Appendix O.
Assessment of Budd Inlet TMDL Open Boundary Load Allocation

This appendix describes the procedure for assessing compliance with the load allocation at the Budd Inlet open boundary. For definitions of terms, refer to the glossary in the main report.

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Background

Budd Inlet dissolved oxygen TMDL was completed in 2022 (Ecology 2022). This report contains load allocations at the Budd Inlet open boundary ("bubble allocation") for total nitrogen (TN), dissolved inorganic nitrogen (DIN), and total organic carbon (TOC). Table 28 contains the total (anthropogenic and natural) annual average daily load allocation for the Budd Inlet open boundary. Figure O-1 shows the location of the Budd Inlet (north of Olympia, WA) and the model grid used in the Generalized Environmental Modeling System for Surface waters (GEMSS) model. The location of the open boundary is also shown.

Figure O-1. Budd Inlet model grid showing open boundary.

Estimating Landward Loading for Different SSM Scenarios

Figure O-2 shows the Budd Inlet GEMSS model grid (pink) overlaid over the Salish Sea Model (SSM) grids (blue). The three grid elements of the SSM at the established Budd Inlet open boundary are highlighted in yellow.

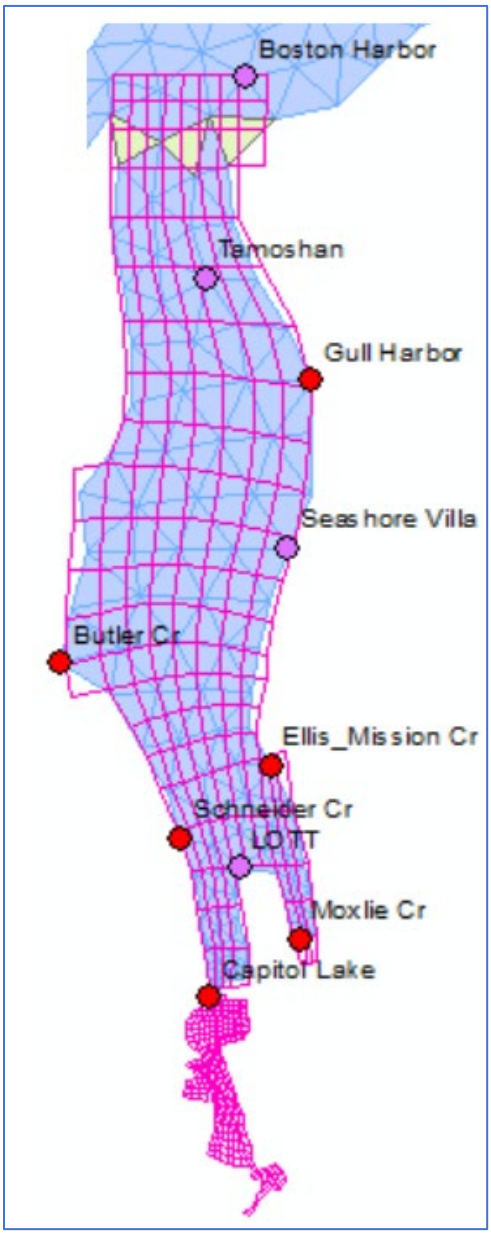

Figure O-2. Budd Inlet GEMSS model grid overlaid over Salish Sea FVCOM model grid.

Figure O-3a shows the three SSM grid elements that were considered to represent the Budd Inlet Open boundary. The SSM hydrodynamic model output for these three elements was used to estimate the flow across a horizontal plane (Figure O-3b, blue line) that represents the horizontal plane on which the seaward sides of these elements would be projected.

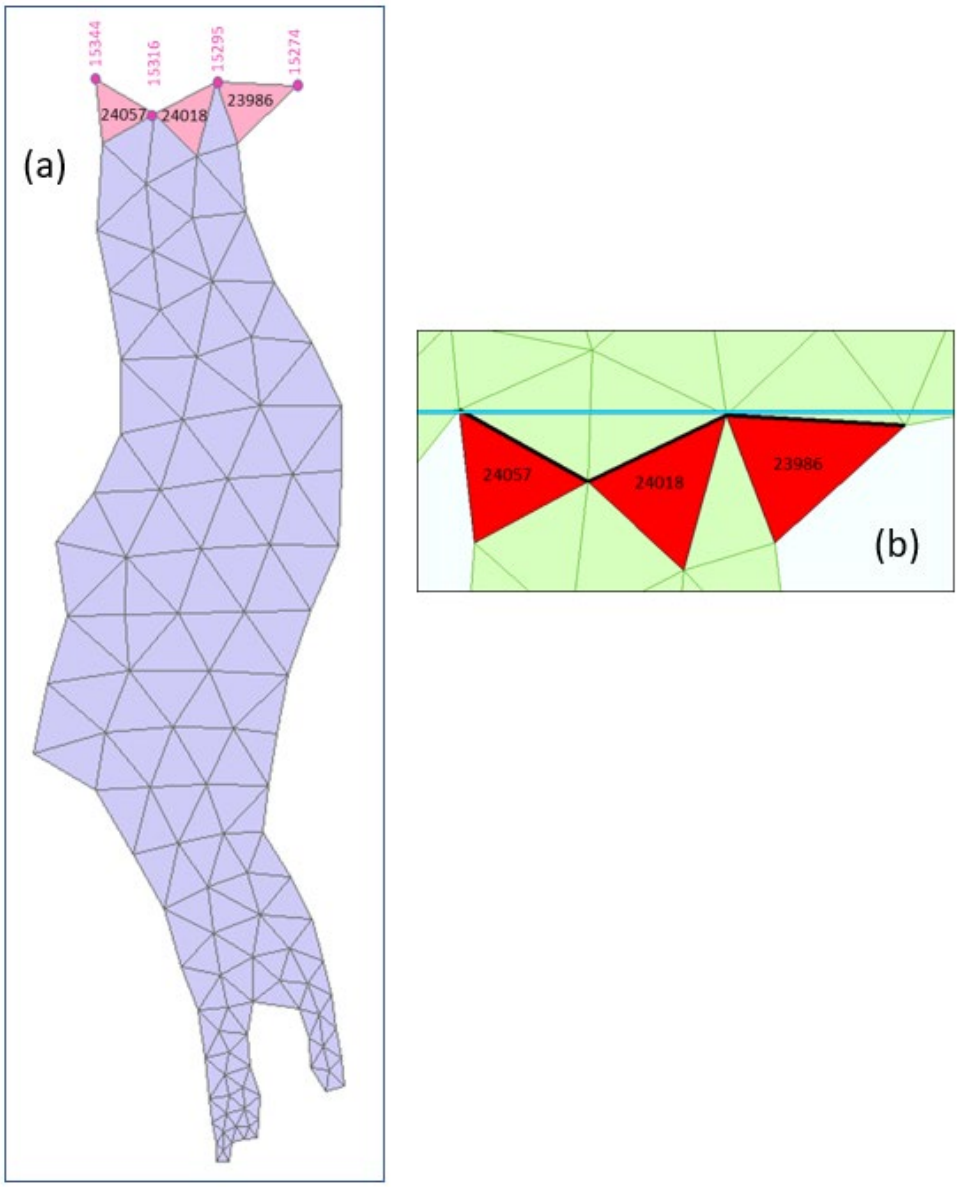

Figure O-3. (a) SSM model grid elements and nodes (pink triangles and dots) representing Budd Inlet's open boundary, as well as (b) horizontal projection (blue line) of the seaward sides of these elements (red).
The numbers within each element are the element numbers, while numbers in pink above the nodes are the node numbers.

The Salish Sea hydrodynamic model output was used to extract hourly northerly and easterly current velocity for each of the three elements, as well as hourly water surface elevations and bathymetry. The hourly difference between water surface elevations and bathymetry gives the hourly depth of the water column. This was divided into 10 layers based on known fractionations in each layer used in SSM. The depth of each layer times the length of the projected seaward element gives the hourly projected area for each layer.

This projected area times the current seaward velocity gives the hourly seaward flow for each layer of the three elements. Some of these hourly flows are negative, meaning they are landward.

The SSM output also contains hourly water quality concentrations for each layer of the model grid, but this output is for the nodes (see Figure O-3). To obtain hourly concentrations at the face of the projected element, the hourly concentrations at the two nodes associated with an element were averaged for each layer. This resultant hourly concentration was multiplied by the projected hourly element flow to calculate the hourly loading at the open boundary. The negative loads signify landward loads entering the Budd Inlet at the open boundary. These landward loads were added to give the total landward load for a particular parameter.

Assessing Compliance with Budd Inlet Open Boundary Load Allocation

Budd Inlet open boundary loads were calculated using the procedure in the previous section for existing, reference, and Scenario Opt2_8 as an example. During this evaluation, a scenario (labeled as "Opt2_8_BI_TMDLcap") was developed to check compliance with the Budd Inlet TMDL "bubble allocation (Ecology 2022). This scenario consisted of two parts: 1) loads that occurred in 2014 within Budd Inlet for watersheds and WWTP were kept the same unless they were in excess of load allocations and wasteload allocations in the Budd Inlet TMDL. 2) Loads outside Budd Inlet open boundary were kept the same as scenario Opt2_8.

Monthly average landward loads at the Budd Inlet open boundary were calculated for this scenario using the Salish Sea Model (SSM) output. This is then compared with SSM output for the reference condition to establish anthropogenic nutrient load at the Budd Inlet open boundary on a monthly average basis. The resultant annual average anthropogenic load is compared with the Budd Inlet open boundary load allocation established in Ecology (2022).

Table O-1 compares the annual average anthropogenic load allowed in the Budd Inlet total maximum daily load (TMDL) set in Ecology (2022) for the Budd Inlet open boundary and that in the Opt2_8_BI_TMDLcap scenario. The Budd Inlet TMDL loadings for the open boundary are met for this scenario.

Table O-1. Annual average anthropogenic load at Budd Inlet Open Boundary (lbs/day).

	TN	DIN	TOC	DOC
Budd Inlet TMDL	2010	1060	8180	3840
2014 Opt2_8_BI_TMDLcap	818	585	2288	1477

Scenario Opt2_8 with Budd Inlet sources capped at the Budd Inlet TMDL loads (Opt2_8_BI_TMDLcap) was compared with scenario Opt2_8 for days, area, and magnitude of DO noncompliance in WA waters. There was no difference between the two. Planview maps comparing noncompliance between these two scenarios are shown in Figure O-4.

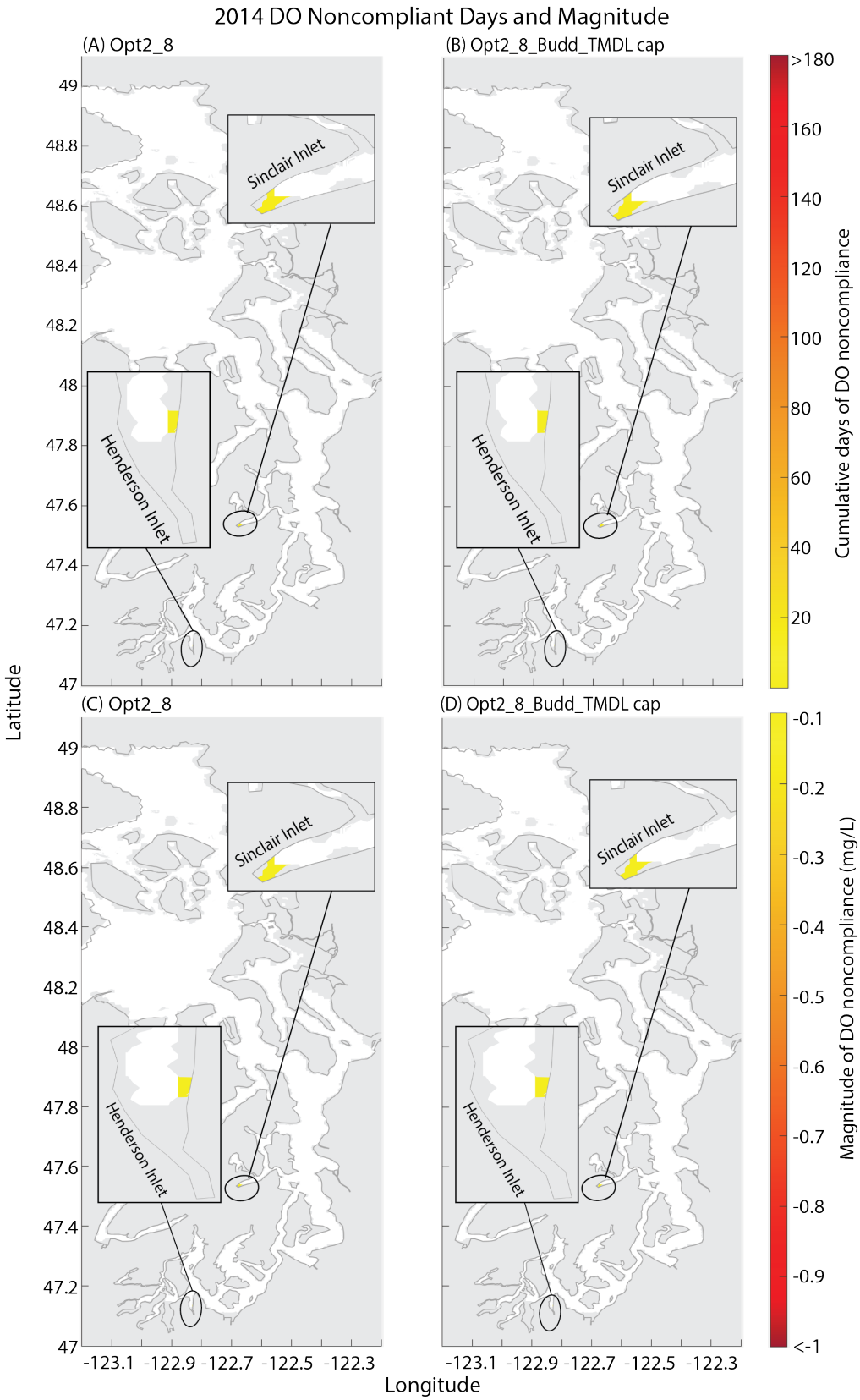

Figure O-4. Noncompliant days (A and B) and magnitude (C and D) planview map for 2014 scenario Opt2_8 (left panel), and 2014 Opt2_8_BI_TMDLcap (right panel).

References

Ecology. 2022. Budd Inlet dissolved oxygen total maximum daily load: Water quality improvement report and implementation plan. https://apps.ecology.wa.gov/publications/SummaryPages/2210012.html