The Department of Ecology's Supplemental Modeling Report.
A Critical Review.
David H. Milne PhD July, 2018

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

7-1. Overview.

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

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

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

7-2. Background.

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

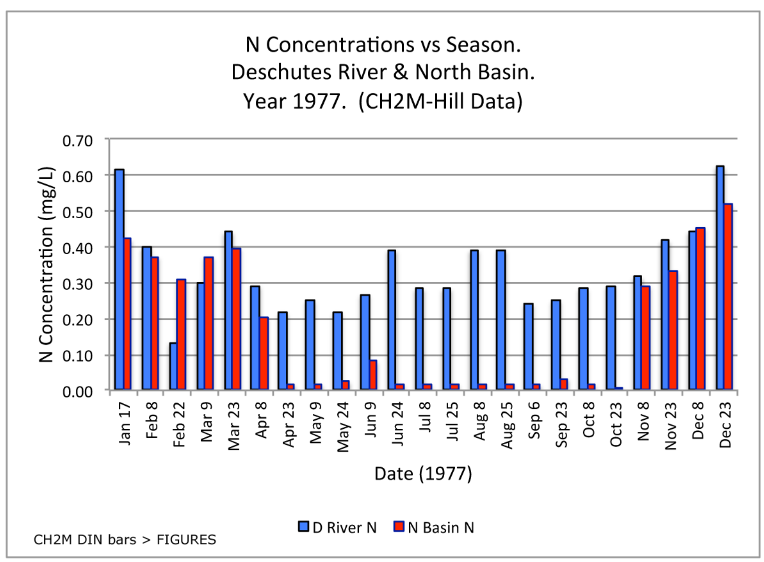

Figure 7-1. Nutrient nitrogen concentrations in the Deschutes River

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

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

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

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

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

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

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

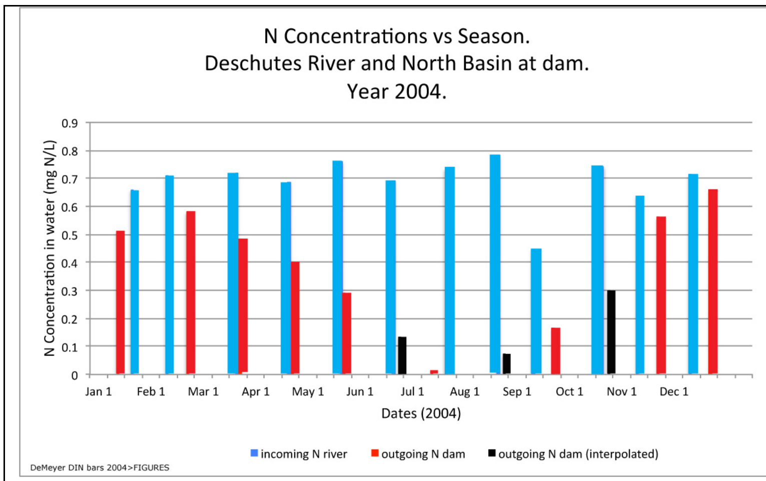

Figure 7-2. Nutrient nitrogen concentrations in the Deschutes River (blue bars) and in water exiting the Lake's North Basin over the dam (red bars), 2004. Same interpretation as Figure 7-1. Black bars are interpolated values for missing data. (DeMeyer data in References.)

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

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

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

Nisqually River	0.20	199

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

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

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

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

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

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

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

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

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

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

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

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

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

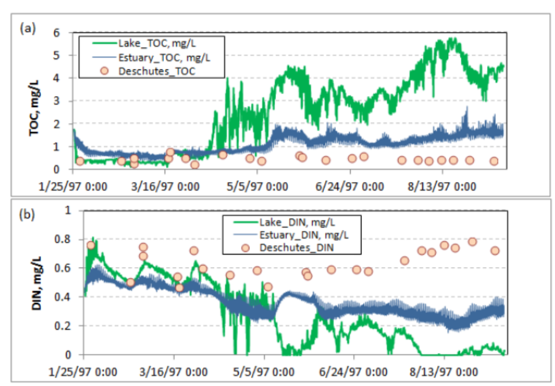

Figure 11. a) Total organic carbon (TOC) and b) dissolved inorganic nitrogen (DIN) concentrations at the location of the Capitol Lake dam under Lake (with the dam) and Estuary (without the dam) scenarios compared with concentrations in the Deschutes River at E Street.

Poster graph Grab2 > Figures

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

Bridge and dam (henceforth, the "dam site").

Poster, 2014.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The following graphs show the results of these calculations.

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

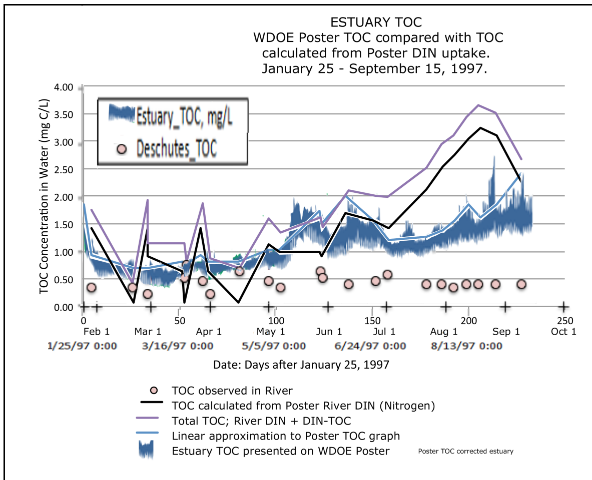

Figure 7-4. Estuary Case. Comparison of TOC calculated from DIN uptake with TOC presented by modelers. Data points show TOC observed in River (as in Figure 7-3a). Black line: DIN-TOC calculated from DIN uptakes (Col. J Table 7-3). Uppermost line; Total TOC in estuary (DIN-TOC + River TOC) at dam site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

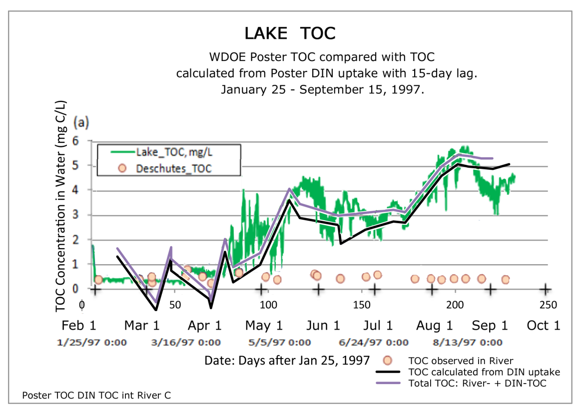

Figure 7-5. Lake Case. Comparison of TOC calculated from 15-day DIN uptakes with TOC presented by modelers. Data points show TOC observed in River (as in Figure 7-3a). Black line: DIN-TOC calculated from DIN uptakes (Col. N, Table 7-4). Uppermost line: Total TOC in lake (DIN-TOC + River TOC, Col. P, Table 7-4) at dam site. Background green graph: modelers' calculation of Lake TOC at Bridge site (as in Figure 7-3a).

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

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

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

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

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

7-7. Waterborne TOC in Real Life.

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

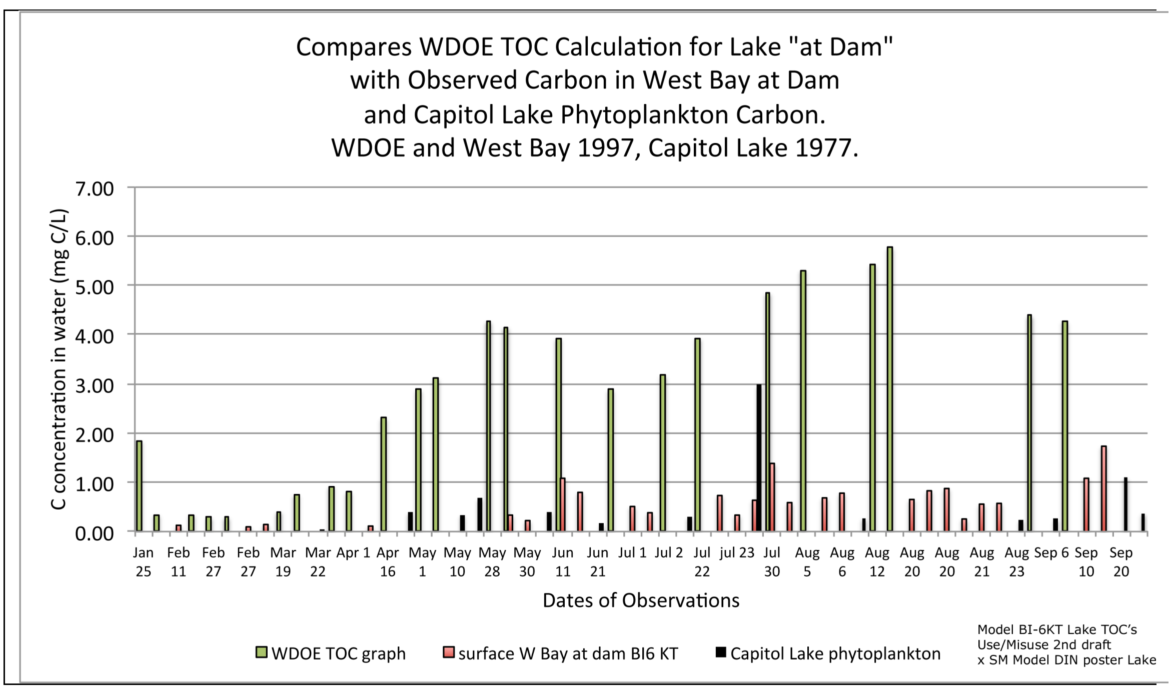

Figure7-6. Comparison of Ecology's calculated TOC levels in water near the dam site (estimated in Table 7-2 Column E, this Review) with nearby observed levels in salt water (BI-6 KT site) and Capitol Lake. BI-6 levels were calculated from measured chlorophyll levels (from Chlorophyll graph p. G2-3 TMDL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

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

7-8. Real Life Estuaries and Lakes.

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

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

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

7-9. Summary of Both Cases.

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

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

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

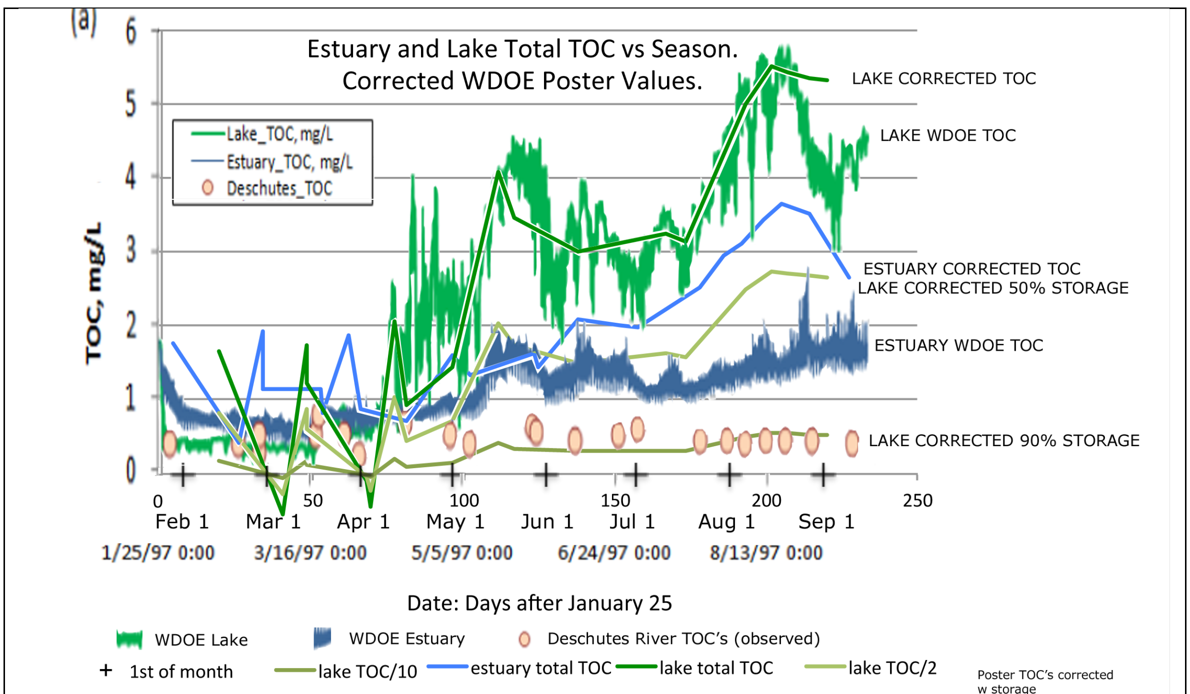

Figure 7-7. Summary. Ecology Poster TOC's compared with (my) corrected calculations. Data points for all Lake Corrected TOC's (points not shown but occurring at breaks in the dark- and light- green linear

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

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

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

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

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

7-10. Why are the Modelers Fixated on Phytoplankton?

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

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

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

<u>7-11. How Would These Errors Affect Our View of Dissolved Oxygen in Budd Inlet?</u>

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