Appendix L. Initial Optimization Phase 2 (Opt2) Model Scenarios

This appendix presents the nutrient loading associated with initial Optimization Phase 2 Scenarios.

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Introduction

Scenario 5e from Optimization Phase 1 (Opt1) (Ahmed et al. 2021) was one of the primary scenarios that informed the development of new model scenarios for Optimization Phase 2 (Opt2). These scenarios involve reductions in anthropogenic nutrient loads. Here, and in other parts of this report, “anthropogenic” refers to local and regional human loads or influence.

Scenario 5e involved a 65% reduction in anthropogenic total nitrogen (TN) and total organic carbon (TOC) loads and wastewater treatment plant (WWTP) effluent total inorganic nitrogen limits of 3 mg/L year-round, achieved through Biological Nitrogen Removal (BNR) at all WWTPs (Ahmed et al. 2021). In this phase, we wanted to develop a new set of scenarios that involved a similar overall percent reduction in nutrients as Scenario 5e, but with variations in where these reductions were applied. For example, instead of applying a 65% reduction to anthropogenic nutrient loads to all watersheds, we wanted to test the impact of having higher reductions in larger watersheds relative to smaller watersheds and higher reductions in watersheds in more sensitive inlets and basins relative to other regions. Similarly, instead of applying BNR3 year-round to all WWTPs, we wanted to test different BNR frameworks with less treatment at some facilities and/or during some seasons relative to others.

The outcome of this process was the development of several ‘watershed frameworks’ and ‘WWTP frameworks’ involving different combinations of total nitrogen (TN) and total organic carbon (TOC) reductions in the watershed and WWTP nutrient loads. Each Opt2 model scenario involved pairing a ‘watershed framework’ with a ‘WWTP framework’ to create an initial set of Opt2 model scenarios. Dissolved oxygen (DO) noncompliance was evaluated for each of these scenarios. This appendix includes the nutrient loads and DO noncompliance associated with this initial set of Opt2 scenarios. The results of this initial set of scenarios informed the development of the ‘refined’ set of Opt2 modeling scenarios (Opt2_1 through Opt2_10), which are discussed in the main report.

All model scenarios described in this appendix were run for the year 2014 and involved only nutrient reductions to watersheds and marine point sources discharging to WA waters of the Salish Sea. Canadian watersheds and point sources, as well as all other model boundary conditions (ocean input and meteorological forcings), remained the same as in the existing 2014 model scenario. The year 2014 is the only modeled year in Opt1 (Ahmed et al. 2021) that included King County’s Brightwater WWTP, which began operation in September 2011.

WWTP Frameworks

Five different WWTP Frameworks (Frameworks A through E) were developed, each one representing different levels of seasonal BNR treatment to be applied to WWTPs with marine outfalls entering WA waters of the Salish Sea. BNR treatment was specified in the SSM model input files in terms of the concentration limits of dissolved inorganic nitrogen (DIN) and carbonaceous biological oxygen demand ($CBOD_5$) in WWTP effluent. BNR treatment was specified in the SSM model input files in terms of the concentration limits of dissolved inorganic nitrogen (DIN) and carbonaceous biological oxygen demand ($CBOD_5$) in WWTP effluent. These BNR levels were applied by setting WWTP effluent DIN concentrations to 3 mg/L, 5 mg/L, and 8 mg/L relative to existing 2014 DIN concentrations. All levels of BNR treatment were associated with setting an effluent limit of 8 mg/L for carbonaceous biological oxygen demand ($CBOD_5$). These levels were based on a study that consisted of a technical and economic evaluation of nutrient removal at WWTPs that involved BNR levels of 3 to 8 mg/L of DIN (Tetra Tech 2011). These three BNR levels are often expressed in shorthand as BNR3, BNR5, and BNR8 to represent effluent DIN concentrations of 3 mg/L, 5 mg/L, and 8 mg/L, respectively.

Seasonal BNR treatment involved applying different BNR levels in different seasons. The three seasons include: 'hot months' (July through September), 'warm months' (April through June, plus October), and 'cool months' (November through March). Since the lowest DO levels in Puget Sound are primarily observed during the hot summer months, the idea was to test the impact on DO noncompliance of having higher levels of WWTP effluent treatment during more critical times (hot and/or warm months) relative to less critical times (cool months).

The following WWTP Frameworks were developed:

- **Framework A**: This framework represents the 'minimum' seasonal BNR treatments that we wanted to test where all U.S. WWTPs were set to BNR5 in hot months and BNR8 in warm and cool months.
- **Framework B**: This framework was designed to achieve the same overall load reductions as Framework A but with a higher level of nitrogen removal during hot and warm months and less removal during cool months. It was developed by first setting all U.S. WWTPs to BNR3 in hot months and BNR5 in warm months and then calculating the DIN concentrations needed in cool months to reach a similar magnitude of load reductions as in Framework A. The DIN concentration in these cool months was 10.4 mg/L.
- **Framework C**: This framework represents the 'maximum' seasonal BNR treatments that we wanted to test where all U.S. WWTPs were set to BNR3, BNR5, and BNR8 in hot, warm, and cool months, respectively.
- **Framework D**: This was a variation of Framework C to test the impact of only implementing BNR treatment at U.S. WWTP facilities discharging to specific basins while holding WWTPs in other basins at existing 2014 loads with no additional treatment. BNR levels of BNR3, BNR5, and BNR8 in hot, warm, and cool months, respectively, were only applied to WWTPs in the Northern Bays, Whidbey Basin, Main Basin, and South Sound. WWTP's effluent in all other basins (Hood Canal, Admiralty, SJF, and SOG) was held at existing 2014 loads.

- **Framework E**: This was another variation of Framework C to test the impact of not implementing BNR treatment in the cool months at those WWTPs that are combined sewer facilities. For all other WWTPs, BNR levels were set to BNR3, BNR5, and BNR8 in hot, warm, and cool months, respectively. The combined sewer facilities had these same BNR levels applied during hot and warm months (BNR3 and BNR5, respectively), but their cool month effluent levels were held at existing 2014 loads with no additional treatment.

All WWTP frameworks and their associated TN loads (by basin) are presented in Table L-1. Industrial facility loads are also included in basin totals, but these loads are held at existing 2014 loads across all WWTP frameworks.

Table L-1. Average annual 2014 total nitrogen (TN) daily loads[1], by basin, from U.S. marine point sources[2] under existing conditions and under the different WWTP Frameworks.

		Existing Total TN load (kg/day)	Reference TN load (kg/day)	Existing anthropogenic TN load (kg/day)	Framework AS anthropogenic TN load (kg/day)	Framework B anthropogenic TN load (kg/day)	Framework CS anthropogenic TN load (kg/day)	Framework D anthropogenic TN load (kg/day)	Framework E anthropogenic TN load (kg/day)
WWTP Framework description		2014 marine point source total existing loads	2014 marine point source reference loads	2014 marine point source anthropogenic loads	Minimum seasonally varying treatment	Higher treatment in hot months and less in cool months	Maximum seasonally varying treatment	Maximum seasonally varying treatment only at WWTPs in basins 1–4	Maximum seasonally varying treatment; no treatment in cool months at combined sewer failities[3]
BNR treatment levels in different seasons[4]		Existing treatment	N/A	Existing treatment	Hot: BNR5 Warm: BNR8 Cool: BNR8	Hot: BNR3 Warm: BNR5 Cool: BNR10.4	Hot: BNR3 Warm: BNR5 Cool: BNR8	Hot: BNR3 Warm: BNR5 Cool: BNR8	Hot: BNR3 Warm: BNR5 Cool: BNR8
Basin	**Basin #**								
Northern Bays	**1**	1,310	13.7	1,296	604	599	543	543	741
Whidbey Basin	**2**	3,810	16.9	3,793	1,550	1,540	1,370	1,370	1,880
Main Basin	**3**	27,500	187	27,313	9,250	9,140	7,980	7,980	10,900
South Sound	**4**	3,270	22.6	3,247	1,220	1,190	1,090	1,090	1,120
Hood Canal	**5**	1.02	0.0064	1.01	0.837	0.800	0.772	1.01	0.772
Admiralty	**6**	67.4	1.75	65.7	56.9	57.6	56.0	65.7	56.0
SJF - US	**7**	290	1.50	289	182	184	170	289	208
SOG - US	**8**	697	10.7	686	508	505	490	686	525
Total TN Load (US)		**36,900**	**254**	**36,700**	**13,400**	**13,200**	**11,700**	**12,000**	**15,400**
Overall percent reduction in anthropogenic TN loads					**63.5%**	**64.0%**	**68.1%**	**67.3%**	**58.1%**

[1] All loads are rounded to three significant digits.

[2] While the loads in this table include all marine point sources (industrial and WWTPS), reductions due to BNR treatment are only applied to WWTPs and industrial facilities are held at existing 2014 loads.

[3] Combined sewer facilities WWTPs include the following: Anacortes, Bellingham, Bremerton, Everett, West Point, LOTT, Mt Vernon, Port Angeles, and Snohomish.

[4] The different seasons are represented by: Hot months = July – September, Warm months = April – June + October, Cool months = November – March.

Watershed Frameworks

Several different Watershed Frameworks were developed (Frameworks F through H), and each framework had sub-frameworks with slight variations, e.g., Framework F1, F2, and F3 are sub-frameworks under 'Framework F'. These watershed frameworks represented different levels of reductions in the anthropogenic watershed TN and TOC loads. Within each framework, percent reductions varied based on the size of each watershed and/or the geographic region or basin in the Salish Sea into which it flows. These reductions were applied only to U.S. watersheds year-round. The following Watershed Frameworks were developed:

- **F series frameworks:** these frameworks represent the estimated minimum watershed TN load reductions needed. F1, F2, and F3 represent frameworks that all result in similar levels of overall anthropogenic TN reductions (~50%), but each one has a slightly different distribution of these percent reductions between different watershed sizes and basins. All three frameworks implement greater reductions in watersheds that have the largest existing loads and implement greater reductions in the following four basins (relative to the other basins): Northern Bays, Whidbey Basin, Main Basin, and South Sound. F2 further increases the percent load reductions in South Sound relative to F1, and F3 increases the percent load reductions in Whidbey Basin relative to F1.
- **G series frameworks:** these frameworks represent the estimated maximum watershed TN load reductions needed. The G series frameworks represent greater overall percent reductions relative to the F series frameworks (~62%) by increasing the percent reductions in the following basins (relative to the F-series): Northern Bays, Whidbey, Main Basin, and South Sound. Like the F series framework, G1, G2, and G3 implement greater reductions in watersheds that have the largest existing loads and implement greater reductions in the following four basins (relative to the other basins): Northern Bays, Whidbey Basin, Main Basin, and South Sound. G2 further increases the percent load reductions in South Sound relative to G1, and G3 increases the percent load reductions in Whidbey Basin relative to G1.
- **H series frameworks:** these frameworks test sensitivity to DO when watersheds entering certain basins are held at existing 2014 loads, i.e., with no reductions in their nutrient loads. H1 and H2 have the same level of percent reductions as the G1 framework for watersheds in some basins while keeping watersheds in the remaining basins at the existing 2014 load. H1 keeps watersheds entering the Strait of Juan the Fuca (SJF) and the Strait of Georgia (SOG) at existing levels, while H2 keeps watersheds entering SJF, SOG, as well as Hood Canal and Admiralty Inlet at existing levels.

Table L-2. Average annual 2014 total nitrogen (TN) daily loads*, by basin, from U.S. watersheds under existing conditions and under the different Watershed Frameworks.

		Existing Total TN load (kg/day)	Reference TN load (kg/day)	Existing Anthro. TN load (kg/day)	F1 Anthro. TN load (kg/day)	F2 Anthro. TN load (kg/day)	F3 Anthro. TN load (kg/day)	G1 Anthro. TN load (kg/day)	G2 Anthro. TN load (kg/day)	G3 Anthro. TN load (kg/day)	H1 Anthro. TN load (kg/day)	H2 Anthro. TN load (kg/day)
Watershed Framework description		No reductions	No reductions	No reductions	reductions in all basins with more in basins 1–4	Similar to F1, with additional reductions in South Sound	Similar to F1, with additional reductions in Whidbey	Increased reductions in all basins with more in basins 1–4	Similar to G1, with additional reductions in South Sound	Similar to G1, with additional reductions in Whidbey	Similar to G1 but no reductions in basins 7–8	Similar to G1 but no reductions in basins 5–8
Basin	**Basin #**											
Northern Bays	**1**	6,600	2,970	3,640	1,670	1,790	1,780	1,240	1,290	1,290	1,240	1,240
Whidbey Basin	**2**	19,200	12,500	6,750	3,040	3,260	2,520	2,250	2,350	1,880	2,250	2,250
Main Basin	**3**	8,510	3,920	4,600	2,160	2,320	2,300	1,600	1,710	1,670	1,600	1,600
South Sound	**4**	5,800	2,350	3,450	1,880	1,440	2,000	1,390	1,070	1,450	1,390	1,390
Hood Canal	**5**	2,020	908	1,110	699	749	742	518	556	539	518	1,110
Admiralty	**6**	116	14.6	102	64.1	68.7	68.1	47.5	63.7	61.9	47.5	102
SJF - US	**7**	1,150	501	650	409	438	435	303	407	395	650	650
SOG - US	**8**	1,320	178	1,140	719	771	764	533	715	694	1,140	1,140
Total TN Load (US)		**44,700**	**23,300**	**21,400**	**10,600**	**10,800**	**10,500**	**7,830**	**8,090**	**7,900**	**8,790**	**9,430**
Overall percent reduction in anthropogenic TN loads					**50.5%**	**49.5%**	**50.9%**	**63.4%**	**62.2%**	**63.1%**	**58.9%**	**55.9%**

*All loads are rounded to three significant digits.

Anthro. = anthropogenic.

Combining Frameworks into Model Scenarios

Model scenarios were created by pairing watershed frameworks with WWTP frameworks and creating model input files that represent marine point sources and freshwater inputs that reflect these frameworks. Scenario 5e was recreated for Opt2 to reflect the updated loading estimates for watershed and point source nutrient loads (as described in Appendix B and C, respectively). We also added a new scenario, Scenario 5f, which was built upon Scenario 5e with BNR3 year-round but with additional reductions in anthropogenic watershed loads in those watersheds that discharged to sensitive inlets that continued to have DO noncompliances under all scenarios. All model scenarios were run for the year 2014.

Table L-3 presents the sequence in which we ran model scenarios. In Step 1, each of the watershed frameworks was run in combination with WWTP framework C. This helped in the assessment of the best watershed framework with the least DO noncompliance. Once the best watershed framework was selected, it was evaluated against all the WWTP frameworks in Step 2 to assess the best WWTP framework that resulted in the least DO noncompliance. Finally, in Step 3, Scenario 5e was evaluated.

Table L-3. Sequence of model scenarios run to identify the best combination of watershed and WWTP frameworks.

Step	Intent	Opt2 Model Scenario	Framework Combinations
Step 1	Find the 'best watershed framework' by pairing it with a single WWTP framework (WWTP Framework C).	F1-C F2-C F3-C G1-C G2-C G3-C H1-C[1] H2-C	Watershed Framework F1 + WWTP Framework C Watershed Framework F2 + WWTP Framework C Watershed Framework F3 + WWTP Framework C Watershed Framework G1 + WWTP Framework C Watershed Framework G2 + WWTP Framework C Watershed Framework G3 + WWTP Framework C Watershed Framework H1[1] + WWTP Framework C Watershed Framework H2 + WWTP Framework C
Step 2	Find the 'best WWTP framework' by pairing the 'best watershed framework'[1] from Step 1 with each of the WWTP frameworks.	H1-A H1-B H1-C[2] H1-D H1-E	Watershed Framework H1 + WWTP Framework A Watershed Framework H1 + WWTP Framework B Watershed Framework H1 + WWTP Framework C[2] Watershed Framework H1 + WWTP Framework D Watershed Framework H1 + WWTP Framework E
Step 3	Re-run this scenario from Opt1, but with updated Opt2 watershed loads.	Scen5e_BNR3	65% reduction in all anthropogenic watershed loads + BNR3 year-round at all WWTPs
Step 4	Variation of Scenario 5e_BNR3 with additional watershed reductions.	Scen5f_BNR3	65% reduction in anthropogenic watershed loads + 90% reduction in watershed Anthro loads in recalcitrant regions + BNR3 year-round at all WWTPs

[1] Both watershed frameworks H1 and G1 resulted in the lowest overall DO noncompliance when combined with WWTP framework C. However, H1 was selected as the 'best watershed framework' to use in Step 2 since it involved fewer nitrogen reductions than G1.

[2] This model scenario (H1-C) was already run in Step 1 and was not repeated but is listed here for completeness.

Nutrient Loading

This section presents nutrient loads for the initial set of Opt2 model scenarios as average annual daily loads (units of kg/day) and as total annual loads (units of kg/year).

Loads to WA waters of the Salish Sea

Figure L-1 and Table L-4 compare the relative contribution of watershed and point source total annual TN loads associated with each initial Opt2 modeling scenario. These loads represent the sum of all loads discharging to Washington waters of the Salish Sea.

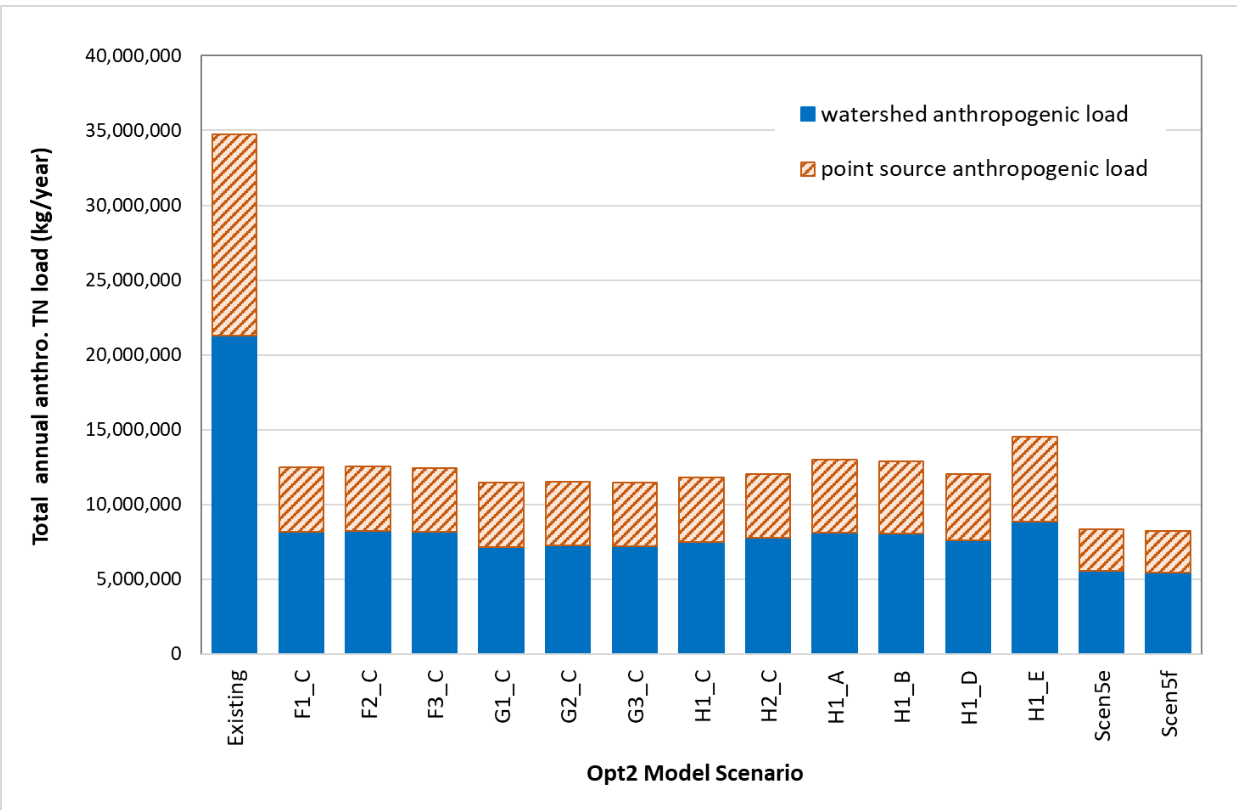

Figure L-1. Anthropogenic (anthro.) watershed and point source total annual TN loads for each initial Opt2 model scenario for the year 2014, discharging to WA waters of the Salish Sea.

Table L-4. Total annual total nitrogen (TN) loads* associated with each initial Opt2 model scenario for the year 2014, discharging to WA waters of the Salish Sea.

Opt2 Model Scenario	Total load (thousands of kg/year TN)	Watershed load (thousands of kg/year TN)	Point source load (thousands of kg/year TN)	Total anthro. load (thousands of kg/year TN)	Watershed anthro. load (thousands of kg/year TN)	Point source anthro. load (thousands of kg/year TN)	Total % reduction in anthro. TN loads	% reduction in watershed anthro. TN loads	% reduction in point source anthro. TN loads
Reference	8,630	8,537	93	0	0	0	100%	100%	100%
Existing	29,930	16,380	13,550	21,300	21,300	13,460	0%	0%	0%
F1_C	16,810	12,440	4,374	8,180	8,180	4,281	62%	62%	68%
F2_C	16,870	12,500	4,374	8,240	8,240	4,281	61%	61%	68%
F3_C	16,780	12,410	4,374	8,150	8,150	4,281	62%	62%	68%
G1_C	15,790	11,420	4,374	7,160	7,160	4,281	66%	66%	68%
G2_C	15,890	11,520	4,374	7,260	7,260	4,281	66%	66%	68%
G3_C	15,810	11,440	4,374	7,180	7,180	4,281	66%	66%	68%
H1_C	16,140	11,770	4,374	7,510	7,510	4,281	65%	65%	68%
H2_C	16,380	12,010	4,374	7,750	7,750	4,281	64%	64%	68%
H1_A	16,750	11,770	4,980	8,120	8,120	4,887	62%	62%	64%
H1_B	16,690	11,770	4,923	8,060	8,060	4,830	62%	62%	64%
H1_D	16,260	11,770	4,492	7,630	7,630	4,399	64%	64%	67%
H1_E	17,500	11,770	5,726	8,870	8,870	5,633	58%	58%	58%
Scen5e	14,180	11,290	2,889	5,550	5,550	2,796	74%	74%	79%
Scen5f	14,070	11,180	2,889	5,440	5,440	2,796	74%	74%	79%

*All loads are rounded to four significant digits.

Figure L-2 and Table L-5 compare the relative contribution of watershed and point source total annual TOC loads associated with each initial Opt2 modeling scenario. These loads represent the sum of all loads discharging to Washington waters of the Salish Sea.

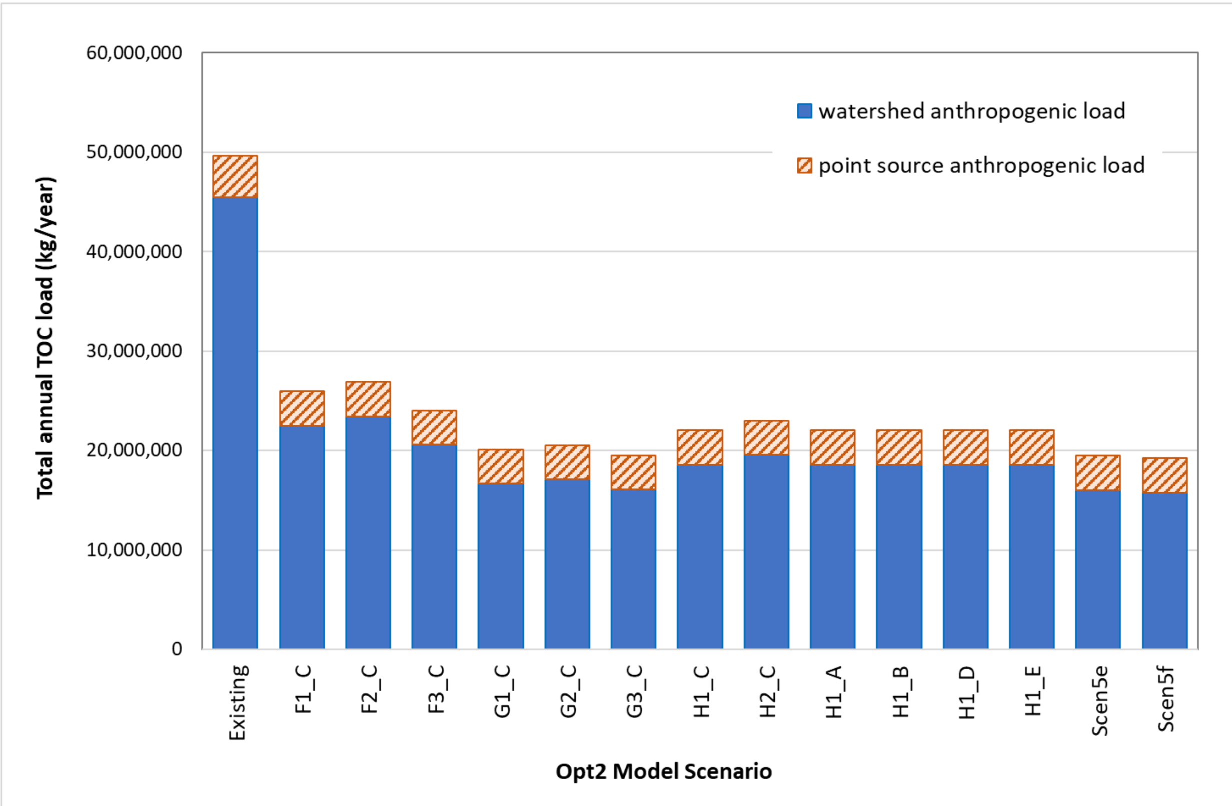

Figure L-2. Anthropogenic watershed and point source total annual TOC loads for each initial Opt2 model scenario for the year 2014, discharging to WA waters of the Salish Sea.

Table L-5. Total annual total nitrogen (TOC) loads* associated with each initial Opt2 model scenario for the year 2014, discharging to WA waters of the Salish Sea.

Opt2 Model Scenario	Total load (thousands of kg/year TOC)	Watershed load (thousands of kg/year TOC)	Point source load (thousands of kg/year TOC)	Total anthro. load (thousands of kg/year TOC)	Watershed anthro. load (thousands of kg/year TOC)	Point source anthro. load (thousands of kg/year TOC)	% reduction in total anthro. TOC loads	% reduction in watershed anthro. TOC loads	% reduction in point source anthro. TOC loads
Reference	73,700	72,540	1,160	0	0	0	100%	100%	100%
Existing	123,400	118,000	5,376	49,700	45,460	4,216	0%	0%	0%
F1_C	99,630	95,020	4,607	25,930	22,480	3,447	48%	51%	18%
F2_C	100,600	95,990	4,607	26,900	23,450	3,447	46%	48%	18%
F3_C	97,750	93,140	4,607	24,050	20,600	3,447	52%	55%	18%
G1_C	93,800	89,190	4,607	20,100	16,650	3,447	60%	63%	18%
G2_C	94,240	89,630	4,607	20,540	17,090	3,447	59%	62%	18%
G3_C	93,230	88,620	4,607	19,530	16,080	3,447	61%	65%	18%
H1_C	95,730	91,120	4,607	22,030	18,580	3,447	56%	59%	18%
H2_C	96,690	92,080	4,607	22,990	19,540	3,447	54%	57%	18%
H1_A	95,730	91,120	4,607	22,030	18,580	3,447	56%	59%	18%
H1_B	95,730	91,120	4,607	22,030	18,580	3,447	56%	59%	18%
H1_D	95,750	91,120	4,629	22,050	18,580	3,469	56%	59%	18%
H1_E	95,770	91,120	4,648	22,070	18,580	3,488	56%	59%	17%
Scen5e	93,170	88,560	4,607	19,470	16,020	3,447	61%	65%	18%
Scen5f	92,910	88,300	4,607	19,210	15,760	3,447	61%	65%	18%

* All loads are rounded to four significant digits.

Loads by basin

Tables L-6 and L-7 present total annual TN and TOC loads from watersheds and point sources, respectively, entering different basins within WA waters of the Salish Sea under each Opt2 model scenario.

Table L-6. Anthropogenic (anthro.) total annual total nitrogen (TN) loads* entering different basins for each initial Opt2 model scenario in the year 2014.

Opt2 Scenario	Source	Northern Bays (thousands of kg/year TN)	Whidbey Basin (thousands of kg/year TN)	Main Basin (thousands of kg/year TN)	South Sound (thousands of kg/year TN)	Hood Canal (thousands of kg/year TN)	Admiralty (thousands of kg/year TN)	SJF - US (thousands of kg/year TN)	SOG - US (thousands of kg/year TN)
Existing	watersheds	1,330	2,460	1,690	1,260	407	37.3	238	419
Existing	point sources	474	1,380	10,000	1,180	0.371	24.1	105	251
F1_C	watersheds	610	1,110	800	689	256	23.5	150	263
F1_C	point sources	199	502	2,920	396	0.282	20.5	62.0	180
F2_C	watersheds	650	1,190	850	529	274	25.2	161	282
F2_C	point sources	199	502	2,920	396	0.282	20.5	62.0	180
F3_C	watersheds	650	920	840	729	272	24.9	159	280
F3_C	point sources	199	502	2,920	396	0.282	20.5	62.0	180
G1_C	watersheds	450	820	590	509	190	17.4	111	195
G1_C	point sources	199	502	2,920	396	0.282	20.5	62.0	180
G2_C	watersheds	470	860	630	389	204	23.4	149	262
G2_C	point sources	199	502	2,920	396	0.282	20.5	62.0	180
G3_C	watersheds	470	680	610	529	198	22.7	145	254
G3_C	point sources	199	502	2,920	396	0.282	20.5	62.0	180
H1_C	watersheds	450	820	590	509	190	17.4	238	419
H1_C	point sources	199	502	2,920	396	0.282	20.5	62.0	180
H2_C	watersheds	450	820	590	509	407	37.3	238	419
H2_C	point sources	199	502	2,920	396	0.282	20.5	62.0	180
H1_A	watersheds	450	820	590	509	190	17.4	238	419
H1_A	point sources	221	569	3,380	442	0.306	20.8	66.4	186
H1_B	watersheds	450	820	590	509	190	17.4	238	419
H1_B	point sources	219	565	3,340	432	0.291	21.1	67.0	185
H1_D	watersheds	450	820	590	509	190	17.4	238	419
H1_D	point sources	199	502	2,920	396	0.371	24.1	105	251

Opt2 Scenario	Source	Northern Bays (thousands of kg/year TN)	Whidbey Basin (thousands of kg/year TN)	Main Basin (thousands of kg/year TN)	South Sound (thousands of kg/year TN)	Hood Canal (thousands of kg/year TN)	Admiralty (thousands of kg/year TN)	SJF - US (thousands of kg/year TN)	SOG - US (thousands of kg/year TN)
H1_E	watersheds	450	820	590	509	190	17.4	238	419
H1_E	point sources	271	687	3,980	405	0.282	20.5	75.8	192
Scen5e	watersheds	460	860	590	459	143	13.1	84.0	147
Scen5e	point sources	145	337	1,800	284	0.209	17.6	47.8	163
Scen5f	watersheds	460	860	540	429	107	13.1	84.0	147
Scen5f	point sources	145	337	1,800	284	0.209	17.6	47.8	163

*All loads are rounded to three significant digits.

Table L-7. Anthropogenic (anthro.) total annual total organic carbon (TOC) loads* entering different basins for each initial Opt2 model scenario in the year 2014.

Opt2 Scenario	Source	Northern Bays (thousands of kg/year TOC)	Whidbey Basin (thousands of kg/year TOC)	Main Basin (thousands of kg/year TOC)	South Sound (thousands of kg/year TOC)	Hood Canal (thousands of kg/year TOC)	Admiralty (thousands of kg/year TOC)	SJF - US (thousands of kg/year TOC)	SOG - US (thousands of kg/year TOC)
Existing	watersheds	6,120	24,200	6,000	3,760	1,580	210	3,240	370
Existing	point sources	228	392	2,540	221	0.129	534	140	163
F1_C	watersheds	2,740	11,600	2,700	2,040	990	132	2,040	230
F1_C	point sources	192	301	1,970	171	0.127	534	135	146
F2_C	watersheds	2,930	12,400	2,900	1,570	1,070	142	2,180	250
F2_C	point sources	192	301	1,970	171	0.127	534	135	146
F3_C	watersheds	2,920	9,000	2,900	2,160	1,060	140	2,160	250
F3_C	point sources	192	301	1,970	171	0.127	534	135	146
G1_C	watersheds	2,020	8,600	2,000	1,510	740	98.0	1,510	170
G1_C	point sources	192	301	1,970	171	0.127	534	135	146
G2_C	watersheds	2,150	8,400	2,200	1,160	790	132	2,020	230
G2_C	point sources	192	301	1,970	171	0.127	534	135	146

Opt2 Scenario	Source	Northern Bays (thousands of kg/year TOC)	Whidbey Basin (thousands of kg/year TOC)	Main Basin (thousands of kg/year TOC)	South Sound (thousands of kg/year TOC)	Hood Canal (thousands of kg/year TOC)	Admiralty (thousands of kg/year TOC)	SJF - US (thousands of kg/year TOC)	SOG - US (thousands of kg/year TOC)
G3_C	watersheds	2,120	7,200	2,100	1,570	770	128	1,970	220
G3_C	point sources	192	301	1,970	171	0.127	534	135	146
H1_C	watersheds	2,020	8,600	2,000	1,510	740	98.0	3,240	370
H1_C	point sources	192	301	1,970	171	0.127	534	135	146
H2_C	watersheds	2,020	8,600	2,000	1,510	1,580	210	3,240	370
H2_C	point sources	192	301	1,970	171	0.127	534	135	146
H1_A	watersheds	2,020	8,600	2,000	1,510	740	98.0	3,240	370
H1_A	point sources	192	301	1,970	171	0.127	534	135	146
H1_B	watersheds	2,020	8,600	2,000	1,510	740	98.0	3,240	370
H1_B	point sources	192	301	1,970	171	0.127	534	135	146
H1_D	watersheds	2,020	8,600	2,000	1,510	740	98.0	3,240	370
H1_D	point sources	192	301	1,970	171	0.129	534	140	163
H1_E	watersheds	2,020	8,600	2,000	1,510	740	98.0	3,240	370
H1_E	point sources	207	325	1,970	173	0.127	534	135	146
Scen5e	watersheds	2,150	8,500	2,100	1,360	560	74.0	1,140	130
Scen5e	point sources	192	301	1,970	171	0.127	534	135	146
Scen5f	watersheds	2,150	8,500	2,000	1,290	470	74.0	1,140	130
Scen5f	point sources	192	301	1,970	171	0.127	534	135	146

*All loads are rounded to three significant digits.

Model Results

SSM results from the initial Opt2 model scenarios were primarily evaluated in terms of DO noncompliance. DO noncompliance algorithms and calculations followed the same methods as documented in Appendix F of Ahmed et al. (2021). Figure L-3 visually illustrates the area of DO noncompliance within different DO noncompliance magnitude ranges across all initial Op2 model scenarios.

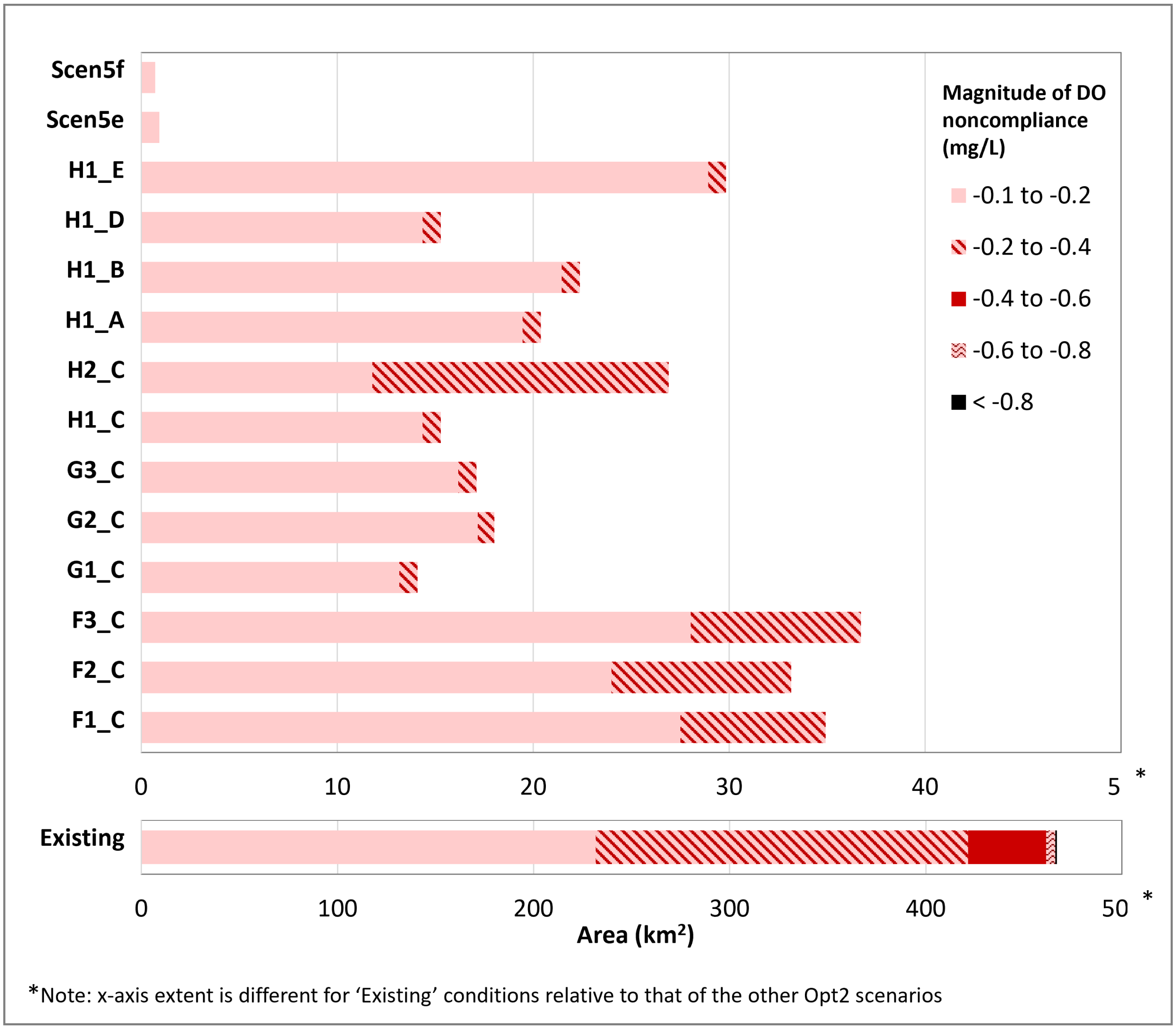

Figure L-3. Area of DO noncompliance and maximum magnitude of DO noncompliance associated with each initial Opt2 model scenario for the year 2014.

Figure L-3 shows that model scenarios G1_C, H1_C, and H1_D result in the least DO noncompliant area. H1 was identified as the 'best watershed framework' since it resulted in similar noncompliance as G1, but with lower effort than G1 in terms of anthropogenic nutrient reductions with no reductions from watersheds in basins 7 – 8. Additionally, we paid specific attention to H1_D, which showed only a slightly higher level of noncompliance compared to H1_C, but with no reductions in WWTPs located in basins 5 – 8 (i.e., effluent from these facilities is held at existing 2014 loads).

The starting point, or baseline scenario, for the refined set of Opt2 models scenarios, discussed in the main report, focused on further increasing the percent anthropogenic watershed reductions (relative to watershed framework H1) for select watersheds and then developing additional WWTP frameworks to pair with these watershed reductions with the intent to identify what levels and combinations of reductions are needed (and where) to achieve full DO noncompliance across all WA waters of the Salish Sea. Descriptions and details for the refined set of Opt2 model runs are included in the Methods and Results section of the main report.

References

Ahmed, A., C. Figueroa-Kaminsky, J. Gala, T. Mohamedali, S. McCarthy. 2021. Technical Memorandum: Puget Sound Nutrient Source Reduction Project Phase II – Optimization Scenarios (Year 1). Washington State Department of Ecology, Olympia, WA. https://www.ezview.wa.gov/Portals/_1962/Documents/PSNSRP/OptimizationScenarioTechMemo_9_13_2021.pdf.

Tetra Tech. 2011. Technical and Economic Evaluation of Nitrogen and Phosphorus Removal at Municipal Wastewater Treatment Facilities. Publication 11-10-060. Prepared for Washington State Department of Ecology, Olympia. https://apps.ecology.wa.gov/publications/SummaryPages/1110060.html.