Appendix I. Development of Loading Scenarios for the Capitol Lake and Budd Inlet Models

The Budd Inlet, Capitol Lake, and Deschutes Estuary simulation models require time series of flows and loads from the land surface, including values for rivers (nonpoint sources) and wastewater treatment plants (point sources). To quantify the relative effect of various sources, five scenarios were defined:

- Scenario 1—Rivers at natural conditions and no point sources
- Scenario 2a—Rivers at current levels of nonpoint sources and no point sources
- Scenario 2b—Rivers at natural conditions and current levels of point sources
- Scenario 3—Rivers at current levels of nonpoint sources and current levels of point sources
- Scenario 4—Rivers at current levels of nonpoint sources and maximum permitted levels of point sources.

These five scenarios were run for Budd Inlet, both with Capitol Lake and a hypothetical Deschutes estuary. The purpose of this appendix is to describe how the loading files were compiled.

Available Information

Wastewater treatment plants are required to monitor treated effluent for parameters established in each facility's NPDES permit. However, in Budd Inlet, only LOTT is required to monitor for nitrogen constituents. No plants are required to monitor phosphorus, carbon, or pH, and dissolved oxygen levels are not available at all times. Plant flows and loads originally were compiled for the Budd Inlet Scientific Study (Aura Nova Consultants, et al., 1998), and these values were used for calibration and verification of the models. However, these loads were updated to current conditions as described below to evaluate the scenarios.

Two sources of information were used to develop current and permitted wastewater treatment plant loads. NPDES-based monitoring reported in plant discharge monitoring reports (DMRs) were available for some parameters for the period 1996-2006. Where no other source of information was available, the ongoing South Puget Sound study results (Roberts et al., 2008) were used. In some cases, the actual Budd Inlet plants were monitored in the South Sound study in 2006-2007, but if no plant-specific results were available, the study median concentration across all plants surveyed was used.

There are no wastewater treatment plants or other individual point-source discharges within the Deschutes River or Percival Creek watersheds. Loads from NPDES discharges covered under the general permits for municipal stormwater, industrial stormwater, construction stormwater, sand and gravel, and dairy facilities are included with the river inputs and were not separated out because little source-specific data are available. Effects of septic systems and land cover activities also are included with the river inputs.

The mouth of the Deschutes River is part of Ecology's ambient monitoring network, and monthly grab samples have been collected at the E Street bridge for over 20 years. Percival Creek has some data from the Budd Inlet Scientific Study, but it was further characterized in this project. Conditions in nine other creeks were monitored in 1996-97 as part of the Budd Inlet Scientific Study. In lieu of more recent information, the 1996-97 water quality concentrations were used to estimate current loads from the smaller tributaries to Budd Inlet.

The model runs use the meteorological forcing from the 1996-97 calibration and verification period. To facilitate modeling, the day of the year was kept constant but the boundary condition files assign the years 1996-97 to the loads. Therefore, while actual recent September information was used for wastewater treatment plants, the input files designate 1996-97 as the year.

Scenario 2a—Current Nonpoint Sources

Scenario 2a includes current nonpoint-source inputs from rivers and streams only, and all wastewater treatment plant discharges were set to zero. River and stream contributions were compiled for current conditions in the Deschutes River, Percival Creek, and the other streams that discharge directly to Budd Inlet as described below. Table I-1 summarizes the information sources to compile current nonpoint-source loads.

Table I-1. Summary of information sources and methods used to estimate current tributary flows and loads for Scenario 2a.

Parameter	Deschutes River		Percival Creek		Other tributaries	
	Data source	Statistic	Data source	Statistic	Data source	Statistic
Discharge	USGS	1996-97 daily	BISS	1996-97 daily	BISS	
Temperature	BISS	1996-97 grab	BISS	1996-97 grab	BISS	1996-97 grab
DO	Project	Sat100	Project	Sat90	BISS	1996-97 grab
Salinity	BISS	1996-97 grab	(negligible)		BISS	1996-97 grab
pH	BISS	1996-97 grab	BISS	1996-97 grab	Assume 7.0	constant
Ammonium	BISS	1996-97 grab	BISS	1996-97 grab	BISS	1996-97 grab
Nitrate+nitrite	BISS	1996-97 grab	BISS	1996-97 grab	BISS	1996-97 grab
Organic nitrogen (diss)	BISS	1996-97 calc	Project	2003-04 calc	BISS	1996-97 grab
Organic nitrogen (part)	BISS	1996-97 calc	Project	2003-04 calc	BISS	1996-97 grab
Orthophosphate	BISS	1996-97 grab	BISS	1996-97 grab	BISS	1996-97 grab
Organic phosphorus (diss)	BISS	1996-97 calc	Project	2003-04 calc	BISS	1996-97 grab
Organic phosphorus (part)	BISS	1996-97 calc	Project	2003-04 calc	BISS	1996-97 grab
POC fast	Project data	2003-04 calc	Project	2003-04 calc	BISS	1996-97 calc
POC slow	Project data	2003-04 calc	Project	2003-04 calc	BISS	1996-97 calc
POC refractory	Project data	2003-04 calc	Project	2003-04 calc	BISS	1996-97 calc
CBOD fast	Project data	1996-97 BOD_5	Project data	1996-97 BOD_5	BISS	1996-97 BOD_5
Chlorophyll	BISS	1996-97 constant	BISS	1996-97 constant	(negligible)	
Phytoplankton	(negligible)		(negligible)		(negligible)	

Notes:

USGS	USGS gage data
BISS	Budd Inlet Scientific Study original input file values
SPS	South Puget Sound Dissolved Oxygen Study
grab	Grab sample results
calc	Calculated parameters (OrgN=TN-NH4N-NO23N; OrgP+TP-OP)
CBODfast	Ultimate BOD values were calculated from grab samples of BOD_5 and assumed to be fast CBOD. Slow CBOD was assumed to be zero.
Sat100	Because the Deschutes River measurements are conducted upstream of the falls, and because the falls add oxygen, DO was set to 100% saturation based on the temperature results.
Sat90	Percival Creek data were approximately 90% saturation

Estimating Deschutes River Current Inputs

The Budd Inlet Scientific Study data collection in 1996-97 coincided with relatively high flows in the Deschutes River compared with long-term flows. Annual average flows in calendar years 1996 and 1997 were 558 and 549 cfs, respectively. Since 1945, annual average flows have been higher than 556 cfs only 10% of the time. Therefore, streamflows during the 1996-97 calibration period were close to the 90^{th} percentile of flows in the Deschutes River since gaging began. Loads developed from these flows represent a reasonable worst-case scenario for nutrient loading. The actual flows for the 1996-97 period were used for the scenarios.

Temperature, salinity, pH, chlorophyll, and phytoplankton levels were set to the values used in the original Budd Inlet Scientific Study input files. The DO concentrations were modified from the values originally reported in the input files. When the natural conditions were compared initially with the current conditions, the grab sample results led to differential DO values in the south basin of Capitol Lake that did not account for the aerating effect of the falls. The falls would increase DO levels in the Deschutes River to achieve saturation based on gas-transfer processes (Chapra, 1997), even with varying DO deficits upstream of the falls. Therefore, DO was estimated as 100% saturation based on the temperature of the Deschutes River, and the same values were used for natural and current conditions.

Nutrient loads were based on the concentrations from 1996-97. Peak summer nitrate concentrations (0.75 mg/L) were slightly lower than those found in 2003-04 (0.87 mg/L). Ammonium, nitrate+nitrite, and orthophosphate concentrations were as reported in the 1996-97 model input files. Organic nitrogen was calculated as the difference between total nitrogen and the sum of ammonium and nitrate+nitrite (dissolved inorganic nitrogen), and organic phosphorus was calculated as the difference between total phosphorus and orthophosphate. Both were apportioned 50% each into dissolved and particulate fractions.

No carbon data were available in the 1996-97 files for the Deschutes River, and data collected during the project in 2003-04 were used. Particulate organic carbon was calculated as the difference between total and dissolved organic carbon, and the average value for 2003-04 (0.13 mg/L) was used throughout the simulation period. Concentrations were apportioned 33% each into fast, slow, and refractory components.

BOD5 data was available in the 1996-97 files in two forms: *reported* (BODRep) and *estimated* (BODEst). BODRep data assigned non-detect results at the reporting limit (RL), while BODEst results gave estimated values for results below the RL. BODEst results were converted to ultimate BOD using the following relationship and assuming a decay rate *k* of 0.23/day (Chapra, 1997):

$$BOD_u/BOD_5 = 1 / (1 - e^{-5k})$$
$$BOD_u = BOD_5 \times 1.4634.$$

Ultimate BODEst data were then used for fast-reacting BOD inputs.

Estimating Percival Creek Current Inputs

Percival Creek flows were based on the predicted values used in the 1996-97 Budd Inlet Scientific Study. No long-term gaging is available for the Percival Creek system; however, because Deschutes River flows for this period were higher than normal, the Percival Creek flows also likely were higher than usual. Loads calculated from the flows represent a reasonable worst-case situation.

Ammonium, nitrate+nitrite, and orthophosphate concentrations were as reported in the 1996-97 model input files. However, the original data files did not include organic nitrogen or organic phosphorus for Percival Creek, and the 2003-04 project data were used. Organic nitrogen was calculated as the difference between total nitrogen and the sum of ammonium and nitrate+nitrite (dissolved inorganic nitrogen), and organic phosphorus was calculated as the difference between total phosphorus and orthophosphate. The 2003-04 average concentration for both organic nitrogen and organic phosphorus was apportioned 50% each into dissolved and particulate fractions.

No carbon data were available for Percival Creek in the 1996-97 files, and data collected during the project in 2003-04 were used. Particulate organic carbon was calculated as the difference between total and dissolved organic carbon, and the average value for 2003-04 (0.32 mg/L) was used throughout the simulation period. Concentrations were apportioned 33% each into fast, slow, and refractory components.

5-day BODEst data in the 1996-97 data files was converted to ultimate BOD as described above, and used for fast-reacting BOD inputs.

Estimating Other Tributary Current Inputs

In addition to the Deschutes River and Percival Creek, other streams discharge to Budd Inlet. Flows from nine streams included in the Budd Inlet Scientific Study were included in the current model, and no changes to flow were made. Although no long-term gaging is available for these streams, because the Deschutes River had higher-than-normal flows in 1996-97, the other creeks likely had higher flows as well. The higher flows used for current conditions represent a reasonable worst-case scenario.

No changes were made to temperature, salinity, or dissolved oxygen, other than removing 0.1 mg/L DO values on July 21, common to several creeks. The original model input files did not include pH, and all tributaries were set to a constant value of 7.0. The original ammonium, nitrate+nitrite, and orthophosphate concentrations were used. During the Budd Inlet Scientific Study data collection, the particulate and dissolved fractions of organic nitrogen and organic phosphorus were determined with filtered and unfiltered samples; the same values were used in this application.

The model input files include organic carbon, but the values did not match those reported in Appendix F of the Budd Inlet Scientific Study for each site. Several values were common to more than one station, although no two records were identical. The Budd Inlet Scientific Study did not include any description of how data were used in modeling. Comparing typical values

for each stream against Appendix F of the Budd Inlet Scientific Study, the values were assumed to be particulate organic carbon. The particulate fraction was then apportioned into fast, slow, and refractory compartments of 33% each.

5-day BODEst data from the Budd Inlet Scientific Study was converted to ultimate BOD, as described above, and used for fast-reacting BOD inputs.

Chlorophyll was set to zero for all small tributaries. While the original model files did not include phytoplankton values, these were set to zero for all tributaries.

Scenario 1—Natural Conditions

Scenario 1 includes inputs from rivers and streams only, and all wastewater treatment plant discharges were set to zero. Natural conditions were established for the Deschutes River, Percival Creek, and other streams that discharge directly to Budd Inlet as described below. Table I-2 summarizes the information sources to compile natural nonpoint-source loads.

Table I-2. Summary of information sources and methods used to estimate natural tributary flows and loads for Scenario 1. (See Table I-1 for notes.)

Parameter	Deschutes River		Percival Creek		Other tributaries	
	Data source	Statistic	Data source	Statistic	Data source	Statistic
Discharge	(current)		(current)		(current)	
Temperature	(current)		(current)		(current)	
DO	Sat100		Sat90		BISS	1996-97 90th %ile
Salinity	(current)		(current)		(current)	
pH	(current)		(current)		(current)	
Ammonium	13A060	1977-2005 10th %ile	BISS	1996-97 10th %ile	BISS	1996-97 10th %ile
Nitrate+nitrite	13A060	1977-2005 10th %ile	BISS	1996-97 10th %ile	BISS	1996-97 10th %ile
Organic nitrogen (diss)	13A060	1977-2005 10th %ile	Project	2003-04 10th %ile	BISS	1996-97 10th %ile
Organic nitrogen (part)	13A060	1977-2005 10th %ile	Project	2003-04 10th %ile	BISS	1996-97 10th %ile
Orthophosphate	13A060	1977-2005 10th %ile	BISS	1996-97 10th %ile	BISS	1996-97 10th %ile
Organic phosphorus (diss)	13A060	1977-2005 10th %ile	Project	2003-04 10th %ile	BISS	1996-97 10th %ile
Organic phosphorus (part)	13A060	1977-2005 10th %ile	Project	2003-04 10th %ile	BISS	1996-97 10th %ile
POC fast	Project data	2003-04 10th %ile	Project data	2003-04 10th %ile	BISS	1996-97 10th %ile
POC slow	Project data	2003-04 10th %ile	Project data	2003-04 10th %ile	BISS	1996-97 10th %ile
POC refractory	Project data	2003-04 10th %ile	Project data	2003-04 10th %ile	BISS	1996-97 10th %ile
CBOD fast	Project data	1996-97 10th %ile	Project data	1996-97 10th %ile	BISS	1996-97 10th %ile
Chlorophyll	(current)		(current)		(negligible)	
Phytoplankton	(negligible)		(negligible)		(negligible)	

Estimating Deschutes River Natural Inputs

No changes to Deschutes River flows were made to represent natural conditions, and the actual 1996-97 flows were used. The same values used as current conditions for temperature, salinity, pH, chlorophyll, and phytoplankton were used for natural conditions. Because the Deschutes Falls are expected to saturate oxygen levels, 100% saturation was used for both natural and current conditions. Above the falls, DO concentrations have declined from a median of 11.8 mg/L in 1978 to 10.1 mg/L in 2005, but the aerating effect of the falls buffers the effect on Capitol Lake.

Natural conditions for nutrient inputs were developed based on historical monitoring of the Deschutes River at the E Street bridge (station 13A060). Deschutes River nitrate levels have increased over time, and the nitrate levels vary inversely with flow. The 10^{th} percentile concentration (0.404 mg/L) was similar to the historical concentration (0.44 mg/L) predicted

based on a regression of available data since 1975. Ammonium levels also have declined over time, and the 10th percentile value (0.010) was used. Organic nitrogen was calculated as the difference between total nitrogen and dissolved inorganic nitrogen, and the 10th percentile of available concentrations (0.038 mg/L) was used. Natural concentrations for orthophosphate and organic phosphorus also were based on 10th percentile concentrations measured at station 13A060.

Neither Ecology's ambient monitoring program nor the Budd Inlet Scientific Study included organic carbon, and data collected during this project in 2003-04 were used. Particulate organic carbon was calculated as the difference between total and dissolved organic carbon, and the 10th percentile concentration (0.000 mg/L) was used for fast, slow, and refractory fractions. BODEst data from 1996-97 was converted to ultimate BOD as described above, and the 10th percentile was used as fast-reacting BOD.

Estimating Percival Creek Natural Inputs

No changes to Percival Creek flows were made to represent natural conditions, and the actual 1996-97 flows were used. The same values used as current conditions for temperature, salinity, pH, chlorophyll, and phytoplankton were used for natural conditions. The 90th percentile dissolved oxygen concentration measured during the Budd Inlet Scientific Study was calculated (12.1 mg/L). The 90% saturation values for measured temperatures also were calculated. For both natural and current conditions, DO values were based on 90% saturation.

Natural conditions for nutrient inputs were developed from the Budd Inlet Scientific Study values supplemented with the 2003-04 data for missing information. Ammonium, nitrate+nitrite, and orthophosphate natural conditions were estimated as the 10th percentile lowest concentrations found in the Budd Inlet Scientific Study (0.008, 0.166, and 0.011 mg/L, respectively). Organic nitrogen and organic phosphorus data were not available in 1996-97, and the 2003-04 data were used to calculate values as the difference between total nitrogen and dissolved inorganic nitrogen or total phosphorus and orthophosphate. The 10th percentile concentrations (0.045 and 0.003 mg/L, respectively) were apportioned 50% each into particulate and dissolved fractions.

No organic carbon data were available for 1996-97. The project data were used to calculate particulate organic carbon as the difference between total and dissolved, and the 10th percentile concentration (0.000 mg/L) was used for fast, slow, and refractory fractions. BODEst data from 1996-97 was converted to ultimate BOD and the 10th percentile concentration was used as fast-reacting BOD.

Estimating Other Tributary Natural Inputs

No changes to tributary flows were made to represent natural conditions, and the actual 1996-97 flows were used. The same values used as current conditions for temperature, salinity, chlorophyll, and phytoplankton were used for natural conditions. As for current conditions, a constant pH of 7.0 was used for each tributary because the parameter was not included in the model input files. The 90th percentile dissolved oxygen concentrations measured during the Budd Inlet Scientific Study were calculated for each creek and kept constant through the

simulation period; original model input files included erroneous 0.1 mg/L values that were not included in the percentile calculations.

Natural conditions for nutrient inputs were developed from the Budd Inlet Scientific Study values. Ammonium, nitrate+nitrite, and orthophosphate natural conditions were estimated as the 10th percentile lowest concentrations found in the Budd Inlet Scientific Study for each tributary. Organic nitrogen and organic phosphorus data were available in 1996-97, and the field protocols also distinguished particulate and dissolved fractions. The 10th percentile concentrations were found for each fraction and each creek. Particulate organic carbon fractions were also based on the 10th percentile concentrations of the 1996-97 data. Ultimate BOD was calculated from the BODEst data and the 10th percentile concentration was used for fast-reacting BOD.

Inputs for North Gull Creek appear to be based on South Gull Creek, but no documentation was provided in the original report. The flows appear to be scaled by the ratio in tributary areas and water quality constituents are identical.

Scenario 3—Current Nonpoint Sources and Current Point Sources

Scenario 3 includes the combined effect of river/stream and wastewater treatment plant current loads. River inputs were identical to those used in Scenario 2a, described above. Four wastewater treatment plants discharge to Budd Inlet. A fifth plant discharged at the time of the Budd Inlet Scientific Study but has ceased operations; all wastewater flows from the previous Beverly Beach wastewater treatment plant are now reflected in totals for the Tamoshan facility. Current condition wastewater treatment plant loads were developed as described below. Table I-3 summarizes the information sources and methods to compile loads for each parameter by plant.

Monthly discharges are available electronically, and these were compiled for the period 1996-2006 for each of the three plants. Several flood[1] events affected flows through the plants; flows for these months were not included in statistics. Mean annual flows were 14 to 27% higher in 2006 than in 1996 at the three smaller plants. Mean annual flow has declined at the LOTT plant approximately 7% over the same time period. Recent (2006) monthly mean discharges are similar to the long-term mean at LOTT except November 2006, also a flood event. Tamoshan's discharge has increased in part due to the diversion from the Beverly Beach plant that ceased operations. Figure I-1 summarizes the available information.

[1] LOTT flows were strongly affected by high precipitation in February 1996 and November 2006. Seashore Villa flows were unusually high in June 1998 and were strongly affected by high precipitation in October 2003. Neither Boston Harbor nor Tamoshan flow records included these outliers.

Table I-3. Summary of information sources and methods used to estimate current facility flows and loads for Scenario 3.

Parameter	Boston Harbor		LOTT		Seashore Villa		Tamoshan	
	Data Source	Statistic	Data Source	Statistic	Data Source	Statistic	Data Source	Statistic
Flow	DMR_Qmaxmo	monthly	DMR_Qmaxmo	monthly	DMR_Qmaxmo	monthly	DMR_Qmaxmo	monthly
Temperature	DMR_LOTT	monthly	DMR_meanmo	monthly	DMR_LOTT	monthly	DMR_LOTT	monthly
Dissolved oxygen	DMR_BHT	annual	SPS_plant	annual	DMR_BHT	annual	DMR_BHT	annual
Salinity	(negligible)	(negligible)	(negligible)	(negligible)	(negligible)	(negligible)	(negligible)	(negligible)
pH	SPS_plant	annual	SPS_plant	annual	SPS_plant	fall 2007	SPS_plant	annual
Ammonium	SPS_plant	annual	DMR_meanmo (1)	monthly	SPS_plant	fall 2007	SPS_plant	annual
Nitrate+nitrite	SPS_plant	annual	DMR_meanmo	monthly	SPS_plant	fall 2007	SPS_plant	annual
Dissolved organic nitrogen (3)	SPS_plant (6)	annual	DMR_TKN	seasonal	SPS_plant	fall 2007	SPS_plant	annual
Particulate organic nitrogen (3)	SPS_plant (6)	annual	DMR_TKN	seasonal	SPS_plant	fall 2007	SPS_plant	annual
Orthophosphate	SPS_plant	annual	SPS_plant	annual	SPS_plant	fall 2007	SPS_plant	annual
Dissolved organic phosphorus (2,3)	SPS_plant	annual	SPS_plant	annual	SPS_plant	fall 2007	SPS_plant	annual
Particulate organic phosphorus (2,3)	SPS_plant	annual	SPS_plant	annual	SPS_plant	fall 2007	SPS_plant	annual
Particulate organic carbon (fast) (4)	SPS_plant	annual	SPS_plant	annual	SPS_plant	fall 2007	SPS_plant	annual
Particulate organic carbon (slow) (4)	SPS_plant	annual	SPS_plant	annual	SPS_plant	fall 2007	SPS_plant	annual
Particulate organic carbon (refractory) (4)	SPS_plant	annual	SPS_plant	annual	SPS_plant	fall 2007	SPS_plant	annual
Carbonaceous BOD (fast) (5)	DMR_meanmo	monthly	DMR_meanmo	monthly	DMR_meanmo	monthly	DMR_meanmo	monthly
Carbonaceous BOD (slow) (5)	DMR_meanmo	monthly	DMR_meanmo	monthly	DMR_meanmo	monthly	DMR_meanmo	monthly
Chlorophyll	(negligible)	(negligible)	(negligible)	(negligible)	(negligible)	(negligible)	(negligible)	(negligible)
Phytoplankton	(negligible)	(negligible)	(negligible)	(negligible)	(negligible)	(negligible)	(negligible)	(negligible)

Notes:

DMR_Qmaxmo	Maximum mean monthly flow from DMRs for 1996-2006
DMR_ann	Annual mean of monthly data from 1996-2006 DMRs
DMR_seasonal	Seasonal (Nov-Mar, Apr-Oct) mean from DMRs for 1996-2006
DMR_meanmo	Mean monthly data from DMRs for 1996-2006
DMR_TKN	Calculated as the difference between TKN and ammonium from DMR data.
DMR_BHT	Mean of all data from Boston Harbor and Tamoshan for 1996-2006
DMR_LOTT	Mean monthly data for LOTT for 1996-2006
SPS_plant	SPSDOS specific plant data
SPS_mean	SPSDOS mean for all plants surveyed
(negligible)	Assume negligible

1. Measured April - October. Estimated for November - March as the difference between total inorganic nitrogen and nitrate+nitrite
2. Organic phosphorus was calculated as the difference between total phosphorus and orthophosphate from SPS DOS data.
3. Particulate and dissolved organic nitrogen and organic phosphorus were assumed to be 50% each.
4. Particulate organic carbon was calculated as the difference between total and dissolved organic carbon from SPS DOS data. Particulate carbon was apportioned into slow, fast, and refractory components as 33% of the particulate values.
5. Carbonaceous BOD (5-day) was converted to ultimate BOD using k=-0.23/d. Fast and slow CBOD were assumed to be 50% each.
6. Organic nitrogen was calculated as the difference between total nitrogen and the sum of ammonium, nitrate, and nitrite from the SPS DOS data.

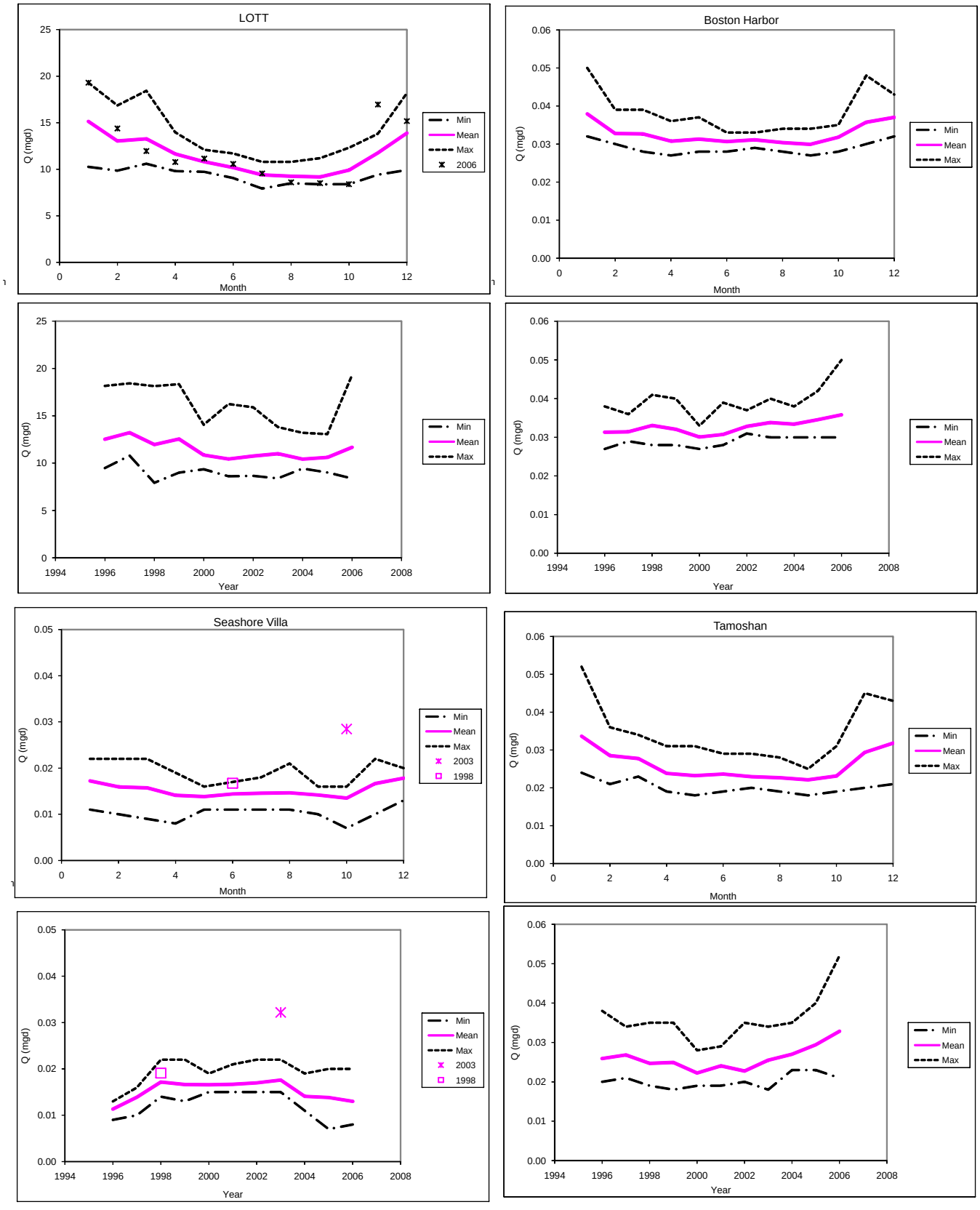

Figure I-1. Monthly and mean annual discharge at the four plants that discharge to Budd Inlet.

The maximum mean monthly flows measured at each plant for the period 1996-2006 were used to develop the loads. These monthly flows occurred once in the ten-year period and represent a reasonable worst-case scenario. Maximum monthly flows are 17% (Boston Harbor) to 31% (Tamoshan) higher than mean monthly flows as plant averages, with less variability in September than the winter months.

The three smaller plants do not measure effluent temperatures, and the LOTT values were used. For LOTT, the mean monthly temperatures reported in the DMRs were compiled for 1996-2006, and the average by month computed. Effluent temperatures reflect seasonal variation, and little inter-annual variation occurs (Figure I-2).

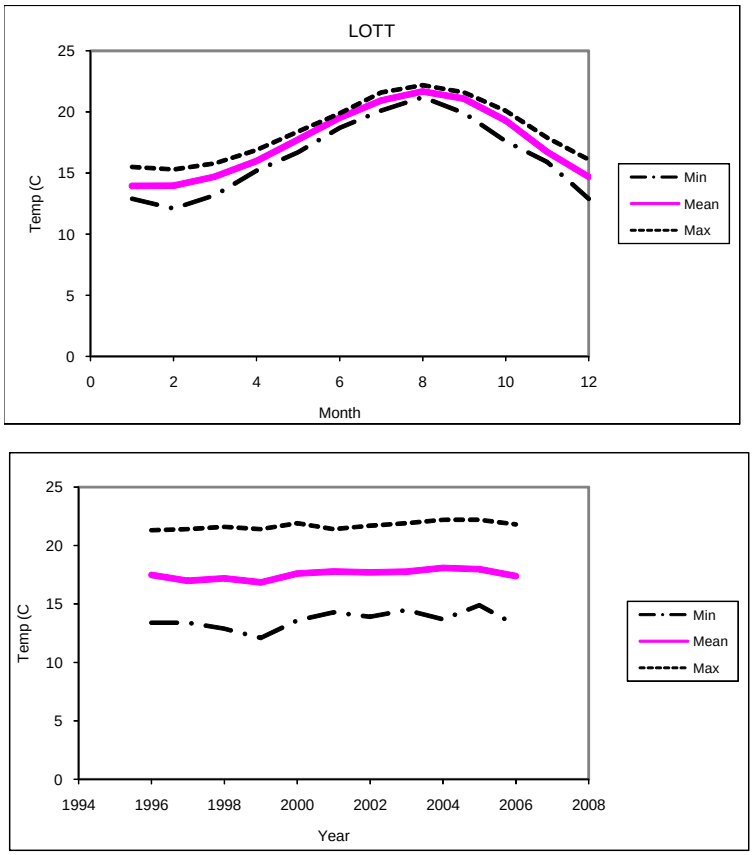

Figure I-2. Monthly and mean annual effluent temperature recorded at LOTT.

Dissolved oxygen is measured in the effluent of Boston Harbor, LOTT, and Tamoshan. Monthly mean DO values were compiled from 1996-2006 DMRs. Ten-year mean monthly concentrations were calculated for Boston Harbor and Tamoshan, which reflect some monthly variation. For both plants, constant effluent DO concentrations of 5.75 and 5.72 mg/L, respectively, were used. Because they were so close in value, the mean of both (5.74 mg/L) was used for Seashore Villa effluent. The electronic DMRs only include DO in LOTT effluent since 2005, coincident with a change in process. Therefore, the mean monthly values from the recent South Puget Sound study were used to represent current conditions at the plant. Figure I-3 presents the available DMR and South Puget Sound Dissolved Oxygen Study DO data.

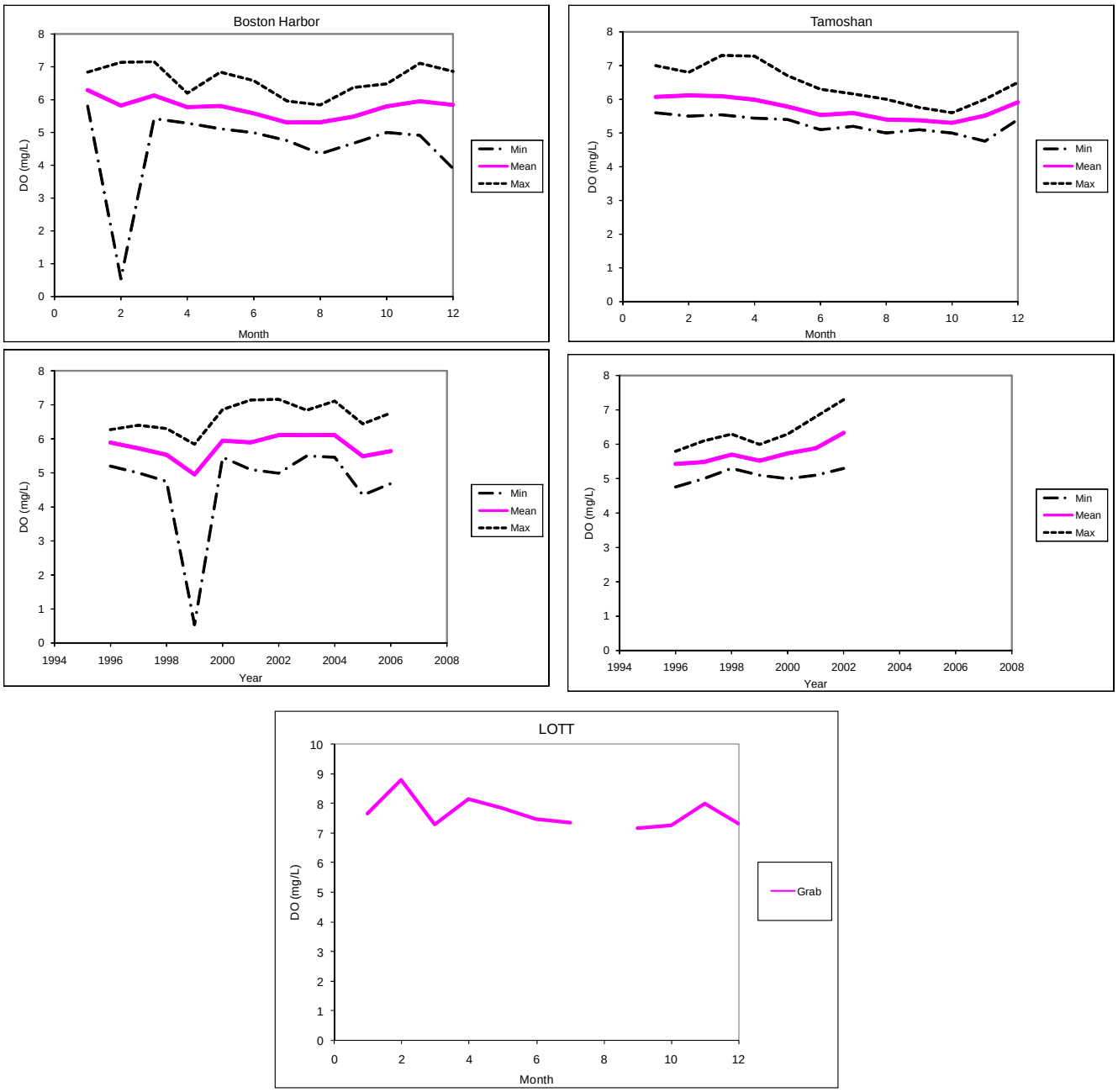

Figure I-3. Monthly and mean annual dissolved oxygen for Boston Harbor and Tamoshan from 1996-2006 DMRs and monthly grab values for LOTT from the South Puget Sound Dissolved Oxygen Study.

No salinity measurements are available for the wastewater effluent. Because any salinity is likely many orders of magnitude below levels in Budd Inlet, effluent salinity was assumed to be zero for all plants.

Electronic monthly DMRs include instantaneous minimum and maximum pH values at all four plants, but mean values are not captured. Therefore, the measurements recorded during the South Puget Sound Dissolved Oxygen Study were used at Boston Harbor, LOTT, and Tamoshan. The values for Seashore Villa were estimated as the mean of the Boston Harbor and Tamoshan values.

While Boston Harbor is required to monitor effluent ammonium levels, there are no coincident measurements of nitrate, total nitrogen, or total Kjeldahl nitrogen (TKN) with which to characterize the complete fractionation of nitrogen. Therefore, because the plant effluent nutrient levels were monitored in the South Puget Sound Dissolved Oxygen Study, those values were used for all nitrogen fractions. Neither Seashore Villa nor Tamoshan are required to report effluent ammonium or other nitrogen concentrations, and the mean plant value for each nitrogen fraction from the South Puget Sound Dissolved Oxygen Study was used to characterize nutrient loads. Tamoshan was monitored for the full 15 months, but only fall 2007 data were available for Seashore Villa.

Monthly DMR data were available for most nitrogen fractions in LOTT effluent for the period 1996-2006. Ammonium was measured between November and March only until October 2005 when year-round monitoring was required. However, TKN and nitrate have been measured year-round. Where needed, missing data were estimated using the ratio of nitrate and dissolved organic nitrogen, which varied seasonally (62% November through March and 87% April through October). Monthly dissolved inorganic nitrogen levels in LOTT's effluent vary considerably due to the seasonal denitrification used by the plant (Figure I-4). Loads were based on the long-term average of monthly mean concentrations of each parameter.

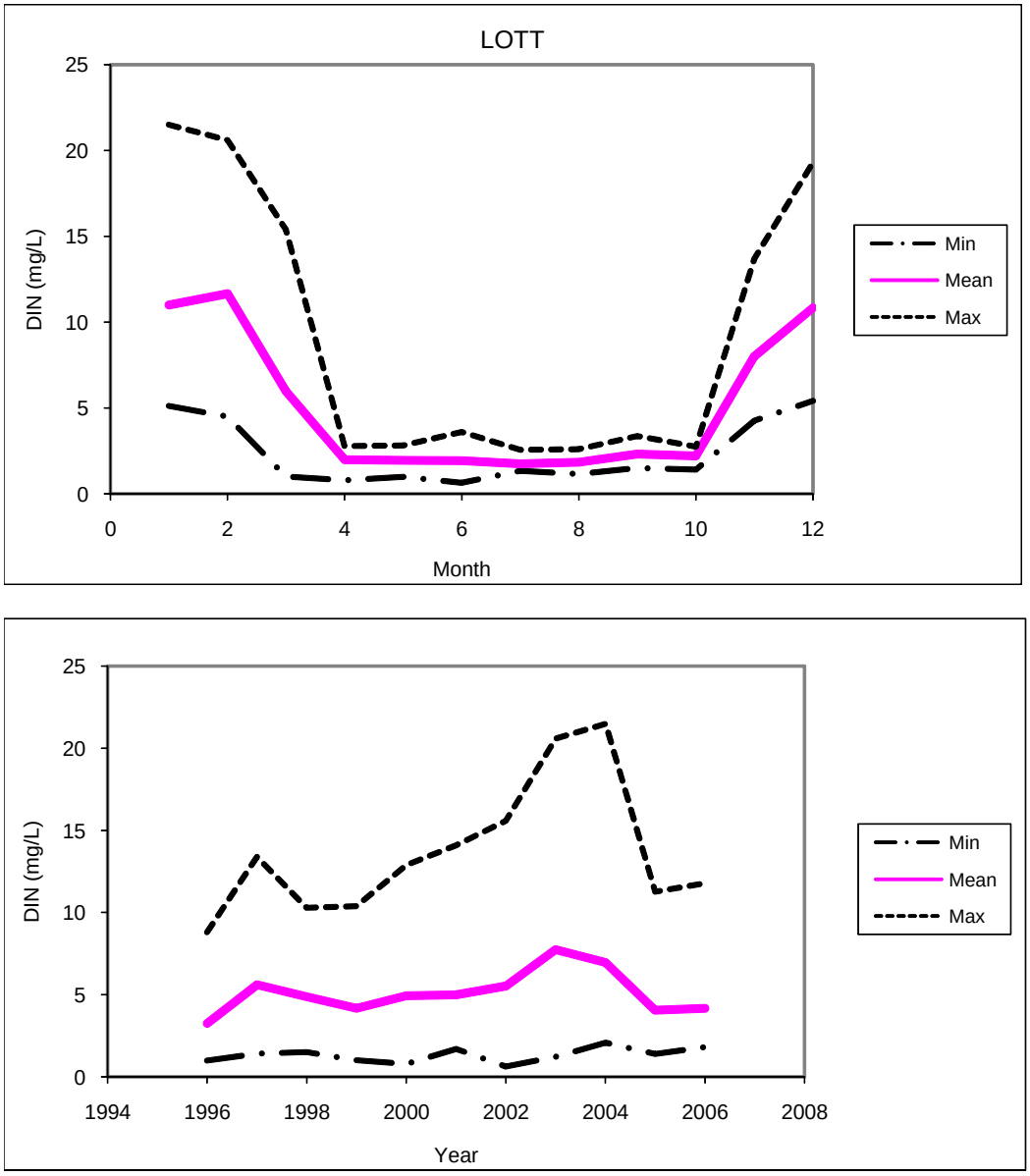

Figure I-4. Monthly and mean annual dissolved inorganic nitrogen levels for LOTT from 1996-2006 DMRs.

Organic nitrogen levels were calculated from monthly TKN and ammonium levels. Because of the variability of the differential calculation, organic nitrogen levels were estimated for two seasons derived from the maximum monthly estimates (2.32 mg/L for April through October and 5.22 mg/L for November through March). Organic nitrogen was separated into pools of particulate and dissolved organic nitrogen by assuming 50% each.

Measurements of orthophosphate are not required for any of the plants. However, all plants were included in the 2006-2007 South Puget Sound Dissolved Oxygen Study (Figure I-5), and plant-specific values from this period were used for each facility. Similarly, monitoring for organic phosphorus, calculated as the difference between total and orthophosphate, is not required, and

results for the South Puget Sound Dissolved Oxygen Study were used. Both phosphorus fractions used the overall annual mean and did not vary parameters monthly.

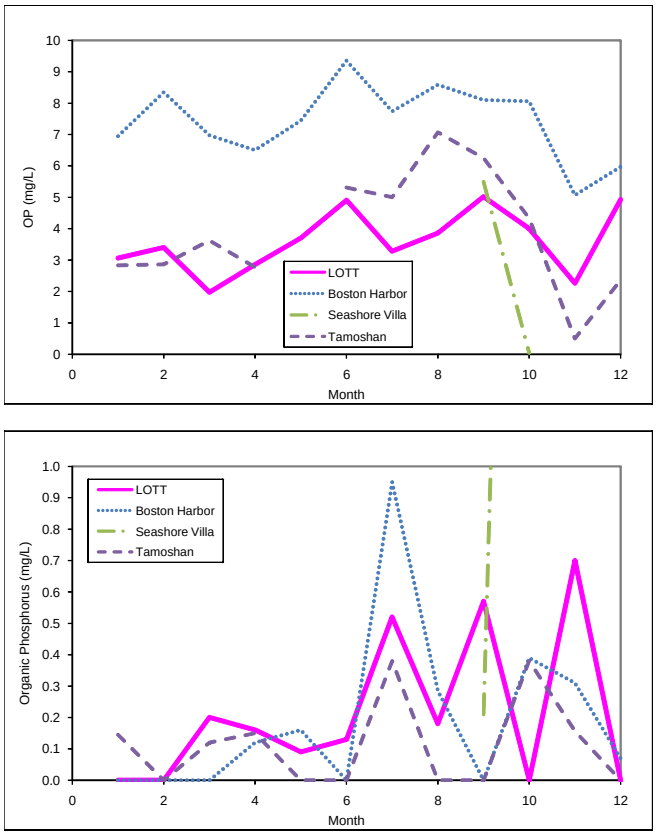

Figure I-5. Orthophosphate and organic phosphorus results for each plant from the 2006-2007 South Puget Sound Dissolved Oxygen Study.

Measurements of organic carbon are not required of dischargers. The South Puget Sound Dissolved Oxygen Study results for each plant were used to estimate particulate organic carbon as the difference between total and dissolved organic carbon measurements. POC was separated into fast, slow, and refractory compartments with 33% each, in lieu of more specific information. The overall annual mean was used for each plant; Seashore Villa was only monitored in fall 2007, and this mean value was used.

Plants are required to monitor 5-day carbonaceous BOD in effluent streams. Monthly values were compiled for each plant for 1996-2006, and average monthly mean values were calculated (Figure I-6). As described earlier, 5-day BOD values were converted to ultimate BOD using a typical wastewater rate constant of 0.23/day, and the monthly ultimate BOD values were used for each plant.

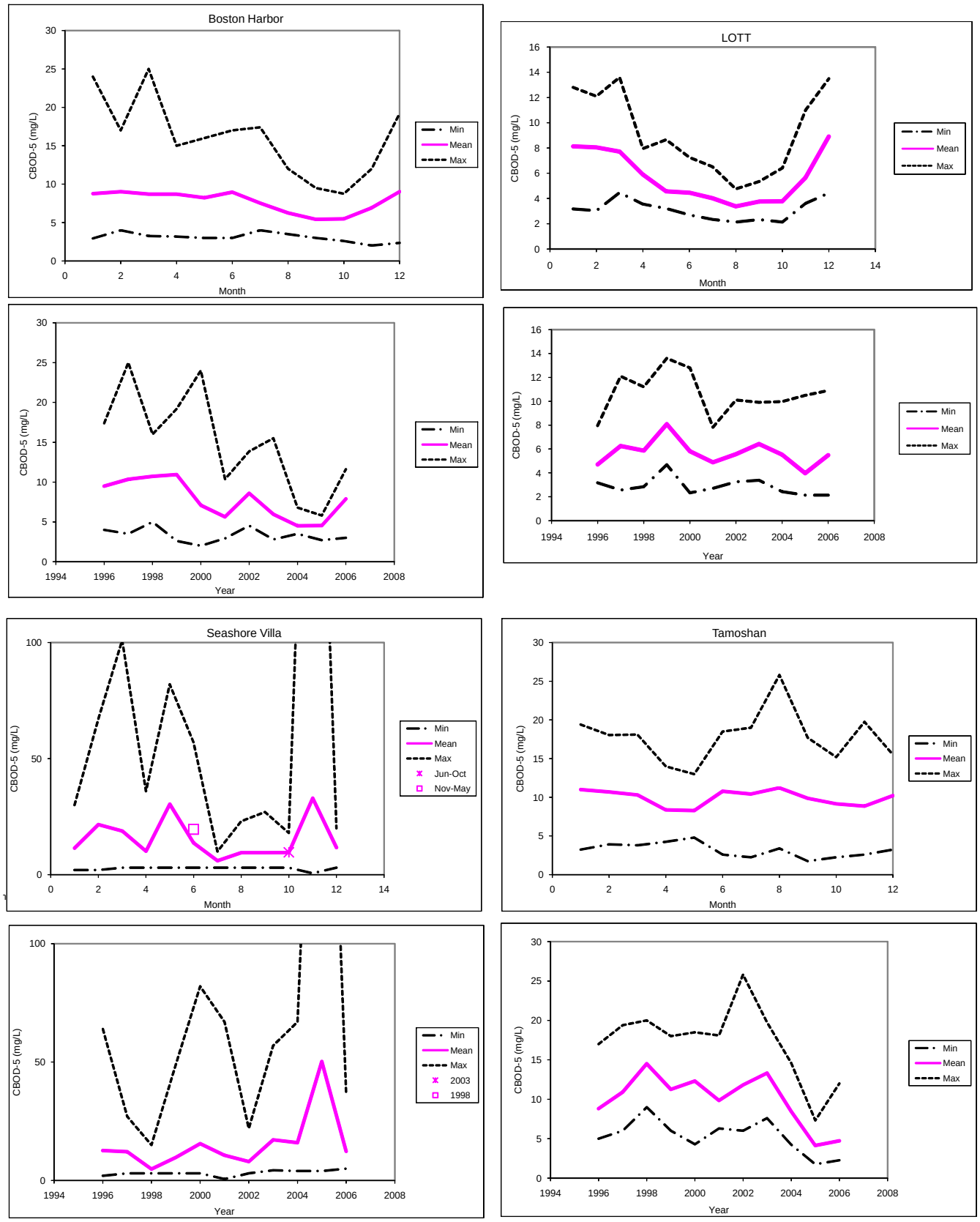

Figure I-6. Monthly and mean annual 5-day BOD at the four plants that discharge to Budd Inlet.

Scenario 2b—Nonpoint Sources at Natural Conditions and Current Point Sources

Scenario 2b includes the combined effect of rivers/streams natural conditions and wastewater treatment plant current loads. River inputs were identical to those used in Scenario 1, while point-source inputs were identical to those in Scenario 3. These have been described earlier.

Scenario 4—Current Nonpoint Sources and Permitted Point Sources

Scenario 4 includes the combined effect of current river/stream loads and maximum permitted wastewater treatment plant loads. River inputs were identical to those used in Scenario 2a, described above, representing existing nonpoint sources. Because facilities discharge at levels below permitted values, but theoretically facilities could increase discharges to the maximum levels allowed in their individual permits, this scenario was evaluated with all facilities operating at the maximum allowable levels. Maximum permitted loads were developed as described below. As for Scenario 3, while the Beverly Beach wastewater treatment plant discharged to Budd Inlet in the 1990s during the calibration period, it has ceased operations and all wastewater flows are reflected in totals for the Tamoshan facilities. For this scenario, four wastewater treatment plants discharge to Budd Inlet. Table I-4 summarizes the information sources and methods to compile loads for each parameter by plant, and details are described below.

Table I-4. Summary of information sources and methods used to estimate maximum permitted facility flows and loads for Scenario 4.

Parameter	Boston Harbor		LOTT		Seashore Villa		Tamoshan	
	Data Source	Statistic	Data Source	Statistic	Data Source	Statistic	Data Source	Statistic
Flow	Perm_Qmaxmo	constant	Perm_Qmaxmo	constant	DMR_Qmaxmo	constant	Perm_Qmaxmo	constant
Temperature	(current)		(current)		(current)		(current)	
Dissolved oxygen	DMR_minmo	constant	SPS_minmo	constant	DMR_BHT	constant	DMR_minmo	constant
Salinity	(negligible)	(negligible)	(negligible)	(negligible)	(negligible)	(negligible)	(negligible)	(negligible)
pH	(current)		(current)		(current)		(current)	
Ammonium	SPS_plant	max DIN	Perm *	seasonal	SPS_plant	max DIN	SPS_plant	max DIN
Nitrate+nitrite	SPS_plant	max DIN	Perm *	seasonal	SPS_plant	max DIN	SPS_plant	max DIN
Dissolved organic nitrogen (3)	SPS_plant	max DIN	DMR_maxmo	seasonal	SPS_plant	max DIN	SPS_plant	max DIN
Particulate organic nitrogen (3)	SPS_plant	max DIN	DMR_maxmo	seasonal	SPS_plant	max DIN	SPS_plant	max DIN
Orthophosphate	SPS_plant	max month	SPS_plant	max month	SPS_plant	max month	SPS_plant	max month
Dissolved organic phosphorus (2,3)	SPS_plant	max month	SPS_plant	max month	SPS_plant	max month	SPS_plant	max month
Particulate organic phosphorus (2,3)	SPS_plant	max month	SPS_plant	max month	SPS_plant	max month	SPS_plant	max month
Particulate organic carbon (fast) (4)	SPS_plant	max month	SPS_plant	max month	SPS_plant	max month	SPS_plant	max month
Particulate organic carbon (slow) (4)	SPS_plant	max month	SPS_plant	max month	SPS_plant	max month	SPS_plant	max month
Particulate organic carbon (refractory) (4)	SPS_plant	max month	SPS_plant	max month	SPS_plant	max month	SPS_plant	max month
Carbonaceous BOD (fast) (5)	Perm **	constant	Perm ****	monthly	Perm ***	constant	Perm ***	constant
Carbonaceous BOD (slow) (5)	Perm **	constant	Perm ****	monthly	Perm ***	constant	Perm ***	constant
Chlorophyll	(negligible)	(negligible)	(negligible)	(negligible)	(negligible)	(negligible)	(negligible)	(negligible)
Phytoplankton	(negligible)	(negligible)	(negligible)	(negligible)	(negligible)	(negligible)	(negligible)	(negligible)

* For April through October, loads are the maximum allowable in the permit. For November through March, concentrations are the highest recorded during the SPSDOS

** Maximum allowable BOD5 is established as a limit on concentration only

*** Concentration modified to discharge at maximum allowable load for each facility

**** Concentrations modified to discharge at maximum allowable load in each of three seasons

The same overall sources of information used to develop current loads were used to establish maximum permitted loads. Discharge limits established in the permit were used as maximum allowable for each permit mentioned by facility.

Under NPDES permit conditions, flows must be reported, but limits are established for nutrient loads and not necessarily for facility flow rates. Each permit reports the maximum monthly flow designed for the facility (Qmaxmo). For Boston Harbor, LOTT, and Tamoshan, the monthly maximum flows were compiled from electronic DMRs for 1996-2006, and the highest flow for each month was compared with Qmaxmo. For all but January at Tamoshan, the maximum of the monthly maximum flows were below Qmaxmo, and Qmaxmo was used as the maximum permitted flow rate. For Seashore Villa, flows reported for all months of the year were above Qmaxmo listed in the active permit. Four months of the year had the same peak maximum monthly value, and that value was used as the maximum permitted flow rate. Figure I-7 presents the monthly flows for the maximum permitted scenario.

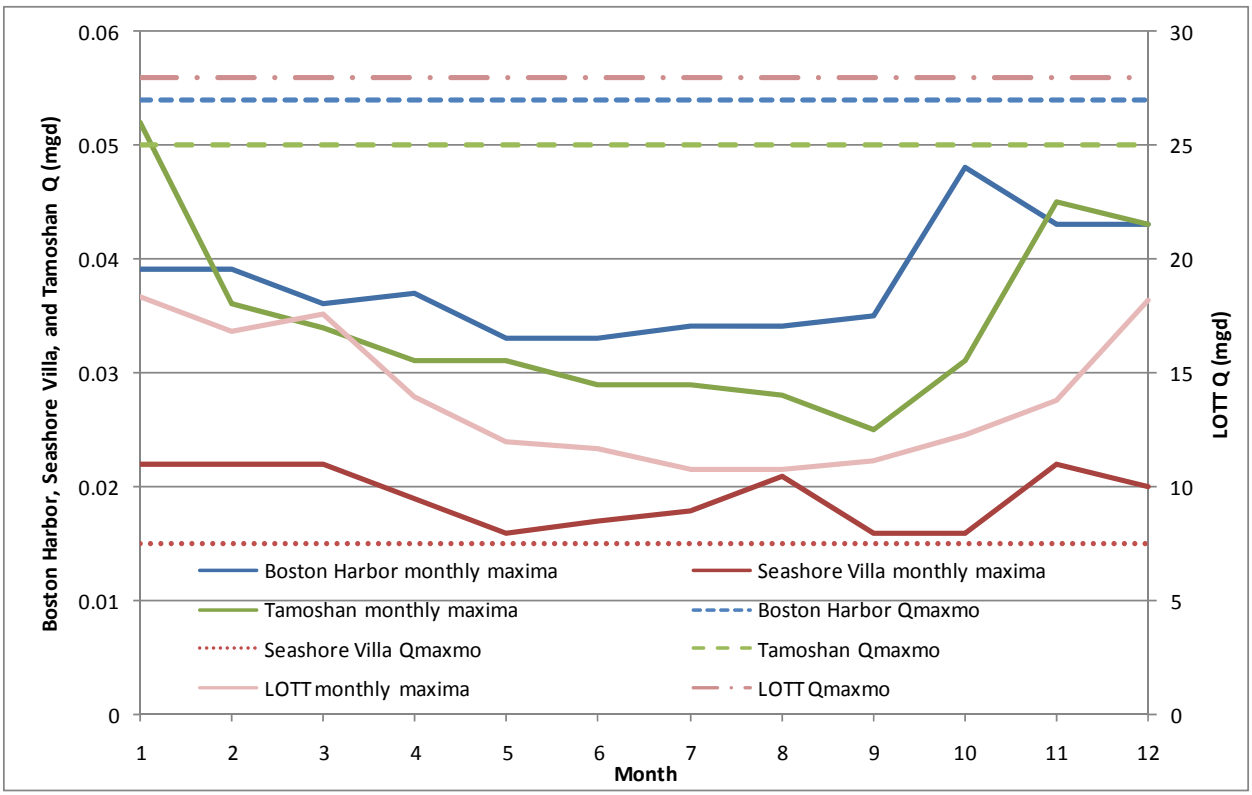

Figure I-7. Monthly flows at wastewater treatment plants.

Effluent temperature was not changed from the current condition. Salinity, chlorophyll, and phytoplankton were considered negligible, as for the current condition load estimates.

For a reasonable worst-case scenario, the minimum of the monthly dissolved oxygen values reported in DMRs for the period 1996-2006 was used for Boston Harbor and Tamoshan. Both facilities had the same minimum value (5.3 mg/L), which also was used for Seashore Villa. Because of the change in the LOTT process in 2005 and lack of relevant data in the electronic monthly DMRs, data from the recent South Puget Sound Dissolved Oxygen Study were used. The minimum value recorded at the plant (7.2 mg/L) was used as a constant value.

To estimate nitrogen levels in the maximum permitted discharges, a combination of the NPDES permit limits, monthly DMR results, and results from the South Puget Sound Dissolved Oxygen Study were used. Boston Harbor reports ammonium but does not monitor nitrate+nitrite or TKN, with which to calculate the organic nitrogen fraction. Seashore Villa and Tamoshan are not required to monitor nitrogen levels. For each plant, the maximum dissolved inorganic nitrogen concentration recorded during the South Puget Sound Dissolved Oxygen Study was identified, and the actual ammonium, nitrate+nitrite, and organic nitrogen for that date were used as a reasonable worst-case level. Within a given plant, the variability in dissolved inorganic nitrogen over time was low, but plant-to-plant differences were significant (Roberts et al., 2008).

A different approach was used for LOTT, which has a permit limit for load of total inorganic nitrogen (TIN), equivalent to dissolved inorganic nitrogen. LOTT can discharge no more than 288 lbs/day for June through September, with a TIN concentration <3 mg/L. For April, May, and October, LOTT can discharge no more than 338 lbs/day with a TIN concentration <3 mg/L. Because flows were set to a constant discharge equivalent to the Qmaxmo, the equivalent inorganic nitrogen concentrations were limited to no more than levels necessary such that the facility does not exceed the load limits. The calculated concentrations, 1.23 and 1.45 mg/L, are below 3 mg/L but necessary to avoid exceeding the load limits. Because actual flows are lower than Qmaxmo, LOTT's effluent may contain TIN values above 1.23 and 1.45 mg/L and still meet permitted load limits; these values are not intended to establish new concentration limits.

The model requires the ammonium and nitrate+nitrite fractions. These were estimated using the seasonal average fraction of nitrate+nitrite compared with dissolved inorganic nitrogen (87.1% from April through October and 61.8% from November through March) from the 1996-2006 DMRs.

LOTT's permit does not include a TIN load limit for the winter (November through March) period. For this time, the highest DIN concentration measured during the South Puget Sound Dissolved Oxygen Study was used.

The monthly DMRs were used to estimate peak organic nitrogen concentrations at LOTT. For the period 1996-2006, monthly organic nitrogen concentrations were calculated as the difference between TKN and ammonium. Maximum monthly average values were calculated, and the values were averaged over the winter (November through March) and summer (April through October) seasons.

Plants are not required to monitor effluent phosphorus or organic carbon levels, and the South Puget Sound Dissolved Oxygen Study values for each plant were used. Monthly values were compiled, and the maximum of the monthly values was used as a constant value over the simulation period to represent maximum levels.

Each plant has limits for 5-day BOD. Boston Harbor's permit limits are in terms of concentration, so the permit limit (30 mg/L) was used as the constant maximum permissible discharge. Seashore Villa and Tamoshan both have 5-day BOD load limits (3.8 and 11 lbs/day, respectively) and the concentrations cannot be higher than 30 mg/L. At the Qmaxmo flows, a concentration of 30 mg/L would exceed the load limits. Therefore, the equivalent 5-day BOD concentrations were adjusted downward such that both plants discharge BOD loads at the maximum allowable under the permit conditions.

LOTT's permit includes seasonal limits for both load and concentration of 5-day BOD. From June through September, LOTT cannot discharge loads above 1050 lbs/day or concentrations above 9 mg/L. For April, May, and October, loads cannot be more than 1251 lbs/day and concentrations cannot exceed 10 mg/L. Between November and March, loads cannot be more than 5640 lbs/day and concentrations cannot exceed 30 mg/L. Discharging at the maximum flow (Qmaxmo), the maximum concentrations would yield loads above the limits. Therefore, the concentrations were adjusted downward so that the facility discharges at the maximum load allowable under the permit load conditions during each of the three seasons. As with TIN, these adjusted concentrations are not intended as revised limits but were established to represent maximum loads appropriately.

Because the model requires ultimate BOD, the 5-day BOD values were converted to ultimate BOD as described above for current loads.

Summary

Loads for tributaries and wastewater treatment plants discharging to Budd Inlet were developed for natural conditions, current conditions, and maximum permitted levels. Five scenarios were evaluated using the Budd Inlet and Capitol Lake water quality models.

References

Aura Nova Consultants, Inc., Brown and Caldwell, Evans-Hamilton, J.E. Edinger and Associates, Ecology, and the University of Washington Department of Oceanography. 1998. Budd Inlet Scientific Study Final Report. Prepared for the LOTT Partnership, Olympia, Washington

Roberts, M., J. Bos, and S. Albertson. 2008. South Puget Sound Dissolved Oxygen Study: Interim Data Report. Washington State Department of Ecology Publication No. 08-03-037.

Chapra, S.C. 1997. Surface Water Quality Modeling. McGraw-Hill Companies, Inc. New York.