing plant material, and probably carbon storage certainly continue through September into October (as in Figure 3-1) but the model can tell us nothing about this. In any event, *if the departures of the green graph from the calculated DIN-TOC line really reflect release of TOC or storage of carbon, then they emphasize the positive effect of Capitol Lake on Budd Inlet*. That is, by the modelers' own calculations, storage of newly manufactured plant material (thus prevention of its entry to Budd Inlet) begins at precisely the time in late summer when the Inlet is most vulnerable to degradation by TOC. Similarly release of stored organic carbon from the Lake in the form of TOC in April and May is shown early enough in the growing season as to have no significant effect on Inlet water quality at that or any other time.

The "fit" of calculated DIN-C to the modelers' calculated values of TOC appears to be even better if one assumes that river NN is taken up and converted to new plant biomass immediately, which biomass then travels to the Bridge site in the lake all in the same day (Figure 3-7). This could only happen if all of the growing plants involved – phytoplankton and/or larger plants -- were to move down the Lake at water-ski speed as they grow, break up, then die and decay, arriving at the Bridge site in one day rather than making a leisurely 15-day drift. That appears to be an unlikely scenario, at best.

2). Estuary Case. The estuary case presents an opposite puzzle. At the heads of estuaries, almost all photosynthesis is carried on by single-celled phytoplankton organisms and by thin layers of algae on intertidal mud. Larger plants – green seaweed, kelps, brown rockweeds, eelgrass – are scarce or absent here. There is almost no capacity for carbon storage, since the phytoplankters and algal cells are eaten almost as fast as they grow, immediately recycling almost all of the NN they took up and the new organic carbon they created back into the water.

Yet Figure 3-5, comparing DIN-C with the TOC calculated by the modelers, shows much more organic carbon must be produced via DIN uptake than is shown by the modelers TOC graph from July 1 through September 15. There is so much "stored carbon" that, if it were all in the form of TOC *and shown in Fig. 3-3a*, the "estuary TOC" would be nearly as large as the "lake TOC" shown there during the summer.

3) Summary of Both Cases. Figure 3-8 summarizes the above discussion. As before, the green and blue graphs show levels of "Lake TOC" and "Estuary TOC" as calculated and presented by the modelers (Figure 3-3a above). The dark green- and blue- lines in Fig. 3.8 are the "Lake Corrected TOC" and "Estuary Corrected TOC" (purple) "Total TOC lines" in Figures 3-5 and 3-6 above, calculated by me.

Two additional lines are shown. The "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 would be the leftovers, whatever TOC is produced by all photosynthesizers during each 15-day interval less the 50% stored in plants. That is shown by the "50% Storage" line. Likewise the "90% Storage" scenario line shows the situation that would result if large plants stored 90% of all carbon in newly manufactured biomass.

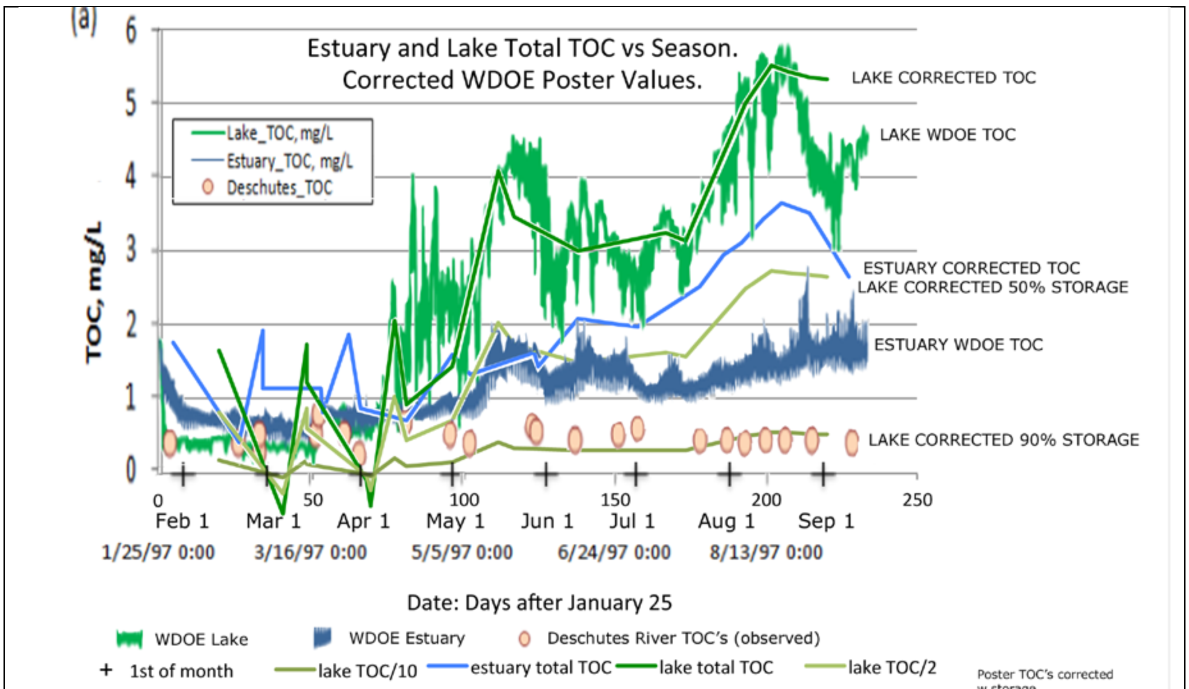

Figure 3-8. Summary. WDOE Poster TOC's compared with (my) corrected calculations. Data points for all Lake Corrected TOC's (points not shown but occurring at breaks in the dark- and light- green linear graphs) are for dates 15 days after the observed River data dates, reflecting the 15-day passage of 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 3-5 and 3-6), present at the Bridge site.

As can be seen, *if the large plants succeeded at 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 the (corrected) Estuary scenario.* My expectation is that the large plants would succeed at storing as much as 90% of all carbon in newly manufactured biomass (the 90% scenario).

It appears that the modelers ignored the large plants in their simulation of the Lake case and assumed that all of the NN uptake and carbon-producing photosynthesis was due to phytoplankton, most of the time. That would be a serious oversight. It also appears that something in their calculation "hides" a lot of the organic carbon created by NN uptake in the estuary case. That, too, would be at odds with what aquatic ecologists would expect to see in a head-of-estuary ecosystem. Absent a plausible explanation of these apparent flaws, the findings presented in their Figures 3-3a and -3b can't be taken at face value. *Nor can any other findings dependent upon accurate simulation of the Lake and Estuary scenarios (see below).* Lacking (and needed) are plausible presentations of the model's calculations of the new carbon stored by large plants *and animals* in the lake, the carbon present each day in phytoplankton, and for the estuary case, the carbon stored in the algal mat *and its animals* (mussels, barnacles) each day.

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 no 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. Perhaps the most aggravating omission from the entire SM Report is the deliberate omission of simulation of a harvesting program. Blithely assuming the role of harvesting experts, 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).

I expect that their guesswork is not the real reason why they didn't attempt such a simulation. The real reason, I expect, is that their Lake model is much too rudimentary to allow any meaningful simulation of a plant harvest. A Lake model like that mentioned in the previous paragraph would be needed – and they know it.

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 are not fully cognizant of the giant presence of macrophyte plants in the Lake (Havens pers. comm., 2015).

3f. How Would These Errors Affect Our View of Dissolved Oxygen in Budd Inlet?

The preceding section ends with a precaution that, due to seeming unrealistic features of the lake model scenario and unreported TOC in the estuary scenario, the TOC present in the Lake at the Bridge site during the growing season would probably be less than the TOC that would be present at that time and place if an estuary replaced the lake. That would translate as follows. Less TOC at the Bridge site from the Lake would mean less nutrient nitrogen release as that TOC material decayed in the salt water and less uptake of dissolved oxygen in the salt water by the decaying material itself. *The Lake, in other words, would have less adverse impact on Budd Inlet than would the Estuary*.

Figure 3-9 shows a Figure from the SM Report that might be regarded as the centerpiece of WDOE's entire effort to incriminate Capitol Lake (SM Report Fig. 16, p.39). This Figure shows calculated DO levels in the bottom water at six sites changing as the summer progresses, all dropping to lower levels if a Lake were present than they would if an Estuary were present. The physical basis for this would be the depletion of DO by decaying organic TOC material entering Budd Inlet at the Bridge site, and the release of nutrient nitrogen (with consequent phytoplankton growth and decay) from that same material, with the least effect caused by the scenario that delivers the lowest level of TOC to Budd Inlet.

In WDOE's Figure, the Lake gets the blame. But WDOE's calculations assumed no meaningful carbon storage in the Lake scenario and neglected to report all of the TOC formed in the estuary scenario (Figure 3-8). That almost certainly means that their Figure 16 (here, Figure 3-9) has got it backward; namely that the Lake's effects would result in higher DO's in Budd Inlet's bottom water than would an Estuary's effects (as suggested by the corrected key to Figure 3-9).

More is said about the movement of organic carbon between the Lake and Budd Inlet in another section. Here we have found reason to believe that the DIN graphs created by WDOE's version of the Budd Inlet Model reveal information about the TOC graphs (Figure 3-3 above) that invalidates the credibility of the agency's allegation that Capitol Lake degrades oxygen levels in Budd Inlet.

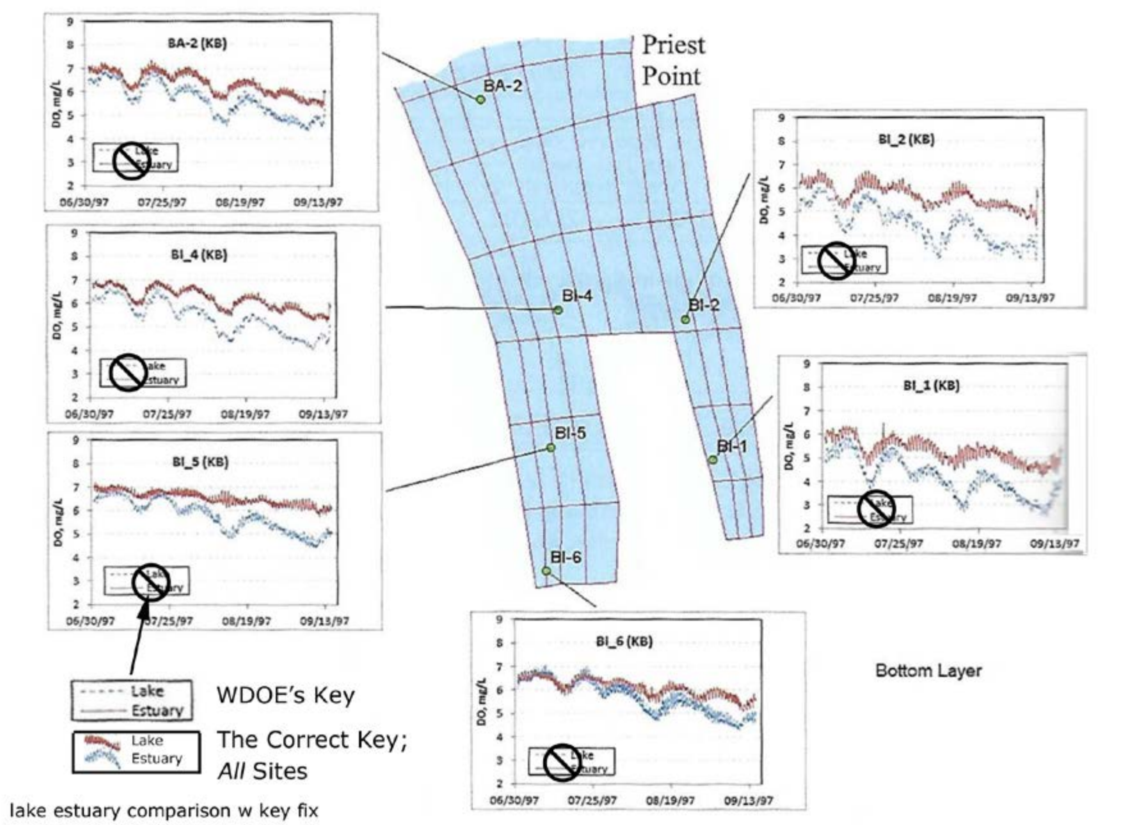

Figure 3-9. WDOE's computer calculations for six locations alleging that DO levels with the Lake in place (blue graphs) start dropping below DO levels that would occur if an estuary was in place (red graphs) at about the end of June. Lake case DO's everywhere are alleged to be about 1-2 mg/L lower than estuary case DO's by September (Modelers' Figure 16, p. 39 SM Report). The corrected key in the lower left corner suggests the positions of the Lake and Estuary graphs that would have been displayed in this Figure had WDOE used a simulation that reports all of the Estuary TOC and also a realistic simulation of carbon storage of Lake TOC (as in Figure 3-8, this Analysis).

SECTION 4. THIS PAGE DELIBERATELY LEFT BLANK …

This document was assembled piecemeal by sections. There was originally a Section 4. Little by little, parts of that section were shifted to other sections until, at final draft time, I realized that there was nothing left in the original Section 4. Rather than massively overhaul the Figure and Table numbers and references to other sections in all of the rest of this text, I simply left Section 4 blank.

Capitol Lake and Puget Sound.
An Analysis of the Use and Misuse of the Budd Inlet Model.

5. CAPITOL LAKE PROTECTS BUDD INLET'S WATER QUALITY.

The SM Report presents a barrage of allegations that all implicate Capitol Lake … or are claimed to implicate Capitol Lake … as an adverse adjunct of Budd Inlet. The main claim is that dissolved oxygen levels in Budd Inlet would be higher if the dam and Lake didn't exist. In reality, hidden among the data presented by the modelers and apparently overlooked by them is exactly the opposite conclusion – namely that DO levels in Budd Inlet would be lower today – probably *much* lower – if the estuary had never been dammed.

In this Section I examine a few lesser errors in the SM Report before analyzing the data that show the Lake's beneficial effect on Puget Sound.

5-a. Miscellaneous Unimportant Mistaken Claims.

Page 34 of the SM Report presents three claims that provide a written description of how the modelers think the Lake exerts its negative effect. They are:

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

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*)[1] with corresponding production of organic carbon alters discharges into Budd Inlet."

1) "Pulsed flow." The modelers don't define this for readers, nor do they say how "pulsed flow" alters circulation to the detriment of Budd Inlet. In this sub-section I explore this claim, with the observation that this is really not the reader's responsibility, the modelers themselves should have provided an explanation.

All estuaries experience "pulsed flow." Water exits seaward during ebb tides, usually at all depths, then reverses its movement and moves landward during flood tides, usually at all depths. Superimposed on this tidal movement is a persistent one-way incoming current along the bottom and a corresponding outgoing current at the surface. This is the crucial "estuarine circulation" that delivers dissolved oxygen to the bottom waters of Budd Inlet. That estuarine circulation is driven by the incoming flows of water from the Deschutes River and all of the creeks that enter Budd Inlet. "Pulsed flow" that "alters circulation" can only result from periodic modulation of (mainly) the Deschutes River discharge.

[1] Emphasis added …

Figure 5-1 shows the winter patterns of daily operation of two tide gates in the 5th Avenue "dam" for a 60-hour interval beginning at 00:01 AM March 9 and ending about noon March 11, 1997. The actual flows through the gates were not monitored during this time, and evidently cannot be reconstructed from any other data (BISS, 1998).

The tide gates are opened and closed 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 tide local tide level.)[2] 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 opening per day is needed in summer to maintain the Set Point water level.[3]

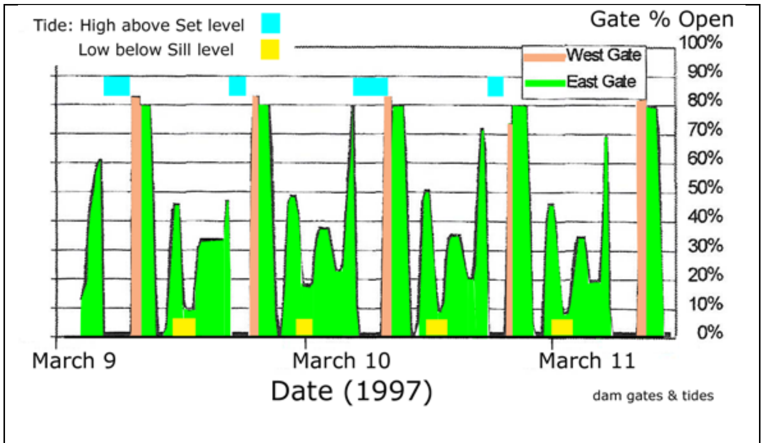

Figure 5-1. Operations of the East and West tide gates in the 5th Avenue dam during 60 hours from March 9 (00:01 AM) into March 11, 1997. Graphs show the durations of gate openings and the percent of maximum opening per incident. (The East and West gates are, respectively, 24 and 36 feet wide.) Blue bars are centered on the times when the high tides were above the Lake Set Level, yellow bars show times when the low tide was below the sill depth of the gates. The durations of the tide levels above and below those elevations are approximated by the widths of the bars. Source: BISS 1998.

This description of the tide gates' operation is as described for year 1997 (the Budd Inlet Model simulation year) in the BISS study (1998).

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 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 times.

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 alongside the tide gates at the east end of the dam. It is closed during the winter but is left open from Aug-

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[2] 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.

[3] The gates are below the observation deck where their operation can't be seen. A torrent of outgoing water on the Budd Inlet side is the main visible evidence that they are open.

ust through December to enable entry of salmon to the Lake. 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 "ladder" opening into the Lake can be seen by onlookers (Figure 5-2). Thus, from August through December there is never a time when ordinary tidal and river flow are completely blocked by gate closure.

To summarize, the tide gates briefly stop the river flow twice daily during the seven months January through July and restrict (but don't block) it during the five months August through December.[4] Since the river flow drives the estuarine circulation, what is the effect, if any, on that circulation?

Figure 5-2. Saltwater with jellyfish pouring over the fish ladder, entering Capitol Lake. (Flow into the Lake is toward the top of the figure.) November 21, 2015.

By analogy, it is as though you lift your foot from the gas pedal for a few moments while driving your car. The car starts to slow down. Then you depress the gas pedal below where you usually hold it, then ease it to let it return back to its usual position. The car momentarily speeds up faster than usual, then settles back to its average speed and stays there until your next adjustment.

By comparison with estuarine circulation, a moving car is a small fast-responding object that is tightly linked to the pedal position, its "driving" force. The estuarine circulation is the motion of a vast slow-moving body of water with enormous momentum, loosely linked to the very small driving force of the river.[5] If there is any "pulsing" of this moving saltwater by periodic slight modulation of the flow that is driving it, I expect that it would be so small as to be undetectable so long as the "pulsed flow" continued. Would there be any negative (or positive) effect on dissolved oxygen in Budd Inlet? I expect not, but in any case it is up to the modelers to describe "pulsed flow" and show readers of the SM Report why they allege that it is detrimental.

The designers of the original Budd Inlet Model considered the pattern of flow from the tide gates to be so irregular (and unimportant enough) 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. If so, could that artifact of the model be the

[4] The maximum amount of lake water that can depart via the salmon ladder (~ 51 cubic feet per second) is about half the amount carried into the Lake by the Deschutes River (~108 cfs in September during the river's low flow period. Hence the need to open the tide gates about once every day at that time.

[5] The estuarine surface current driven by watershed runoff is typically 10 to 50 times as large that freshwater runoff (in Budd Inlet, almost all of it from the Deschutes River). TMDL Appendix G, p. 49.

reason for whatever "pulsed flow" the modelers are seeing? 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 clarified by the modelers. And if it really causes problems, those could be fixed without removing the dam, simply by changing its operation to keep the output discharge the same as the river's input discharge at all times.

Figure 5-3 shows 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 is that important?

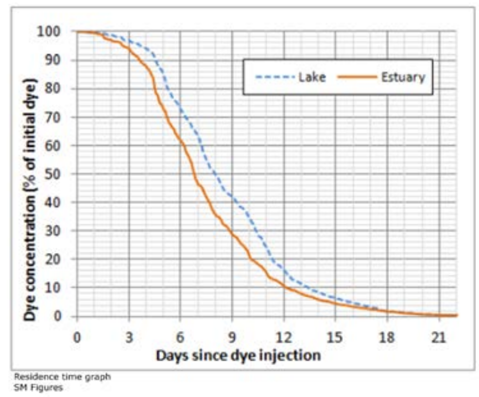

Figure 5-3. Simulated decline of a tracer dye released in bottom water, East Bay, with time. Source: SM Report's Figure 10 and Poster (2014). (The "e-folding time is mentioned in the Poster.)

The graph in Figure 5-3 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. No mention is made of how it relates to the "pulsed flow" claim. The graph shows the amount of dye that is still there 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 there in place of the Lake (y axis). (The modelers don't tell us the time of year when the release is made, an important oversight.)

The modelers used a calculation technique that is not appropriate in 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.) East Bay is not a "well mixed" system – it is a "two-layer flow-through" system with a net outgoing surface current driven by Moxlie Creek and an incoming bottom flow, ultimately from the Pacific Ocean, coupled by an ongoing rise of bottom water to the surface (that is, the "estuarine circulation").

Table 5-1 shows the "flow through" effect at station BI-1 (at the head of East Bay near the mouth of Moxlie Creek). Highlighted cells show the depths where DO levels were below the standard (4.8 mg/L) on August 20 and August 21, 1997. As can be seen, the rising tide of early morning August 21 brought in a bottom layer that slid under the layer of DO-deficient "violation" water present on August 20 and raised it toward the surface – the kind of flow-through action to which the "e-folding time" doesn't apply. 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.

As part of this discussion, the modelers state that increased residence time … "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. They forgot to mention that it 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.

How large an error is made by using the e-folding time to calculate the residence time of water in a flow-through system? 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 Report).

In summary, the "pulsed flow" and "increased residence time" claims are founded on very incomplete flawed and inadequate explanations.

Station BI-1	Time & Date, 1997	
DO's (mg/L)	23:36	5:29
Depth	Aug 20	Aug 21
(m)		
-0.5	4.79	4.14
-1.0	4.45	3.96
-1.5	4.64	3.96
-2.0	4.60	4.10
-2.5	4.96	4.22
-3.0	5.10	4.20
-3.5	5.04	4.34
-4.0	4.86	4.61
-4.5	4.74	4.86
-5.0	4.79	4.91
-5.5		4.90
-6.0		4.90
-6.5		4.90
-7.0		4.90
-7.5		5.02
-8.0		

Table 5-1. Dissolved oxygen levels at depths from the surface to the bottom. Station BI-1 (head of East Bay) August 20 and 21, 1997. Highlighted DO levels below 4.8 mg/L (WQ standard violation threshold) at the bottom Aug 20 are replaced by higher DO bottom water Aug 21. Source: BISS data.

2) "The dam and lake alter the concentrations and loads of carbon." Of course they do. The ways in which those alterations benefit Puget Sound are analyzed in Sections 3 and 6. Those alterations seem to benefit water quality in Budd Inlet.

3) "The dam and lake alter the concentrations and loads of nitrogen." Of course they do. The ways in which those nitrogen alterations benefit Puget Sound are also analyzed in other Sections.

5-b. Miscellaneous Puzzling Figures.

Beginning on page 31, the SM Report presents a barrage of Figures aimed at showing that "the dam" causes widespread DO depletion throughout Budd Inlet. As usually seems to be the case, the modelers' Figures raise more questions than they answer.

Regarding nitrogen, the modelers present three Figures using data from other sources. These are reproduced here. Two of them show nothing that supports their claims. The third 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 5-5 shows additional data included in the SM Report, equally devoid of anything that supports the modelers' claims.

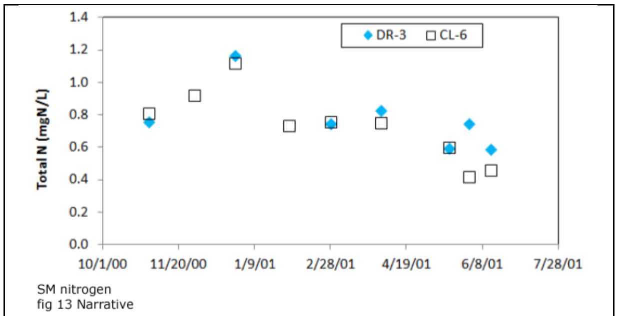

Figure 5-4. Modelers' portrayal of "total nitrogen" in the Deschutes River and at location CL-6 ("near the dam") vs. date in 2000. (Site CL-6 is not shown on an accompanying map of Capitol Lake.) Attributed to CH2M-Hill 2001 Source by SM Report.

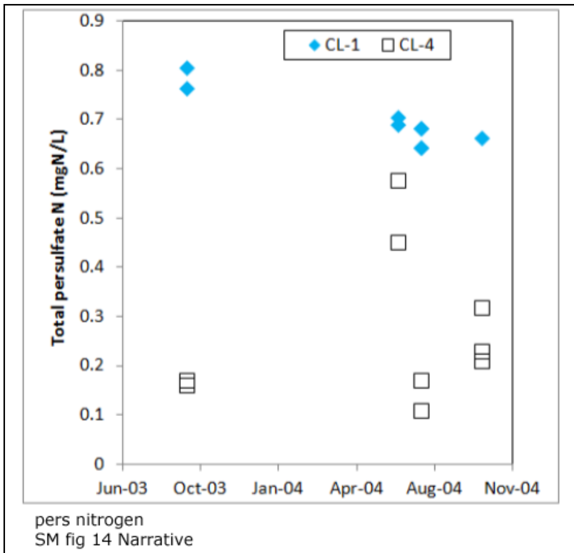

Figure 5-5. Removal of persulfate nitrogen from Lake water as the water moves toward the dam. Sites in Capitol Lake are CL-1 (near the entry of the Deschutes River to the Lake) and CL-4 (in the North Basin near the dam). Source: Roberts, Bos and Albertson, 2008, as cited in SM Report p. 37.

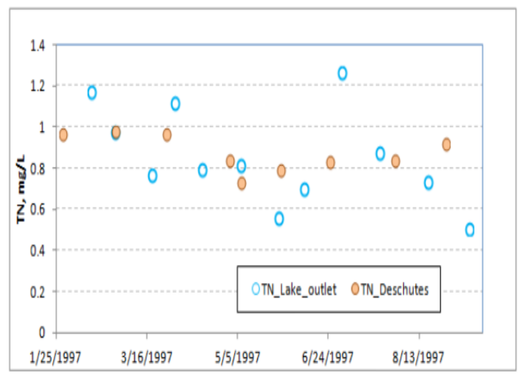

Figure 12. Total nitrogen concentration in the Deschutes River and at the location of the Capitol Lake outlet near dam during 1997.

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, including caption. Modelers' sources "Evans-Hamilton" and "Budd Inlet Scientific Study" are not cited in their References.

Figure 5-5 shows the concentrations of "persulfate nitrogen" (obtained via a technique that measures nitrogen in drifting bits of organic matter as well as the 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, and fall 2004. That is exactly consistent with what we already know about the Lake, namely that it removes nitrogen from the water as the water flows toward the dam.

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 during summer,

1997. Taken at face value, this contradicts the findings of other researchers but would support the modelers' claims if verified.

5-c. Where are the Estuary Data?

Figure 5-7a shows the modelers' portrayal of the theoretical water quality violations in Budd Inlet allegedly caused by "the dam" and also (Figure 5-7b) by all modern "anthropogenic" (that is, human-caused) agents of oxygen depletion. These Figures show that theoretical water quality violations occur throughout most of the modern Inlet. Figure 5-8 shows another example from the barrage of Figures shown on nearby pages of the SM Report. *All of the Figures presented in this format have colored DO scales in which dark blue is the smallest possible violation.* With that in mind, Figure 5-7a shows that the about half of the widespread theoretical violations "caused" by the dam are the smallest possible "violations."

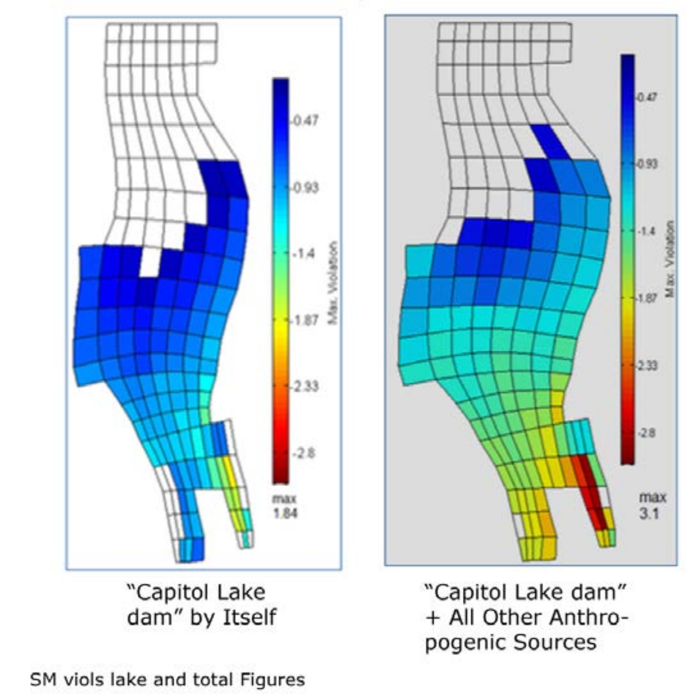

Figure 5-7. Figures from the SM Report showing theoretical widespread DO depletion in Budd Inlet due to (left) "Capitol Lake dam" by itself, and (right) "Capitol Lake dam" plus all other anthropogenic (modern) sources. The scale colors show the maximum theoretical violation in each cell. Source: SM Figures 9 (dam) and 8 (total), p 34 and 33.

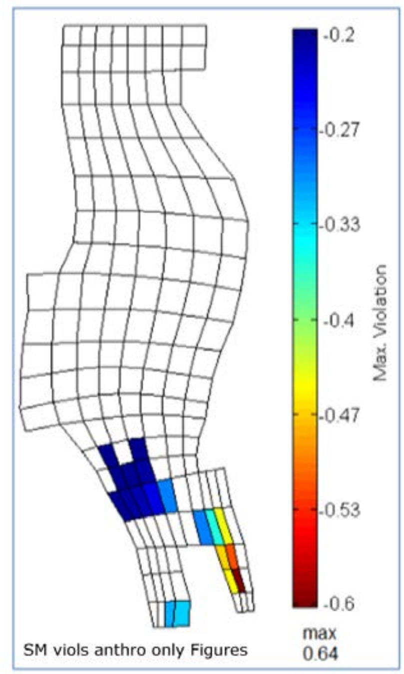

Figure 5-8. Portrayal of theoretical oxygen depletion alleged by the modelers to be due to "all anthropogenic nutrient loads with no Capitol Lake dam." Source: Figure 17 of SM Report, p. 40.

A puzzling feature of all of these graphs is that the captions assign the blame to "the dam" – not to "the lake." In Figure 5-8, this is especially puzzling. Does "with no dam" mean "estuary?" And if that Figure predicts the situation in a restored modern estuary, does it imply that the huge nutrient nitrogen load in the modern Deschutes River would have only the tiny localized effect shown? Or does the Figure show only the net effect of a creative interpretation of "anthropogenic?" Readers shouldn't have to wonder about interpreting the Figures. Nor should they have to resort to the following to get an unvarnished "big picture" of what the modelers are presenting.

1) Finding the 'Natural Estuary.' The most glaring of all omissions in the modelers' presentation is the apparent absence of an explicitly labeled Figure -- *in the format of Figures 5-7 and 5-8* -- that shows what theoretical water quality violations would be present if a modern-day estuary were to replace Capitol Lake and the dam. That would provide the quickest, easiest way for readers to see and compare the two options (a 'Modern Estuary' Figure with Figure 5-7b, say) and judge for themselves. Yet there is no such labeled formatted Estuary Figure in the entire Report.

There is, however, a way to reconstruct one, at least for the 'natural' pre-modern estuary. That reconstruction follows.

2) Methods and Results. Reformatting the 'Natural Estuary.' Figure 7 in the SM Report shows the minimum theoretical dissolved oxygen level for each grid square in the 'natural estuary' as calculated by the Budd Inlet model. That Figure is reproduced here as Figure 5-9[6] for readers' convenience in visualizing the method by which a re-formatted Figure (Figure 5-10) was constructed. Note that the colored scale of Figure 5-9 is visually similar to those of Figures 5-7 and 5-8 above (dark blue at the top, red at the bottom for those Figures), but Figure 5-9b's scale shows something entirely different – actual DO levels with the best water quality at the top.

The formatting procedure that I used is the same as the one by which the WDOE 'natural' estuary Figure was analyzed in another context in section 2, there to show the extent of Budd Inlet throughout which it is impossible to check up on the modelers' calculations. Here the procedure is described in detail.

I examined a full screen image of WDOE's 'natural' estuary portrayal (Figure 5-9b) using Photoshop software (Photoshop Elements 12 Expert Level). First I constructed a black-and-yellow scale bar with numbers and calibrated it by stretching it to fit the modelers' essentially unreadable color scale (see Figure 5-10a). I then used the "polygonal lasso" selection tool to carefully select the interior color of one grid square on the image in Figure 5-9b, 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.* The selected color on their scale always spanned a small range that could be measured with my calibrated scale. I hand-colored 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.

[6] This Figure was also used in Section 2 of this (my) Analysis, there as Figure 2-8.

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 squares, or appear as 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 square was selected I considered the whole square to be selected.

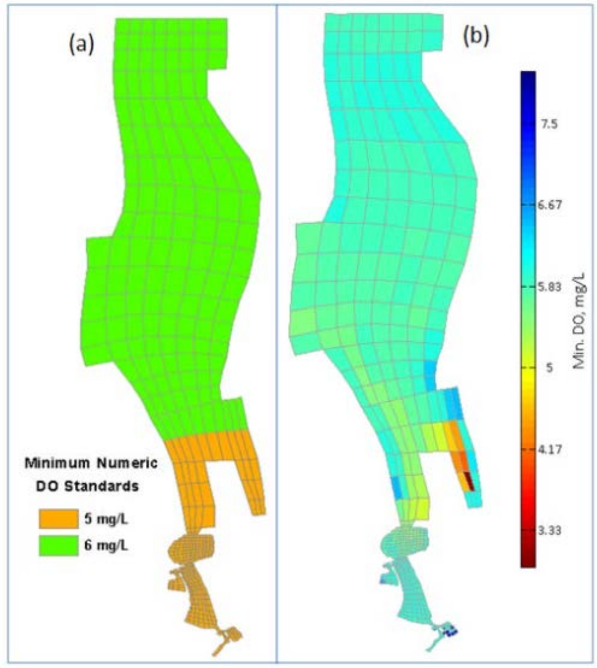

Figure 5-9 (a). Modern water quality standards that apply to Budd Inlet. (b) Minimum dissolved oxygen levels in Budd Inlet as calculated by the modelers for 'natural' waters before they were altered by human activity. (In Fig. 5-9b, the "Capitol Lake" area is an estuarine extension of West Bay.) Source: Both images constitute Figure 7 (p. 32) in the SM Report. Note the impossibility of judging the extent of standards violations in Fig. 5-9b by visual comparison with Fig. 5-9a.

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 Figure 5-9a), or whose mean DO's exceeded these limits (as explained below) were judged to be in compliance with water quality standards and were left uncolored in Figure 5-10b. Figure 5-10b is the end result of that process.

This procedure identifies the theoretical DO concentrations in the 'natural estuary' grid squares, not the sizes of the water quality standards violations. To convert the DO levels to "violations" I used the procedure shown in Table 5-2 (page 5-11). In the Table, Columns A and B show the upper and lower DO values of all selected grid squares grouped in "similar" batches as shown by my scale in Figure 5-10a. Column C shows the means of the numbers in A and B. Batches of selected squares with means greater than 5.8- (Central Inlet) or 4.8- (Lower Inlet) mg/L were considered to meet or exceed the standards; that is, "no violations" were assigned in those squares. Column D is the maximum size of the "violation" obtained by subtracting the lower DO value of each batch (in Column B) from the 6.0- or 5.0- mg/L standard for the Central or Lower Inlet areas. Column E shows the key colors assigned to the various violations. The vertical bar in Figure 5-10b uses those colors; the same colors with the corresponding DO limits of each batch are also shown at the bottom of the Figure.

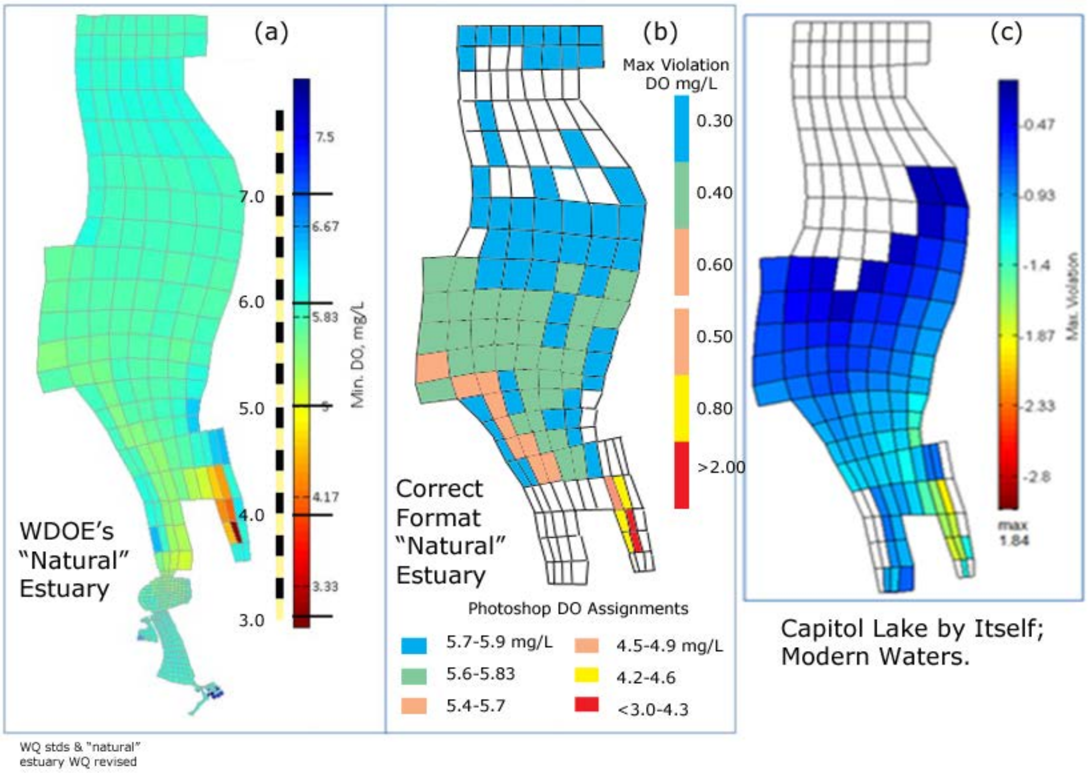

Figure 5-10. Budd Inlet 'natural estuary' theoretical water quality violations reformatted for comparison with alleged modern violations attributed to the "Capitol Lake dam." (a) Natural estuary theoretical DO minimum levels as presented by the modelers. (Black and yellow scale bar added by me.) (b) 'Natural estuary' theoretical violations formatted for visual comparison with the alleged Capitol Lake effect (Figure 5-10c). The key color DO ranges shown at the bottom of the central figure are from Columns A and B of Table 5-2; their corresponding "violations" are in Column E. Source: Figures 5-10a and 5-10c are from SM Report's Figures 7 and 9, pp. 32 and 34.

No attempt was made to include the Capitol Lake part of the "natural estuary." The grid squares are so tiny as to be indistinguishable and only vague washes of color are discernible there (Figure 5-10a) hinting at a null zone at the dam site but not interpretable.

The key colors used are not precisely the same as those of the modelers' scale (Figure 5-10c). As with the modelers, blue on the scale shows the smallest (near-zero) violations and red (not actually used by the modelers' in their Capitol Lake figure) shows the largest theoretical violations. The intermediate colors used by me were chosen to make the "violation" zones visually distinct in the 'natural estuary.' The exceptionally laborious nature of this Photoshop procedure required that I divide the inlet into the two zones with different water quality standards and key colors (Central and Lower Inlet, 6 and 5 mg/L respectively). Thus orange in Figure 5-10b shows the largest violations in the Central Inlet but also shows the smallest violations in the Lower Inlet.

3a) Discussion 1. Interpreting the Simulation of the 'Natural Estuary.' The modelers' discussion of their "natural estuary" findings is abbreviated. In fact, their entire discussion of Figure 5-9b (here same as Figure 5-10a) consists of just one sentence; "*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).

More accurately, that sentence should have read "The minimum DO under natural conditions is predicted to fall below the water quality standards in *most* of Budd Inlet, with lowest DO predicted in East Bay." The reformatted natural estuary simulation and comparison with modern Budd Inlet (Figure 5-10) tells us much more than that, as noted below.

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

Table 5-2. Conversion of the scale of Figure 5-10a (amount of oxygen in the water, mg /L) to the scale of Figure 5-10c (size of WQ '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.

Recall that all three of the images in Figure 5-10 are based on uncertain values. The computer often gets wrong answers in its calculations of DO's in grid squares (see Section 2) and there is no way to tell whether the computer got it right in any particular square or missed the mark. That is, the exact values shown in such Figures are not terribly trustworthy. But the value of a simulation is that it is broadly suggestive, not precisely predictive. That is, the overall visual impression – not the exact values of the numbers assigned to the squares – provides the "take home" message. *In this case, the main visual impression is that the 'natural' estuary has about as many and as widespread theoretical water quality violations as does modern Budd inlet with the dam.*

Another noticeable visual impression is that the 'natural estuary' doesn't have a low-DO null zone in West Bay, as would most real estuaries, modified or unmodified by human activity. The "Capitol Lake" part of WDOE's 'natural estuary' (Figures 5-9b and 10a) shows mostly blue high-DO water with only a visual threshold hint of an orange wash, essentially not interpretable. There probably was such a zone in the pre-modern estuary; if it was where Capitol Lake is now located, restoring the estuary would change that basin for the worse.

Another strong overall impression is that almost all of the theoretical violations in the 'natural estuary' and modern Budd Inlet are small – marginal – right on the edge of what we can measure. Individual calculations are not to be trusted, but when almost all of them are roughly the same, perhaps that is an indication that none of this is (from an ecological standpoint) worth worrying about. Neither is it worth worrying about from a regulatory standpoint; numbers from a computer are not real-world water quality violations.

3b) Discussion 2. The enigmatic puzzle of Figure 5-8. Why does Figure 5-8, showing the effects of "all anthropogenic nutrient loads with no Capitol Lake dam" show such tiny localized effects? The Deschutes River today almost certainly has much higher nutrient nitrogen levels than it did in the pre-modern past. If the dam were not present, that load of nitrogen would go full blast directly into Budd Inlet, creating as much plant growth (mainly in the form of phytoplankton) as it creates today in Capitol Lake, with consequent bottom water DO depletions. That would color most of Budd Inlet with "violations." Did the modelers subtract the "natural" NN load of the pre-modern Deschutes River from the modern real-life NN load and call the difference "anthropogenic" to get the tiny "anthropogenic effect" shown in that Figure?

Figure 5-7b supposedly shows the combined total effect of both the Capitol Lake dam and "all other anthropogenic sources" of oxygen depletion (in the Figures to the left and right of Figure 5-7b) on Budd Inlet. The "combined effects" Figure could not have been obtained by simply adding the data in the two Figures that flank it. "All anthropogenic effects" (Figure 5-8) shows no effect at all in West Bay, except for two corner grid squares. Capitol Lake by itself (Figure 5-7a) shows mostly tiny effects in West Bay, with grid squares along the west shore (same as in the "all effects" Figure) totally unaffected. Yet addition of the blank squares in both the "dam" and "all anthropogenic" Figures created theoretical violations throughout all of West Bay.[7] Elsewhere (say along the east shore of Central Budd Inlet) the total violation sizes are, according to their colors on the modelers' scale, greater than the sums of their parts. In addition the range of the area affected by both dam and "all other" sources has been extended northward from the limit "caused" by the dam by itself.

Figure 5-7b – "total effects" -- can't be obtained simply by adding the dam effects and the "all other anthropogenic sources" effects of the two Figures flanking it. Something else not explicitly mentioned has been added to produce Figure 5-7b. I speculate that the "something else" is the full sum total blast of nutrients from the Deschutes River, "natural" and "anthropogenic" (the amount used in creating Figure 5-8). But readers should not have to speculate about how the modelers arrived at their answers; the modelers should have made that clear.

[7] If certain squares had DO's barely above the standards – say, depleted by only 0.1999 mg/L, not technically "violations" – they would appear uncolored in the Figures. Addition of two such squares from Figures 5-8 and 5-7a could give a "violation" of up to 0.4 mg/L. The colors of the previously uncolored grid squares in Figure 5-7b usually show "violations" in excess of 0.4 mg/L, indicating that this mathematical accounting artifact is not the reason for "violations appearing out of nowhere."

What would a modern Estuary look like, formatted in the manner of the Capitol Lake Figures, with the full blast of modern-era "natural" + "anthropogenic" NN pouring into it? *The absence of a "modern estuary" Figure formatted like the other Figures is the most glaring omission from the entire SM Report.* The modelers didn't show us that, *and need to do so*.

<u>5d. Conclusions.</u>

The modelers have not shown us that Budd Inlet would be better off if the dam were removed. On the contrary, the information contained in this part of the SM Report strongly suggests the opposite. That is;

Budd Inlet in its "natural" pre-dam condition would have had as widespread water quality violations as it does in modern times with the dam and Capitol Lake in place.

Another way of phrasing that is this;

The dam and Capitol Lake have kept modern Budd Inlet at nearly the same overall level of water quality with regard to modern standards as would be present in the "natural" Budd Inlet of pre-modern times.

Or, *Budd Inlet's water quality is no worse today than it would be if the 'natural estuary' were here instead of the dam*.

However, there is no bringing back the 'natural estuary.' If the dam were removed today, we would have a 'modern estuary' loaded with Deschutes River N-nutrients. This would almost certainly cause serious low DO violations virtually everywhere. That is almost certainly the reason why the modelers didn't show it.

The dam and the Lake provide powerful protection of the Inlet's water quality from the anthropogenic effects of modern activities. Without the dam, it is to be expected that the condition of modern Budd Inlet would be much more degraded than it is today. That is to be expected, from the ecology of Capitol Lake behind the dam and its huge removal of nutrients from the Deschutes River.

6. THE LATE-SEASON DEPARTURE OF ORGANIC CARBON. AN ALTERNATIVE HYPOTHESIS.

6-a. WDOE's "Organic Carbon" Hypothesis and an 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.

WDOE's proposal is a valid scientific hypothesis. 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?)

In the spirit of good science, here is an alternative hypothesis. That is, 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. This hypothesis is that most of the organic matter that escapes from the Lake does so "later," not "sooner" as in Ecology's hypothesis. In the following, I cite evidence that this alternative hypothesis fits the facts better than the Department of Ecology's hypothesis.

6-b. Seasonal Change in Capitol Lake.

To people who visit Capitol Lake, the most familiar fact is that the whole Middle Basin and some 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 the 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. All of the organisms that respire in the Lake water as they consume this material prevent an equal amount of oxygen consumption in Budd Inlet. Their deaths and decay release the NN contained in them – but 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 recycles 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 everywhere. This giant submerged "forest" of plants (with over 50 times the biomass of the phytoplankton;[1]) gets "first dibs" on the NN in the river water moving through it and takes up about 58% of all of the NN delivered by the River (58% figure from Figure 34, CH2M-Hill 1978).

Several factors delay the escape of each summer's new plant biomass from the Middle Basin. The rooted plants stay put except for pieces that break off and drift around. 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 tend to hold the floating algae on 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 (which take up nearly 25% of the total NN delivered by the River) 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, 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 6-1). This effect of the wind probably keeps most of each summer's newly formed plant biomass in Capitol Lake until about October.

Figure 6-1. 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 key word. The Lake intercepts NN and uses it to build new plant biomass. If that new biomass is eaten or decays in the Lake, the NN released is again recaptured.

[1] The ratio "macrophyte carbon/particulate organic carbon" was calculated by me from Lake data for September 2004. POC values in mg/L concentrations were taken from Figures H13-H14, TMDL Appendix H by scale measurement and interpolation. (The graph "Matlab" 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 even greater; say about 100:1.

Its best opportunity to move into Budd Inlet is after September, October and November, when plant growth stops and NN, now delayed in its journey to the sea by weeks or months, finally escapes to Budd Inlet. Delay also results from the fact that escaping freshwater plant material is rich in cellulose, one of the most indigestible carbon compounds in nature. It can drift for a long time and distance before finally succumbing to the (mostly bacterial) processes that finally decay it.

Capitol Lake continues to take up NN well into October (see Figures 3-1, 3-2, and 6-3 below). After that time (I expect), plant growth ceases for the year, masses of senescent plant material break loose and (pushed by the prevailing southwest winds of that season), finally make their way into Budd Inlet (Figure 6-2). That is when (I expect) their decay begins to use up a lot of oxygen in the salt water.

Figure 6-2. Floating mats of Capitol Lake plants at the dam exiting to Budd Inlet. October 28, 2015.

This scenario is taken for granted by the authors of a consultants' report on results of a Lake drawdown in 1997 (Entranco, 1997). Their expectation is that "… decay of the plants and algae occurs over a 60-day period at the end of the growing season, and that 100 percent of the nitrogen and phosphorus contained in plant tissue is contributed to the water column at that time …" with this daily loading (2 kg P and 16 kg N) constituting only about 2% of the phosphorus contributed to Puget Sound by the river during this time. (The % contribution of nitrogen is not mentioned.) (Entranco, p. 28, 1997).

It is impossible to learn anything about this phenomenon from the Budd Inlet Model. As shown in Figure 6-3, the model's calculations stop on September 15. 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.

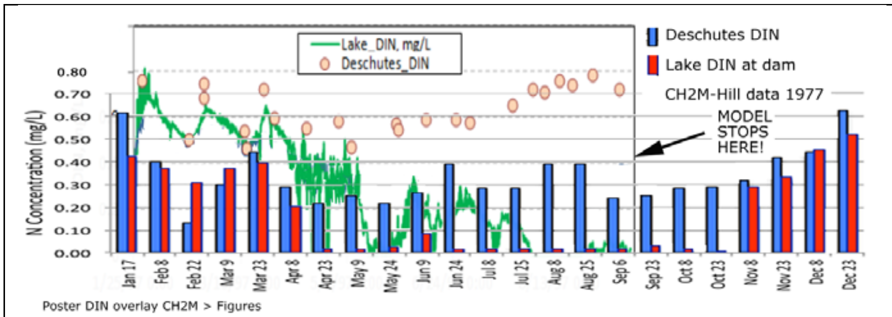

Figure 6-3. Budd Inlet Model prediction of Dissolved Inorganic Nitrogen (DIN) in Capitol Lake compared with observed data. Model simulation stops while DIN uptake in the Lake is still continuing through mid-September and October. Superposition of Figures 3-1 (1977 data, CH2M-Hill) and 3-3b (1997 Poster- and SM Report- data and graph in Organic Carbon section, Section 3.)

If "delayed release" of most of Capitol Lake's decaying 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. The picture is clouded by the fact that trees and other land plants shed their leaves at this time, around and into South Puget Sound. The plant material that enters the water virtually everywhere during the fall has the same effect on the dissolved oxygen of the whole Sound as would rafts of dead material from Capitol Lake.

How to sort out the Lake effect in Budd Inlet? My analysis is based on the circulation pattern of Budd Inlet and an assumption that the Lake's huge summer-long accumulation of aquatic plant matter driven by nitrogen from the Deschutes River briefly outweighs the autumn leaf-fall effects of trees along the River, smaller streams, and the shoreline of Budd Inlet in its relatively confined waters.

6-c. Background for a Test of the Alternative Hypothesis.

To investigate this hypothesis, I used 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 BISS data from fall, 1996.)

Figure 6-4 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; the tides simply move the whole pattern northward and southward. 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 pattern as "strong circulation." As can be seen from data in TMDL Appendix G2, water leaving Capitol Lake proceeds northward from the mouth of West Bay where it begins to influence this incoming stream (Figure 6-5). 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." By comparing the properties of the incoming and outgoing waters might we detect Capitol Lake's effect? (The "effect" we are looking for is a big drop in DO levels in the Inlet during October and/or November.)

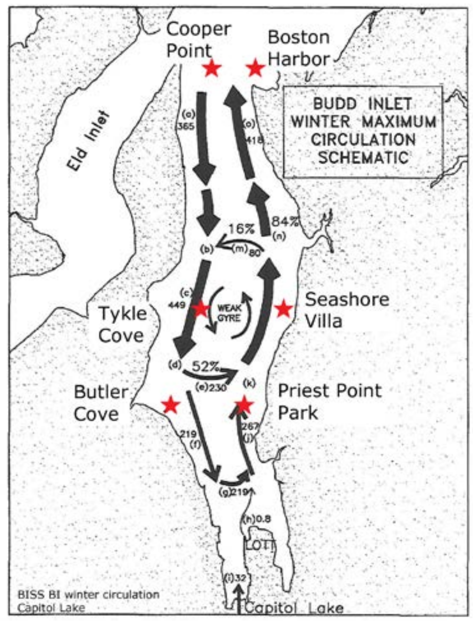

Figure 6-4. Circulation of water in Budd Inlet. Winter. Widths of arrows show sizes of flows. Stars show stations discussed in the text. Source: BISS 1998.

To anticipate the Results … no clear effect was detected.[2] But this comparison identifies something else quite remarkable that may be happening. That is, if most of the Capitol Lake biomass really does enter the Sound during October and November, it may decay without having any negative effect on Budd Inlet dissolved oxygen whatsoever. At that time, Capitol Lake organic carbon may run into the underwater equivalent of an "oxygen blast furnace" that disposes of it once and for all.

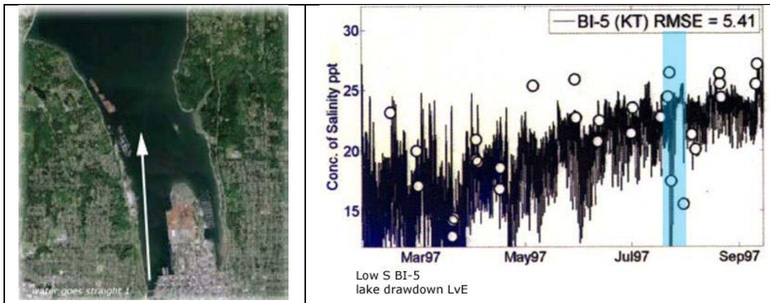

Figure 6-5. a) Direction of surface water movement from West Bay as indicated by data in TMDL Appendix G2. b) Example of Appendix data showing drastically reduced surface salinity at West Bay site BI-5 during dates of a massive freshwater discharge from Capitol Lake (highlighted). This pattern is strongly evident at BI-6 (near the dam) and weakly present at BI-4 (at the mouth of West Bay). There is no surface salinity decline at East Bay stations BI-2 and BI-1, nor is it detectable in the Appendix or BISS data at the BA and BB stations for these dates. [3]

6-d. Methods. The Search for a Late-Season Lake Effect.

The search for an effect is a three-part process, illustrated by the next three Figures. First, we examine the DO levels of representative stations BC-3 (Tykle Cove) and BC-1 (Seashore Villa) in Figures 6-6 and 6-7 at all depths, from surface to bottom.[4] We then examine fall season phenomena that affect mixing of the water from top to bottom. Finally, we directly compare the waters of stations BC-3 and BC-1 for insight on what's happening to dissolved oxygen in the Inlet.

Part 1. DO levels of incoming- and outgoing water in mid-Budd stations.

Figures 6-6 and 6-7 show DO levels at stations BC-3 (incoming water) and BC-1 (outgoing water) for dates from September 10 1996 through January 8 1997.[5] The incoming water shows less and less dissolved oxygen as the fall progresses, dropping to below the water quality standard for the BC-3 station by early November (6 mg/L; see Figure 5-9a).

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[2] After writing this, I continued to study the central Inlet seasonal oxygen pattern and concluded (late in 2016) that the changes in those waters really do show the effect I was looking for – massive decay of Capitol Lake vegetation starting in November.

[3] The only other graphs in Appendix G2 that show this lake effect are those for "CBOD," carbon biological oxygen demand. No observed data are shown in these graphs, only computer calculations. These calculations show the lake effect occurring strongly at stations BA-2 and BB-2, with a feeble hint of an effect at BI-2. This is useful as a trace of where the computer "thinks" the water from the Lake goes after it enters West Bay. That is, directly outward, not over toward East Bay.

[4] The names and positions of stations referred to in this section are shown in Figure 1-2 of section 1 and also in Figure 6-4, this section.

[5] Fall 1996 data are used for this analysis, since the BISS DO data don't show Late Fall 1997 DO's.

The outgoing water generally has slightly lower DO levels than the incoming water from September through mid-October, then switches over to higher levels in November. It is in November that we would look for a “decaying vegetation effect” due to Capitol Lake, namely a depression of DO levels. As shown in the Figures, we find the opposite – an increased DO level. Either there is no Capitol Lake effect at this time, or something else is happening that swamps it. A “something else” may be recognizable from the following.

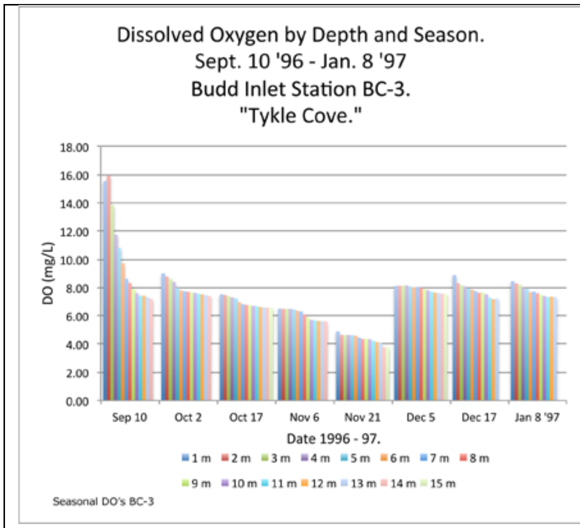


Figure 6-6. Oxygen levels in incoming water at the position of Tykle Cove, west shore of Budd Inlet. Each group of bars shows DO’s ranging from the surface (leftmost bar of group) to the bottom (rightmost bar) on one of eight different dates. Overall DO’s decrease from Sept. 10 through Nov. 21, then increase abruptly. Source: BISS spreadsheet 1998.

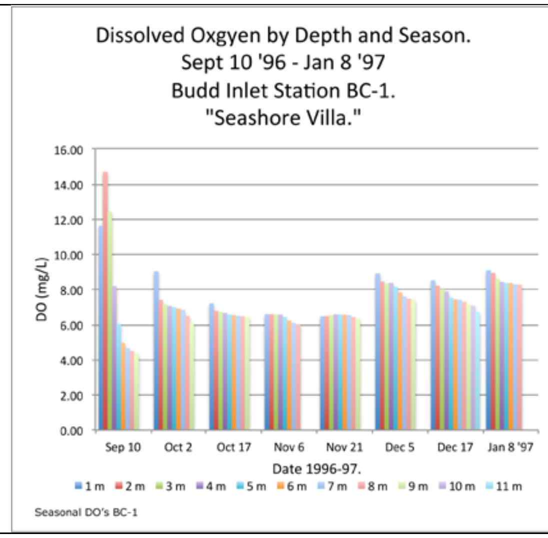
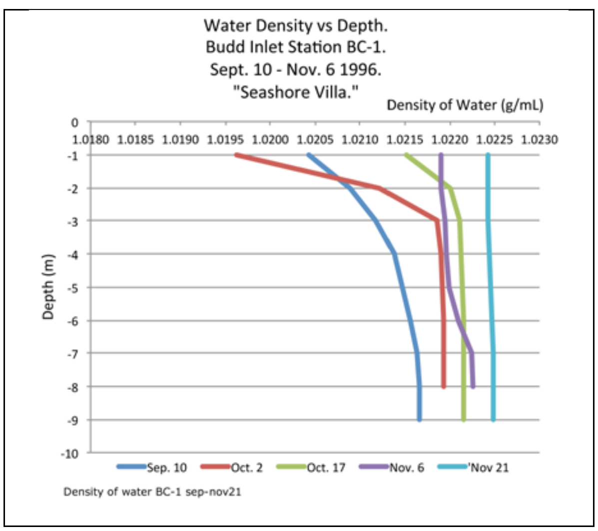


Figure 6-7. Oxygen levels in outgoing water at the position of Seashore Villa, east shore of Budd Inlet opposite Tykle Cove. Oxygen levels are less in deep water at BC-1 than at BC-3 in September, then about the same as at BC-3 on dates Oct. 2 – Nov. 6 on the west shore, then jump up rapidly after Nov. 21. Source: BISS spreadsheet 1998.

Part 2. Oxygen Uptake from the Atmosphere in November.

Figure 6-8 shows the change in stratification of the water along the east shore of Budd Inlet at station BC-1 (Seashore Villa) from September 10 through November 21, 1996. The water is strongly stratified in September and even more so in early October due to reduced salinity at the surface (not shown here). The effect is to isolate deeper water from contact with the atmosphere, enabling oxygen-consuming processes to deplete DO levels in deep water. By November 6, stratification has mostly disappeared (due to cooling at the surface) and the water is well mixed from surface to



near-bottom. The effect is now 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 at this time, this huge seasonal re-oxygenation of water from the atmosphere would probably 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.

Figure 6-8. Density of water vs. depth at Budd Inlet station BC-1, Sept. 10 – Nov. 21 1996. Source: BISS spreadsheet 1998.

Part 3. Massive Re-Oxygenation of All Depths in Budd Inlet in Late Fall.

Figure 6-9 shows a view of this reoxygenation process in action. In this 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 removal of oxygen from the water is very strong in September, moderate through October, and near zero (no change) on Nov. 6. On November 21, a startling surge in reoxygenation of the water at all depths takes place. Afterward oxygen is lost from the water in small amounts through December, then regained in small amounts in January 1997.

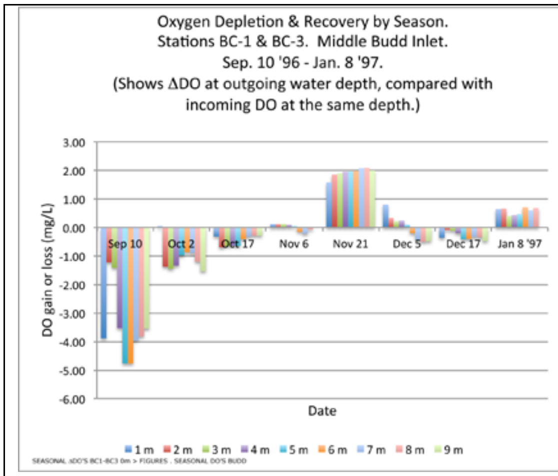


Figure 6-9. Changes in oxygen levels in water at all depths between entry to Budd Inlet (BC-3, Tykle Cove) and exit from Budd Inlet (BC-1, Seashore Villa). Bars show (DO at BC-1) minus (DO at BC-3) for water of the same depth, both stations. Negative values show loss of oxygen from water, positive values show gain of oxygen by water. Loss continues through October, large uptake occurs in November, little change occurs afterward.

Comparisons between stations BB-1 and BB-3 (KGY area) and BF-1 and BF-3 (Boston Harbor area), not shown here, show the same patterns. Comparisons in which the water at each depth on the east side is compared with the water one meter deeper on the west side, also not shown here, also show this pattern. This appears to be a general pattern of oxygen exchange throughout Central Budd Inlet.

6-e. Conclusions. The Search for a Late-Season Lake Effect.

The alternative hypothesis – most of the organic carbon that escapes from the Lake leaves and decays late in the growing season (September – November) is "not supported" by these data. But neither is the hypothesis disproved. It is possible that the rush of atmospheric oxygen back into the water in November swamps the predicted effect. The stream of water shown exiting Capitol Lake (Figure 6-4) (volume 32 m^3/sec) mixes with an incoming stream whose volume is 219 m^3/sec – that is, nearly seven times the size of the stream carrying the organic matter from the Lake. This may dilute the Lake effect beyond recognition in the BISS data. Or perhaps there really is no Lake effect at all during the fall.

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 – and only a field study can answer these questions -- would be decisive for determining whether organic matter from Capitol Lake is – or is not –having an adverse impact on Budd Inlet.

7. CAPITOL LAKE: ERRORS AND MIS-CHARACTERIZATIONS.

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 in Figure 7-1 below. (The original first appearance of this image was in 2012 in the TMDL Report, there shown as Figure 92.) Wherever this image appears in the SM Report, the caption refers to "oxygen depletion" in Capitol Lake. As I show in the following, there is *never* any meaningful, real-life oxygen depletion in Capitol Lake, and even the theoretical "depletions" shown in this image are grotesquely in error.

7-a. There is *No* "Oxygen Depletion" in Capitol Lake.

A few introductory words on how lakes (and marine waters) become oxygen-depleted are in order. The oxygen depletion story begins with the addition of excess nutrients (usually nitrogen and phosphorus) to the water. There they fuel the rampant 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 oxygen in the bottom water. This process is well known to aquatic ecologists.

The result of this process is shown in Figure 7-2, 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 of sinking plant matter by the bacteria there.

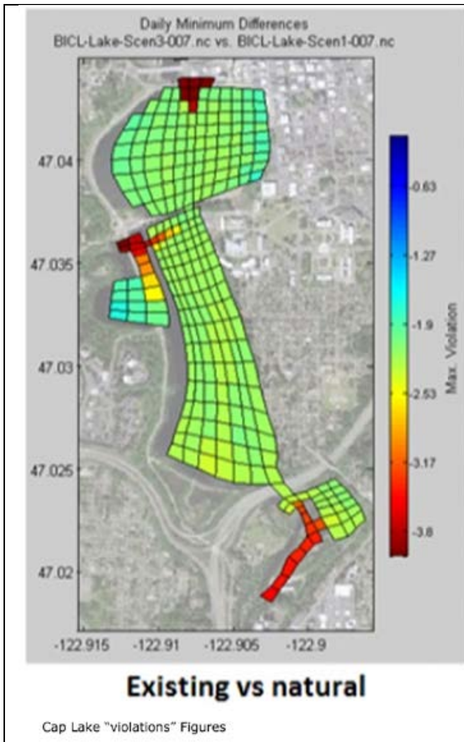


Figure 7-1. Output of the Ecology computer model that portrays all of Capitol Lake in significant "violation" of some dissolved oxygen water quality standard. Source: SM Report p. 60.

Figure 7-3, 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 7-4) 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).

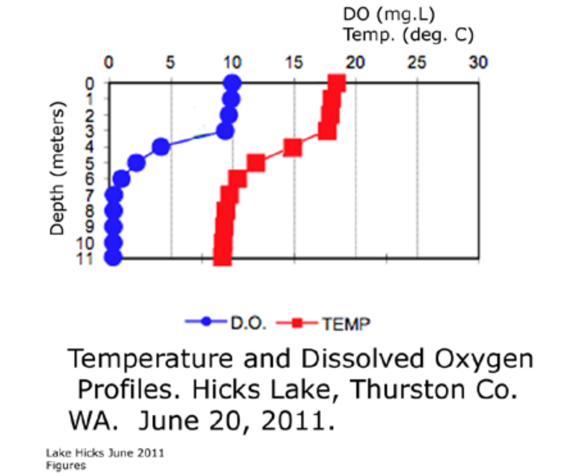


Figure 7-2. Change in dissolved oxygen and temperature with depth, Hicks Lake, Thurston County, June 20 2011. Source: Thurston County Water Resources Report 2012. (The TCPHSS original Figure has been simplified by removal of vertical profiles of pH and conductivity.)

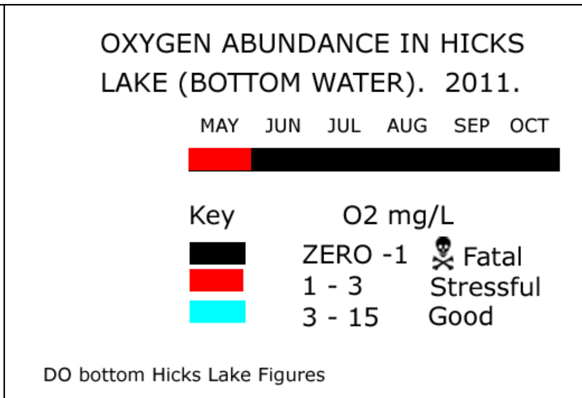


Figure 7-3. Dissolved oxygen in the bottom water of Hicks Lake, May – October 2011. Source: TCPHSS 2012.

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

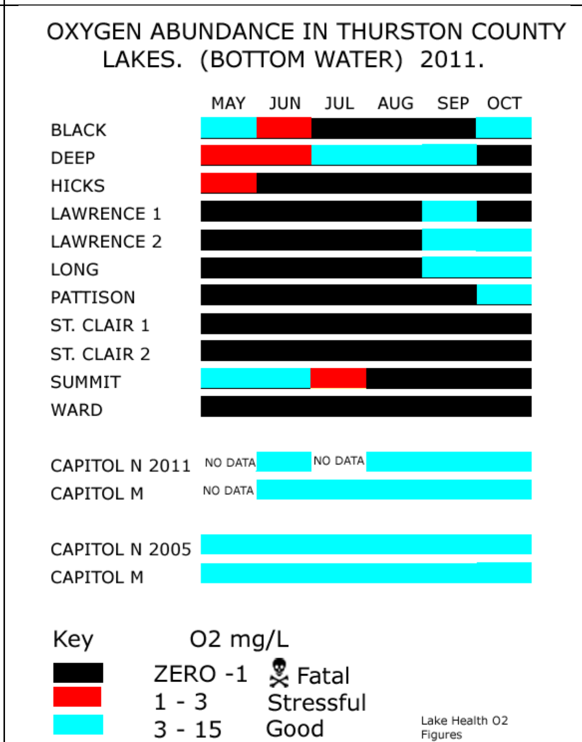


Figure 7-4. Seasonal bottom water DO concentrations in 10 monitored Lakes in Thurston County in 2011. Source: TCPHSS Report 2010-12.

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 7-5 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).

There is *never* a real-world problem with "oxygen depletion" in Capitol Lake. The modelers' use of that term is misleading and should be discontinued. The term they should use is what they actually mean, that is "Theoretical Water Quality Standards Violations."

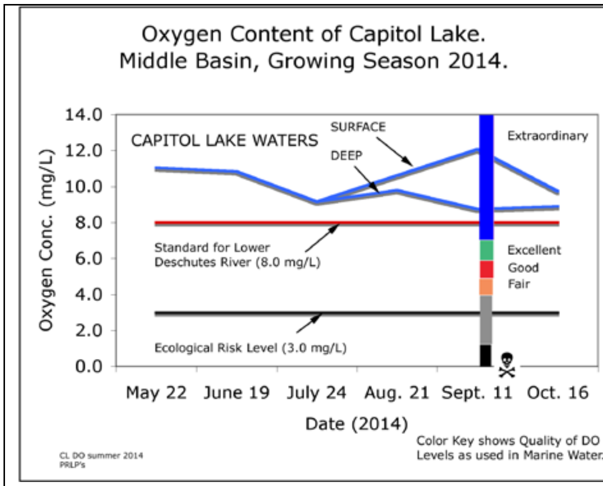


Figure 7-5. Real-world Capitol Lake dissolved oxygen levels, 2014. Measured DO levels of Capitol Lake (upper lines), May – October 2014, Middle Basin. Water quality standard for lower Deschutes River (8.0 mg/L) and low-DO ecological risk level (3.0 mg/L) are also shown. Water quality labels used to describe DO levels of various amounts are shown on colored scale. Sources: TCPHSS 2012-14; Ahmed et al 2013; Vaquer-Sunyer and Duarte 2000.

<u>7-b. Phosphorus Levels are Irrelevant in Capitol Lake.</u>

The SM Report devotes considerable space to a discussion of phosphorus nutrients in Capitol Lake. While that is of interest, that is irrelevant. Phosphorus inputs to Capitol Lake are high, as they are in several other County Lakes.[1] This common affliction has little to do with Capitol Lake's relationship with Budd Inlet.

Phosphorus nutrients, as do nitrogen nutrients, support plant growth in Capitol Lake. So much plant growth occurs there, in fact, that the Lake is classified as "Eutrophic." The term has a negative connotation, mainly because eutrophic lakes often have the kinds of oxygen-depleted bottom waters that occur seasonally in most of our area lakes, other than Capitol Lake (as in Figure 7-4). That negative connotation is not applicable in this case. Nevertheless it is used by the modelers to brand Capitol Lake as somehow impaired. Two of the SM Report Figures (Figs. 37 and 38, not reproduced here) aim to show the seeming hopelessness of removing Capitol Lake from the "Eutrophic" category by dredging as a way of reducing phosphorus loading. That is probably true, but it is of no significance.

Phosphorus nutrients consist almost entirely of phosphate ions, PO_4^{3+}. Unlike the nitrogen nutrients, phosphate is removed from lake water by chemical combination with ele-

[1] Five local lakes (including Capitol Lake) are listed by the EPA as "Clean Water Act Category 5 impaired waters" requiring remedial attention to elevated phosphorus levels. (The other four are Long, Lawrence, Pattison and Black Lakes. Source: WDOE 303d List).

ments in the sediments (mainly iron). For as long as the bottom water is oxygenated, the phosphorus stays trapped in the sediments. For Capitol Lake, that is all year long. When more typical eutrophic lakes go anoxic at the bottom, the ferric compound that bonds the phosphate ($Fe_3(PO_4)_2$) becomes a ferrous compound and liberates the bound phosphate, which escapes back to the water column. The escaped phosphate eventually returns to the sediments later in the year, but before that happens some of it fuels the luxurious growth of plants and phytoplankton for which eutrophic lakes are noted. This is probably the case for the lakes listed in Figure 7-4 above – but not in Capitol Lake.

There is no discussion in the SM Report of how reducing nitrogen nutrient inputs would affect the lake and, by extension, Puget Sound. Unlike the situation in other eutrophic lakes, nitrogen – not phosphorus -- is the limiting nutrient in Capitol Lake (CH2M-Hill 1978; see also Figures 23 and 24, TMDL Report). Capitol Lake is one of the few area lakes that doesn't support a significant population of blue-green algae, the biotic creators of nitrogen nutrients that eradicate nitrogen shortages in those other lakes and make phosphorus the key to their rampant plant growth.

The myopic focus of the SM Report on the hopelessness of changing the eutrophic classification of the Capitol Lake (pp. 65 and 66) and the impossibility of changing its "oxygen concentrations" by changing its phosphorus budget (p. 68) is a tangential distraction that misses the point. Nitrogen is the key to the Lake's ecology and its powerful role as a protector of Puget Sound – phosphorus has little to do with it.

7-c. Dissolved Oxygen "Deficiencies" in Capitol Lake Were Calculated Incorrectly.

1) Background for the *Correct* Calculation.

Repeated mention is made 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 (Figure 7-5). 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 the same Violations Happy Hunting Ground that we encountered in Section 2 -- the computer "cyber space" that simulates the "natural conditions" of a water body and then compares them with its simulated modern conditions.

The "violations" obtained by the Model from the "natural" water comparison 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 7-1). How does this relate to the Lake that we know? Some 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 WQ 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 were in the Lake before the modern era. There is a difficulty here in that the Lake didn’t exist in pre-modern times, but it is easy to envision one such impoundment formed by natural causes (say, 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 end of the computer modeling story.

A dammed reservoir can be defined as a “lake,” however, 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,[2] 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.”[3]

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 in the Lake 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. Since lakes don’t have fixed modern standards, this opens the gates to the Violations Happy Hunting Ground for the whole lake, every location, every moment, every depth. Figure 7-1 above, showing every location in this 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 initial condition.[4]

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

[3] 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 should be expected only once in every 47 years – a complication that suggests that this frequently-recurring modern condition is only tentatively comparable with typical past ‘natural’ conditions (Orsborn and others, p. 45).

[4] [Due a formatting difficulty this footnote is on the following page.]

An important drawback of using ‘natural’ conditions to find DO “depletions” in modern water is that it is almost always impossible for some third party 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. Whether the water was more or less saturated 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 (the “red zone,” Figure 7-1) back when the river is said to have been 3°C cooler and compare them with the modelers’ grotesquely mistaken findings.

2) Methods. Checking The Dissolved Oxygen Calculation.

Figure 7-6 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°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 acquire via contact with the atmosphere if its temperature is 8.64°C to become 100% saturated.

[note 4 p. 7-5] The full text 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).)

I used the nomograph to calculate the sizes of the "violations" of DO standards for five dates in the river's 'natural' past. Table 7-1 illustrates the procedure and the values obtained.

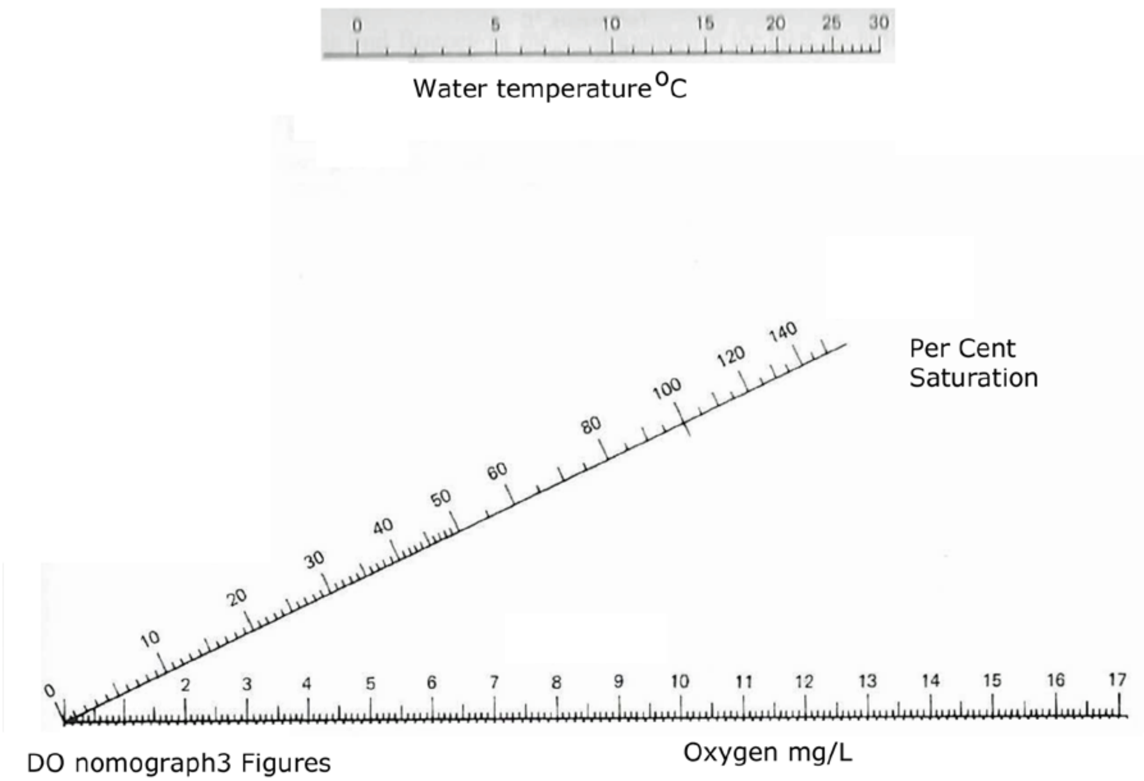

Figure 7-6. Nomograph for determining the amount of dissolved oxygen in fresh water at full (100%) saturation, using the temperature of the water (at sea level atmospheric pressure). Full (100%) saturation is the amount that the water acquires via contact with the atmosphere with no additions from plant 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.

The calculation begins with observed modern water temperatures and DO's for the River water as measured in Tumwater Falls Park, a location below the Falls that is marginally the southernmost part of Capitol Lake (2010 data, TCPHSS 2012, Columns A, B and C, Table 7-1). I used the nomograph to confirm that these modern values are at or near 100% saturation (Column D). Column E shows the 'natural' temperatures that the modelers would assign to the pre-modern era, namely temperatures 3°C lower than those in Column B. Column F shows the dissolved oxygen levels that would have been present if the water were 100% saturated with oxygen at the 'natural' temperatures. Because of the colder 'natural' water, these levels are higher than the modern levels. The differences are shown in Column G. 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 H.

A	B	C	D	E	F	G	H	
				Temp-3	100% sat	difference	"violations"	
Date	Temp	DO	% sat.	=B-3	DO @T-3		G-0.2	
(2010)	(°C)	(mg/L)		(°C)	(mg/L)	(mg/L)	(mg/L)	
Apr 19	11.64	10.24	98	8.64	11.35	1.11	0.91	
May 10	11.64	10.18	97	8.64	11.35	1.17	0.97	
Jun 15	11.92	10.37	99	8.92	11.20	0.83	0.63	
Jul 12	15.83	ND	-	-	-	-	-	
Aug 16	16.58	9.31	98	13.58	10.05	0.74	0.54	
Sep 13	13.27	9.52	95	10.27	10.40	0.88	0.68	

Table 7-1. 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. (Source: TCPHSS 2012.) Column D; percent DO saturations of observed waters (Cols B & C) from nomograph. Column E; 'natural' water temperatures (Col. B values minus 3°C). Column F; DO's at 100% saturation using 'natural' temperatures in Col. E from the nomograph. Column G; 'natural' DO's minus observed modern DO's (Col. F values – Col. C values). Column H; sizes of the DO "violations" (Col. G values – 0.2 mg/L). Grey shows nomograph calculations, yellow shows worst case "violation," 'natural' vs modern, in Col. H. (Observations were apparently attempted on July 12 but no data are listed in the source.)

<u>3) Results. The Corrected Dissolved Oxygen Calculations.</u>

As can be seen from Column G of Table 7-1, the largest difference between the DO levels of modern waters and 'natural' waters at 100% DO saturation would be about 1.17 mg/L, using 2010 observed water temperatures and DO's. The theoretical water quality "violation" on that date would be about 0.97 mg/L (Column H). The modelers' depiction of Capitol Lake (Figure 7-1) shows "violations" of about 4 mg/L in the 100%-saturated area – roughly four times the size of the one calculated here. Their calculation is in error for the south end of the Lake.

Suppose that the modern oxygen contents of the southernmost waters of Capitol Lake are really 4 mg/L below the 'natural' summertime levels that prevailed in pre-modern times. How cold would the 'natural' waters have to be, to hold that much more oxygen at 100% saturation? Table 7-2 shows a calculation of those 'natural' summertime water temperatures. Columns B and C are observed modern values as in Table 7-1. Column I shows how much oxygen the 'natural' water would hold if it had 4 mg/L more than at present. Column J (from the nomograph) shows the 'natural' water temperatures that would be needed for the pre-modern waters to hold 4 mg/L more oxygen than at present. Those 'natural' waters would need to be close to (or at) freezing levels to hold that much oxygen at 100% saturation.

4) Discussion. The Lake's Theoretical Water Quality Violations are Tiny or Nonexistent.

The modelers' depiction of DO "violations" (Figure 7-1) 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 initial conditions (thus creating the same errors) 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 the deep hole in the bottom to hold as much DO as the fresh water overlying it, compounded by the modelers' assumptions about past river temperatures.

A	B	C	I	J
Date (2010)	modern Temp (ºC)	modern DO (mg/L)	assumed natural DO (C+4) (mg/L)	natural Temp (ºC)
Apr 19	11.64	10.24	14.24	0.00
May 10	11.64	10.18	14.18	1.00
Jun 15	11.92	10.37	14.37	<0
Jul 12	15.83			
Aug 16	16.58	9.31	13.31	2.50
Sep 13	13.27	9.52	13.52	2.00

Table 7-2. Pre-modern ('natural') water temperatures needed to hold 4 mg/L more oxygen than modern waters at 100% saturation. Columns A, B, C observed modern data as in Table 7-1. Column I; DO levels higher by 4 mg/L than modern levels (C+4). Column J; 'natural' water temperatures needed to hold the amounts of oxygen in Column I at 100% saturation. Grey column is calculated from the nomograph.

Throughout the rest of the Lake, the green areas (Figure 7-1) show the success of plants at raising the water's dissolved oxygen level and reducing the sizes of the 'violations' shown by the modelers. There the per cent saturation of the water is unknown and unknowable and the nomograph correction can't be applied.

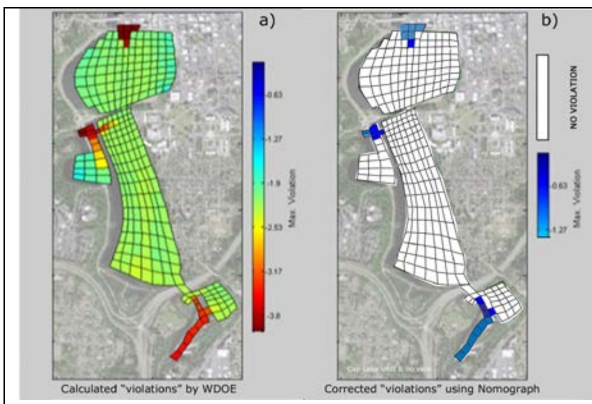

Figure 7-7. Theoretical WQ standards violations in Capitol Lake as calculated by the WDOE computer model (left) and as recalculated by the author using a nomograph (right). The value in each "blue zone" (right) is the violation calculated in Table 7-1. The "red zone" (left) violations are in error by about 3 mg/L. All other calculated violations 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.

The violations shown by the modelers in the red zones are some 3+ mg/L higher than are indicated by the nomograph calculations. If the same absolute errors characterize the green zone (that is, 3 mg/L higher than "real" or "likely" over most of the Lake), then its "violations" would appear as shown in Figure 7-7b.

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 and (almost always) higher than the adjacent salt water DO levels at their highest.

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If possible, it is most instructive to read the most recent Capitol Lake chapter in TCWR available (at the time of this writing, 2014). The descriptions include recent developments which are updated yearly. (TCPHSS = Thurston County Public Health and Social Services Department.)

WDOE List. 2015. The following enables a user to identify water bodies designated as "303d" in accordance with the Clean Water Act of the EPA. Using the Google search tool, 1) enter ("Google") < *Water Quality Assessment and 303(d) List* >. A page of choices appears. 2) On that page select ["click" and Return] *Water Quality Assessments (303[d]) Water Quality …* A Department of Ecology page comes up. On it "click" on *Current EPA-Approved Marine Assessment and 303(d) list* . 3) On the page that comes up, click on the Map icon. On the map that comes up, enlarge the view over the Capitol Lake area. As the view approaches the ground, the water bodies (including Capitol Lake) with 303d listings are shown in red. Click on any of the red water bodies for details of their listings.

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Capitol Lake and Puget Sound.
An Analysis of the Use and Misuse of the Budd Inlet Model.

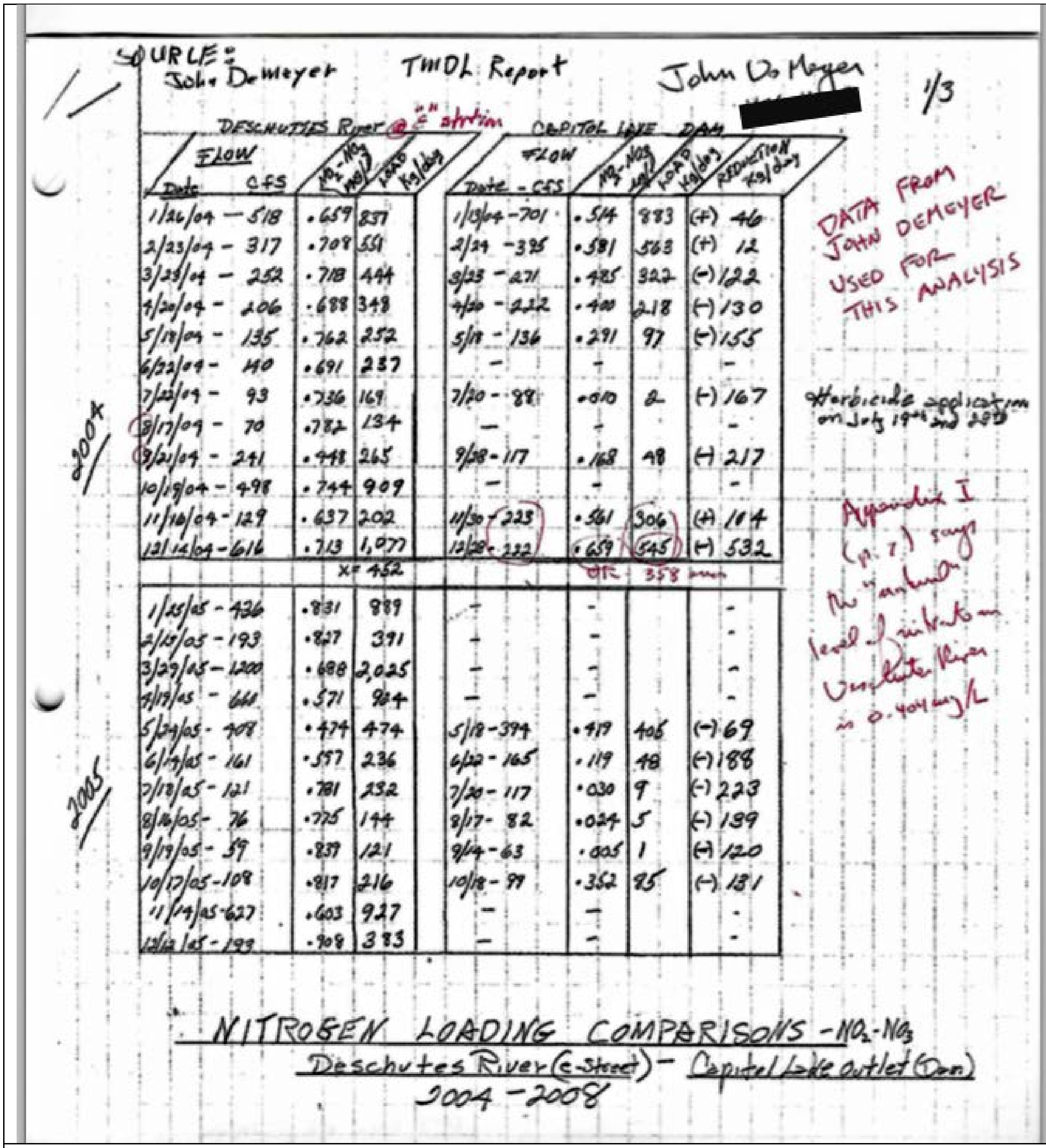
9. APPENDICES.

A. Recommendations presented to WDOE staff during a meeting in November, 2014.

Recommendations for further refinement of the Budd Inlet simulations.

Recommendation	Rationale
1) Simulate the inlet between dates March 15 and October 15.	Some WQ standards violations occur after Sept. 15, the present cut-off date of the simulation. There are none before March 15.
2) Change the present unconventional practice of reporting model outputs (as a single unspecified depth on a single unspecified date showing the maximum level of WQ standards violation for the duration of the simulation) to showing a vertical profile of DO on the date(s) of the violations. If impractical for all violation locations, at least do so for violations at stations reported in the BISS data.	It is presently impossible to compare the model outputs with observed data. The present mode of reporting precludes conventional interpretation by aquatic ecologists.
3) Always report the 90% confidence limits on estimates of the size of WQ stds violations.	Estimates of unknown values of DO's in nature may or may not be far off the mark. Confidence limits put such estimates in perspective.
4) Use as the criterion for identifying WQ stds violations whether or not the upper confidence limit (not the estimate itself) falls below the WQ standard.	If the upper confidence limit falls below the standard, we may be very sure that there really is a violation. *Especially* if it is an UCL of a mean of several estimates.
5) For validation of whichever model is used, calculate dissolved oxygen vertical profiles for all the BISS stations, on the same dates as the BISS stations were observed and at the same times of day.	These stations, dates, and times are available in the BISS data spreadsheet. This makes a crucial model validation test possible. This calculation is critical to determining whether the model replicates the structure of Budd Inlet water or not.
6) Find a way to extend the Budd Inlet model's "view" into the water beyond Boston Harbor, or use the larger South Sound model for the simulations.	It appears that significant Estuary Scenario effects occur right up to the edge of the Budd Inlet model's domain. For accurate simulations of Estuary Scenarios, it is essential that the water beyond Boston Harbor be brought into the simulation.
7) Articulate the perceived problems to be fixed when modifying the model, and what constitutes "success."	[I am thinking of the poster. Maybe this has already been done, I lost my copy! If so, good work.]
8) It would be helpful if model output maps show the calculated DO's of water in the bottom layer over the whole of Budd Inlet at representative dates.	The bottom layer is almost always the place where DO goes lowest. This would provide valuable overviews of the situation at the bottom.

B. The “DeMeyer data” used in this Analysis.



SOURCE: John DeMeyer TMDL Report John DeMeyer [redacted] 1/3

DESCHUTES River @ "E" station CAPITOL LAKE DAM

DATA FROM JOHN DEMEYER USED FOR THIS ANALYSIS

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	–	–		–
7/20/04 – 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	
1/25/05 – 436	.831	889	–	–		–
2/15/05 – 193	.827	391	–	–		–
3/29/05 – 1200	.688	2,025	–	–		–
4/19/05 – 661	.571	924	–	–		–
5/24/05 – 408	.474	474	5/18 – 394	.417	405	(–) 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	.837	121	9/14 – 63	.005	1	(–) 120
10/17/05 – 108	.817	216	10/18 – 97	.352	85	(–) 131
11/14/05 – 627	.603	927	–	–		–
12/12/05 – 193	.908	383	–	–		–

2004

2005

Herbicide application on July 19th and 20th

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

Figure A-1. Page 1 of the “DeMeyer data” used in this analysis. 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 WDOE website showed data from 2004 through 2008. Data for 2004 (used in my Figure 3-2) 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 3-2.)

After two weeks, the data unaccountably disappeared from the WDOE 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.)