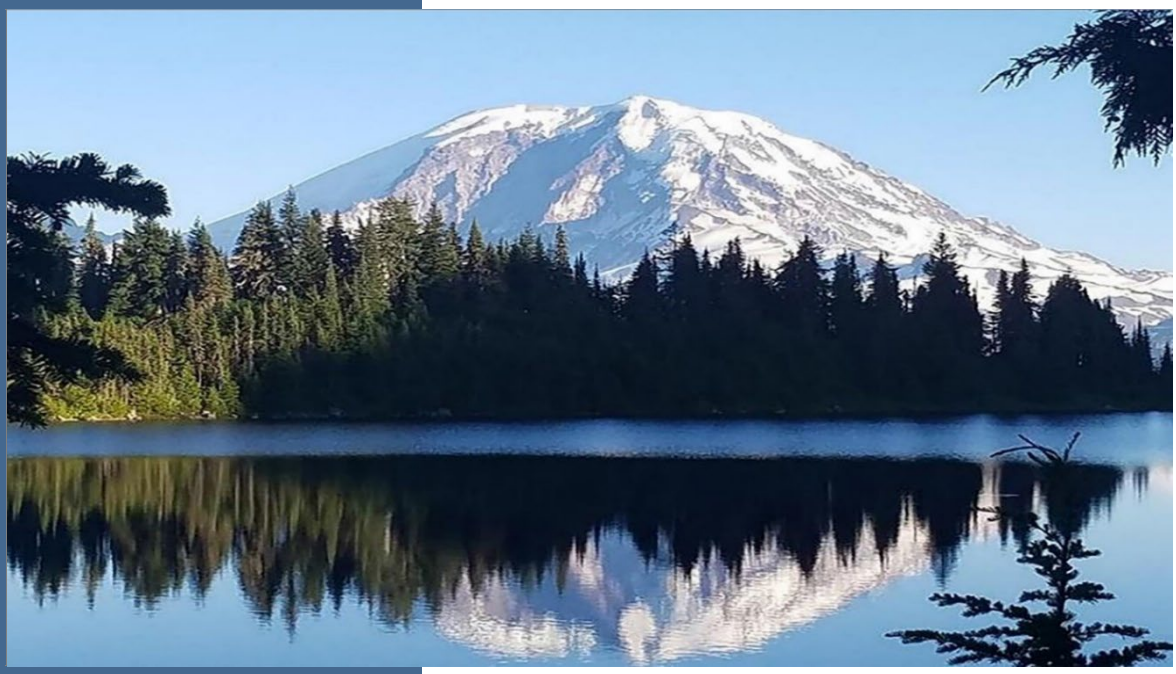

A Performance-Based Approach for Developing Site-Specific Natural Conditions Criteria for Aquatic Life in Washington

Water Quality Program

Washington State Department of Ecology

Olympia, Washington

September 2025, Publication 25-10-001

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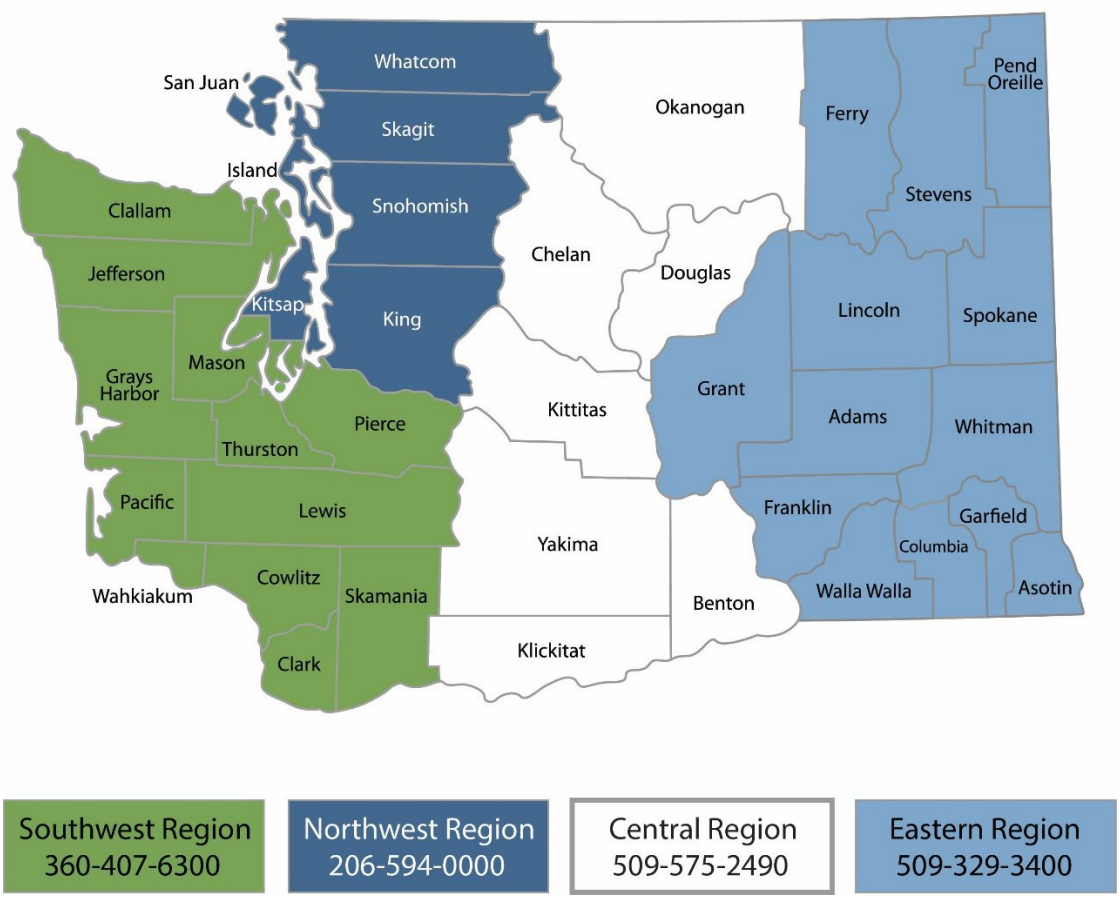

Region	Counties served	Mailing Address	Phone
Southwest	Clallam, Clark, Cowlitz, Grays Harbor, Jefferson, Mason, Lewis, Pacific, Pierce, Skamania, Thurston, Wahkiakum	PO Box 47775 Olympia, WA 98504	360-407-6300
Northwest	Island, King, Kitsap, San Juan, Skagit, Snohomish, Whatcom	PO Box 330316 Shoreline, WA 98133	206-594-0000
Central	Benton, Chelan, Douglas, Kittitas, Klickitat, Okanogan, Yakima	1250 W Alder St Union Gap, WA 98903	509-575-2490
Eastern	Adams, Asotin, Columbia, Ferry, Franklin, Garfield, Grant, Lincoln, Pend Oreille, Spokane, Stevens, Walla Walla, Whitman	4601 N Monroe Spokane, WA 99205	509-329-3400
Headquarters	Across Washington	PO Box 46700 Olympia, WA 98504	360-407-6000

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Introduction and Background

Introduction and purpose

Washington Department of Ecology (Ecology) recognizes that in some portions of some waterbodies, the assigned aquatic life criteria may not be met due, in part, to the natural conditions of the waterbody. Therefore, if these natural climatic or landscape attributes are preventing attainment of applicable numeric aquatic life criteria, then site-specific numeric aquatic life criteria representing these natural conditions can be calculated following processes listed at Washington Administrative Code (WAC) 173-201A-260(1)(a)). This includes the performance-based approach (WAC 173-201A-470).

When the performance-based approach is used by Ecology to establish natural condition aquatic life water quality criteria, development of these criteria values must follow the procedures and methods in this document as per WAC 173-201A-470. The performance-based approach is limited by WAC 173-201A-470 to the following water quality parameters:[2]

- Dissolved oxygen (DO; fresh water and marine water)
- pH (fresh water)
- Temperature (fresh water and marine water)

If the determination of aquatic life criteria values cannot meet the requirements set forth in this document, then site-specific criteria can be established by following the alternatives listed at WAC 173-201A-260(1)(a)(i).

Regulatory information

Federal

The Clean Water Act (CWA) requires states to adopt water quality standards that consist of designated uses, water quality criteria, and an antidegradation policy. Section 303(c)(2)(A) of the CWA gives the responsibility for adopting water quality standards to states and authorized Tribes, and that these standards will protect the public health or welfare, enhance the quality of water, and serve the purposes of the Act.

40 CFR 131.3(b) defines criteria as elements of the water quality standards (expressed as constituent concentrations, levels, or narrative statements) that represent a quality of water that supports a particular use such that when criteria are met, water quality will generally protect the designated use.

[2] This document currently sets forth the performance-based approach methodology to establish aquatic life criteria for dissolved oxygen in marine waters. Performance-based methods applicable to dissolved oxygen in fresh waters, temperature in fresh or marine waters, or pH in fresh waters may be added in the future. Any added methods or substantive edits to this document undergo a public process and are submitted to EPA for review and action pursuant to Clean Water Act Section 303(c).

States and authorized Tribes must adopt water quality criteria that protect these designated uses (see 40 CFR 131.11). States and authorized Tribes may adopt, where appropriate, other criteria that differ from the Environmental Protection Agency's (EPA's) recommendations, so long as the criteria are:

- Based on sound scientific rationale,
- Contain sufficient parameters or constituents to protect the designated use or uses, and
- Support the most sensitive designated use of the waterbody.

States and authorized Tribes can adopt criteria that are modified to reflect site-specific conditions (see 40 CFR 131.11(b)(1)(ii)), so long as they are based on sound scientific rationale and protect designated uses. EPA has provided guidance for derivation of site-specific criteria outlined in *Water Quality Standards Handbook Chapter 3: Water Quality Criteria*.[3]

Any new or revised criteria adopted by states or authorized Tribes must be submitted to EPA for review to determine if the criteria meet the requirements of the CWA and its implementing regulations (CWA Section 303(c)). If approved by EPA, the criteria become applicable for CWA purposes and remain the applicable criteria until EPA approves a change, deletion, or until EPA promulgates more stringent criteria if necessary to meet CWA requirements (40 CFR 131.21(c), (e)).

State

Water pollution control in the State of Washington is regulated under Chapter 90.48 Revised Code of Washington (RCW). This includes RCW 90.48.010 which states that it is the public policy of the state to maintain the highest possible standard to ensure purity of waters consistent with public health, public enjoyment, and propagation and protection of wildlife, birds, game, fish, and other aquatic life.

RCW 90.48.035 establishes the rule-making authority for the Department to promulgate rules and regulations necessary to carry out the provisions of Chapter 90.48, including water quality standards for the state.

The Water Quality Standards for Surface Waters of the State of Washington are codified at Chapter 173-201A WAC. This chapter establishes standards for public health and public enjoyment of waters in the State and for propagation and protection of fish, shellfish, and wildlife.

[3] United States Environmental Protection Agency (USEPA). 2023. Water Quality Standards Handbook Chapter 3: Water Quality Criteria. Office of Water, Office of Science and Technology. Washington, D.C. EPA 823-B-23-001.

Performance-Based Approach

Overview

A performance-based approach is a binding methodology that provides a transparent, predictable, repeatable, and scientifically defensible procedure to derive numeric criteria protective of designated uses. A performance-based approach must be submitted to EPA for review and action pursuant to Clean Water Act Section 303(c). When EPA has determined that a performance-based approach is sufficiently detailed and has suitable safeguards to ensure predictable, repeatable outcomes, EPA's approval of the approach also serves as an approval of criteria derived consistent with the approach.

Aquatic life water quality criteria values developed using the performance-based approach are applicable to the waterbody upon derivation, so long as all requirements set forth in this document are met.

Applicability

Use of the performance-based approach is limited to the parameters listed at WAC 173-201A-470(2). This document currently sets forth the performance-based approach methodology to establish aquatic life criteria for dissolved oxygen in marine waters (see Chapter 1). Performance-based methods applicable to dissolved oxygen in fresh waters, temperature in fresh or marine waters, or pH in fresh waters may be added in the future. All methods or substantive edits to this document must undergo a public process and are submitted to EPA for review and action pursuant to Clean Water Act Section 303(c).

Natural conditions aquatic life criteria for other water quality parameters must be developed using site-specific criteria pursuant to WAC 173-201A-430 (as specified at WAC 173-201A-260(1)(a)(ii)), as applicable, and must follow all applicable state and federal rulemaking regulations prior to becoming effective for state and federal CWA actions. Natural conditions water quality criteria are appropriate only for the protection of aquatic life designated uses, not human health uses.

Chapter 1: Marine Dissolved Oxygen

Introduction

This is a binding approach for deriving natural condition aquatic life water quality criteria for marine dissolved oxygen (DO) through the use of water quality models. Water quality models can estimate the water quality dynamics for marine DO at the site of interest under current and natural conditions. This approach will allow quantification of effects at a site from both human sources and natural sources.

In this process, developing the natural conditions criteria consists of:

1. Defining where natural conditions apply (i.e., the site boundary) and the model domain.
2. Compiling existing, readily available, and credible current and historical water quality and site data.
3. Developing a Quality Assurance Project Plan (QAPP).
4. Obtaining new field data, if needed.
5. Compiling, reviewing, and assessing any new field data to ensure it meets quality assurance (QA) / quality control (QC) goals.
6. Developing and calibrating a mechanistic model or models of the existing conditions of the waterbody or watershed, including defining temporal and spatial boundaries.
7. Evaluating model performance.
8. Estimating natural condition inputs to the model(s) by removing known and estimated human-caused impacts.
9. Calculating the natural conditions criteria values by running the model(s) with natural condition inputs.
10. Documentation of performance-based approach use.

The performance-based approach will generally be conducted stepwise; however, as modeling is an adaptive process, it may be necessary to repeat or circle back through certain steps during the project.

The analysis of data and development of the criteria values must be documented. If the developed criteria values are used in subsequent state or federal CWA actions, then documentation and criteria values must be accessible to the public. Finally, developed natural condition criteria values must be protective of existing and designated aquatic life uses.

Step 1: Define site boundaries and model domain

The first step in this process is defining the site boundaries, model domain, and model cell resolution. The site boundaries encompass where natural conditions criteria are being determined. The model domain refers to the specific aspects of an area that the mechanistic model aims to represent and analyze. It defines the boundaries and scope of the model's application, and therefore, the model domain must include the site boundaries and contributing waters to the area where the natural conditions criteria are being determined. The

site and model domain may include multiple CWA 303(d) assessment units of interest to the project. The site boundaries and model domain for the site of interest must be defined and documented. Boundary information must include geospatial information. This information must be documented in the respective project QAPP and/or other documentation as part of this performance-based approach.

Cell resolution refers to the size of the individual cells in a grid, with higher resolution meaning smaller cell sizes, which can lead to a more detailed representation of features within the model. For cell resolution, it must be sufficient to predict horizontal and vertical variations in water quality on at least an hourly basis. Establishing the model grid is model- and project-specific, and therefore, the process for doing so must be documented in the respective project QAPP and/or other documentation. When establishing the model grid(s) and selecting cell resolution, considerations include, but are not limited to, the following:

- Sufficiently fine to resolve features of the site (e.g., shoreline, islands, watersheds, river mouths).
- Allow for selected temporal simulation (e.g., year-long).
- Bathymetry information and accuracy for the site.
- Ensuring representation of identified subbasins in large model domains.
- Simulation of key location-specific biogeochemical forcings (e.g., temperature, flow, and water quality timeseries developed for each stream inflow into the model).

Step 2: Compile data

All existing, readily available, and credible data and information to characterize the site of interest and waters that affect the site of interest must be considered to model current and natural conditions. Determination of whether data and information are credible must follow Washington's Water Quality Data Act (RCW 90.48.585), which is also discussed in Ecology's Water Quality Policy 1-11 Chapter 2,[4] publication 21-10-032. Waters that affect the site of interest include, but are not limited to:

- Upstream waters (e.g., tributaries, groundwater, wetlands), and
- Oceanic inputs

A description of the relevant data compiled and data sources must be documented in the project QAPP. For these data, including initial conditions for model setup, the data must encompass the variability of a site in space and time, waterbody type, and parameter of interest. Table 1 provides potential data needs for both current conditions and estimation of natural conditions.

[4] https://apps.ecology.wa.gov/publications/SummaryPages/2110032.html

Table 1. Potential data needs for current conditions and estimating natural conditions.

Category	Current Conditions	Natural Conditions
Marine Water Quality	Marine water quality observations (e.g., salinity, temperature, photosynthetically active radiation, chlorophyll-*a,* dissolved oxygen, dissolved and particulate fractions of speciated nutrients, density)	--[1]
Watershed Inflows	Freshwater quality observations (e.g., nutrient inputs such as total nitrogen or organic carbon, temperature)	Inferred from freshwater quality observations, atmospheric deposition data
Fresh Water Hydrology	Freshwater hydrology (e.g., flows, precipitation)	Inferred freshwater hydrology (e.g., flows, precipitation)
Oceanic Boundary Conditions	E.g., Oceanic boundary conditions (e.g., water chemistry, tidal pulses)	Inferred oceanic boundary conditions (e.g., water chemistry, tidal pulses) within expected natural variability
Point-Source Marine Discharges	Nutrient loadings for direct marine point source discharges	Nutrient loadings for direct marine point source discharges reflective of no anthropogenic influence
Meteorology	Meteorology (e.g., air temperature, solar radiation, wind velocity) and changes to meteorological variables (e.g., air temperature)	Meteorological variables (e.g., air temperature) modified to reflect pre-anthropogenic conditions
Other Data	E.g., sediment oxygen demand, respiration, productivity, kinetic and physical rates, bathymetry	E.g., inferred rates within variability of natural conditions
Site Information	E.g., GIS data, site-survey data, records from federal, state, and tribal agencies	E.g., historical records from federal, state, and tribal agencies, traditional knowledge

[1]Quantitative, high resolution, existing, credible data for marine water quality natural conditions is generally not available.

Site characterization data

In addition to the data types identified in Table 1, all relevant, existing, readily available, and credible data must be considered to characterize current and natural conditions at the site. These data must also be sourced from waters that affect the site of interest. Potential site characterization data include, but are not limited to:

- Waterbody morphology
- Hydrodynamics and physical properties
- Hydrological modifications (e.g., water withdrawals)
- Nonpoint source discharges (including tributary boundaries)
- Surrounding vegetation and riparian conditions
- Submerged aquatic vegetation

Existing, readily available, and credible data

Sources of existing and readily available data include, but are not limited to, state and federal water quality databases. Washington maintains the Environmental Information Management[5] (EIM) database, which contains environmental monitoring data collected by Ecology scientists, local governments, other state agencies, Tribes, non-profit organizations, and other partners. Federal water quality data includes data in the Water Quality Portal[6], which integrates data from the EPA and other state, federal, Tribal, and local agencies. Other sources of information may include water quality data collected by the United States Army Corps of Engineers, United States Department of Interior (including the Bureau of Reclamation), data from the United States Geological Survey (USGS), other state water quality databases, Tribal water quality data, or other credible water quality data from outside the United States.

Any data obtained from academic and literature works (e.g., research journals) must be from published and reputable sources. Additional sources of data may include data collected under state or federally approved QAPPs, private and public facilities (e.g., data collected as part of National Pollutant Discharge Elimination System, or NPDES, permits), and utilities (e.g., drinking water facilities).

Ecology has gathered relevant external data sets useful and applicable for water quality impairment studies, and Ecology may use these external datasets in this performance-based approach. A list of these data sources, quality assurance information, and links to data are available in Appendix A of Ecology's Programmatic QAPP for Water Quality Impairment Studies[7] or any subsequent updates to this document. This programmatic QAPP references data sets for water quality process-based modeling which can be used to develop natural conditions aquatic

[5] https://apps.ecology.wa.gov/eim/search/default.aspx
[6] https://www.waterqualitydata.us/
[7] https://apps.ecology.wa.gov/publications/SummaryPages/1703107.html

life criteria. Data used must follow the quality objectives outlined in the section "Quality Objectives" of the above-referenced document.

Finally, determination of whether data and information are credible must follow Washington's Water Quality Data Act (RCW 90.48.585), which is also discussed in Ecology's Water Quality Policy 1-11 Chapter 2,[8] publication 21-10-032. If Ecology determines that a lack of credible data will impede estimating natural conditions, in order to proceed with this performance-based approach, Ecology must collect additional data under an amended QAPP, project-specific QAPP, or scope of work (see Steps 4 and 5 of this chapter).

Data timeframe and metadata requirements

There are no restrictions or limits on obtaining applicable data other than those previously identified (i.e., all existing, readily available, relevant, and credible data). Ideal datasets will include long-term data[9] for the water quality parameter of interest and data that represents pre-industrial periods or before large-scale human impacts.

If combining data across multiple time frames to estimate natural conditions, the methodology used in combining data sets must be documented and must be appropriately conservative to capture the range of conditions that protect existing and designated aquatic life uses across the scales of aggregation.

All associated metadata must be included and documented in the respective dataset, and data sources must be cited and listed in the project QAPP. This includes all quality assurance or quality control information, geospatial information, and data collection information (e.g., time of collection, depth).

Data gaps

Any data gaps must be identified. If data gaps are filled using estimates, the process for doing so must be documented and justified. Methods to estimate data gaps include, but are not limited to interpolation, regression, and using information from regional models.

If Ecology determines that a lack of credible data will impede estimating natural conditions, in order to proceed with the performance-based approach, Ecology must collect additional data under an amended QAPP, project-specific QAPP, or scope of work (see Steps 4 and 5 of this chapter).

[8] https://apps.ecology.wa.gov/publications/SummaryPages/2110032.html
[9] Defined as data collected regularly (e.g., monthly) over at least ten years.

Step 3: Develop a project Quality Assurance Project Plan

A Quality Assurance Project Plan (QAPP) must be developed and followed. Data quality objectives and measurement quality objectives must be established within the QAPP to ensure proper model calibration and evaluation such that, once met, the output of the model informs the determination of appropriate criteria.

The project QAPP must provide:

1. Key objectives, goals, and questions that are to be addressed by this project.
2. Observational data quality objectives.
3. Description of the data to be used, identified data needs, and data sources.
4. Model capability descriptions or references, including identification of key processes that drive water quality.
5. Model peer-review approach and/or documentation.
6. How spatial and temporal variability will be addressed in any model to ensure that natural condition estimates protect designated and existing uses.
7. Model approaches and key assumptions, which may include boundary conditions and associated determinations, initial or existing conditions, model resolution, inflow loads, or watershed inputs.
8. Description of the computational setup.
9. Model quality objectives, including how model calibration performance and model skill will be evaluated using both quantitative statistics, skill metrics, and qualitative methods.
    a) Model segment or grid size descriptions and rationale as to appropriateness linked to (4).
    b) Description of reasonable fit or other statistics between model-estimated and measured conditions following model calibration.
    c) Performance goal targets.
    d) Any model limitation, uncertainties, and assumptions, and how these could impact (if applicable) the reasonableness to meet the goals and objectives of the project.
    e) Quality Assurance and Quality Control considerations, such as adherence to the Department's programmatic QAPP for assessing impaired waters and any relevant previous QAPPs.

Step 4: Collect new data

If Ecology determines that existing, readily available, and credible data are insufficient and will impede estimating natural conditions and the ability to proceed with the performance-based approach, Ecology must collect additional data under an amended QAPP, project-specific QAPP, or scope of work, and there must be information that details the spatial and temporal scope of data collection and any other requirements for collection. The QAPP or scope of work must include the methods used to collect new data. This may include Ecology's standard operating

procedures for watershed health monitoring.[10] Collected data must meet requirements for data listed in Step 2 of this document.

Step 5: Ensure new data meets quality assurance and control goals

If any new field data are collected (Step 4 of this chapter), then compiling, reviewing, and assessing these data must be done to ensure it meets Ecology's quality assurance and quality control goals outlined in the project QAPP. These processes must be documented, such as in the project QAPP. Additional information on Ecology's quality assurance and quality control is found on Ecology's Quality Assurance webpage.[11]

Step 6: Develop and calibrate the model(s)

The performance-based approach includes developing a water quality model or models for current conditions and then uses the model(s) to estimate natural conditions of a system. Any model(s) used must follow the requirements set forth in the project QAPP (Step 3) as well as the following requirements:

- The model(s) must allow for reproducibility of results.
    - Model code must be open source, with existing and natural condition input and output files, alongside data sources, made available to the public.
- The model framework, including model code, must have undergone a formal peer-review process before application, or if not previously peer reviewed, must be recognized as widely-used code in the published literature and fully documented.
    - Documentation of the peer-review process must be described in the project QAPP or other documentation as part of the performance-based approach.
- Model selection must be from a set of best available modeling tools applicable for the specific purpose to estimate current and natural conditions based on the project requirements.
    - This includes, but is not limited to, the Salish Sea Model[12] and other models of comparable rigor.
- Model or models chosen must simulate all key processes and sources affecting marine DO, and must be described in the model documentation.

[10]https://apps.ecology.wa.gov/publications/UIPages/PublicationList.aspx?IndexTypeName=Topic&NameValue=Standard+Operating+Procedure+(SOP)+%e2%80%94+Watershed+Health+Monitoring&DocumentTypeName=Publication.

[11] https://ecology.wa.gov/issues-and-local-projects/investing-in-communities/scientific-services/quality-assurance

[12] https://ecology.wa.gov/research-data/data-resources/models-spreadsheets/modeling-the-environment/salish-sea-modeling

    - Processes include, but are not limited to, those identified in the QAPP for a Dissolved Oxygen Modeling Study for Puget Sound[13] (e.g., microbial rates, circulation or residence time, phytoplankton dynamics).
- Model calibration must be done using reasonable adjustments of model parameters to achieve a reasonable fit between model-estimated and measured conditions based upon peer review of the individual model, or by comparing to documented model fit statistics from other similar applications using the same model.
    - The quality of the model calibration must be documented and include both qualitative and quantitative evaluations.
    - A sufficient number of calibration locations must be defined and identified prior to model application.[14]
- Model documentation must include information about errors and uncertainties in model outputs.
- The model or models must have sufficient resolution[15] (and such resolution must be documented) to:
    - Predict horizontal and vertical variations in water quality. These predictions must be generated on at least an hourly basis.
    - Capture the impacts to all designated aquatic life uses, including the most sensitive designated aquatic life use, and provide rationale for this determination in the report generated as part of this performance-based approach.
    - Resolve features of the site (e.g., shoreline, islands, watersheds, river mouths).
    - Allow for selected temporal simulation (e.g., year-long).
    - Reflect available bathymetry information.
    - Ensure representation of identified subbasins in large model domains.
    - Incorporate simulation of key location-specific biogeochemical forcings (e.g., sediment diagenesis and flux processes).
- All key model parameter values must be documented.

[13] https://apps.ecology.wa.gov/publications/SummaryPages/0903110.html. Table at Page 42, Appendix A, Section 3 titled "3. What are the dominant processes affecting dissolved oxygen?"

[14] If the model skill goals outlined in the project QAPP are met, the number of calibration locations are deemed sufficient.

[15] Model resolution will depend on available data and site of interest. See Puget Sound Dissolved Oxygen Modeling Study: Development of an Intermediate Scale Water Quality Model (https://apps.ecology.wa.gov/publications/documents/1203049.pdf), Puget Sound Nutrient Souce Reduction Project Volume 1: Model Updates and Bounding Scenarios (https://apps.ecology.wa.gov/publications/SummaryPages/1903001.html), or Puget Sound Nutrient Source Reduction Project Volume 2: Model Updates and Optimization Scenarios, Phase 2 (https://apps.ecology.wa.gov/publications/SummaryPages/2503003.html) for examples of how cell sizes were determined for the Salish Sea Model.

- Sensitivity testing must be conducted on the means and ranges on selected key parameters which could significantly affect the natural condition outcome.

Step 7: Evaluating model performance

Model performance must be evaluated and documented. Methods and approaches for model evaluation must be included within the project QAPP. Performance documentation must include comparisons of model outputs to historic or collected field data, summary statistics, figures, or data tables. The model(s) must meet any quality assurance, quality control, and performance minimum requirements outlined in the project QAPP. Model evaluation includes, but is not limited to: sensitivity tests; uncertainty analyses; evaluation of observed water quality conditions during specified years; and simulating the effects of various, alternative nutrient-loading scenarios.[16]

If model performance does not meet QAPP requirements, all feasible and practicable steps to improve model performance and representativeness of the model(s) must be taken prior to model acceptance and used to estimate natural conditions. If the model performance cannot meet these requirements, then the performance-based approach cannot be used to develop marine DO aquatic life criteria based on the natural conditions of a site.

Step 8: Estimating natural conditions

Introduction

When estimating natural conditions, use of performance-based approach must consider all required anthropogenic impacts listed in this step. If any required impact is not applicable or relevant to a site, then its non-applicability or non-relevancy must be documented.

Anthropogenic impacts

The use of the following anthropogenic impacts and subsequent analyses based on corresponding data must be documented in any final report associated with this performance-based approach. These impacts must be considered, accounted for, and removed, if feasible and practicable, when estimating natural conditions. If an impact is not accounted for or removed, then the reasoning must be documented. Anthropogenic impacts include but are not limited to:

- Establishing oceanic open boundary and initial conditions.
  - Oceanic water temperature, salinity, dissolved oxygen, nitrogen, organic carbon, and Chlorophyll-*a*.
  - Global-scale ocean circulation changes, if any.
- Establishing freshwater input loads, which includes all upstream watershed point and nonpoint sources.

[16] Such as was done in Puget Sound Nutrient Source Reduction Project Volume 2: Model Updates and Optimization Scenarios, Phase 2 (https://apps.ecology.wa.gov/publications/SummaryPages/2503003.html).

    - Flow and water quality information.
    - Natural background nutrient concentrations, including but not limited to upstream tributaries and adjacent wetlands.
- Other sources, as identified, that affect boundary conditions, such as legacy sources.
- Marine point source discharges.
- Activities affecting hydrodynamics, channel morphology, channel complexity, light availability, riparian environments, and sediment mobilization.
- Meteorological conditions (e.g., air temperature changes, climate change).
- Submerged aquatic vegetation.
- Invasive species.
- Any necessary kinetic and physical model rate changes.
    - Kinetics include, but are not limited to, those connected with eutrophication, such nutrient cycling, algal dynamics, sediment and biogeochemical oxygen demand.[17]

Developing a scenario without anthropogenic impacts

Natural conditions are initially estimated through modeling by removing all anthropogenic impacts from the model simulation for those sources that are feasible and practicable to model.

For impacts:

- That are not feasible or practicable to model, and
- Where there are sufficient, existing, readily available, and credible information, and
- Where such impacts will have an impact on dissolved oxygen, then

such impacts on dissolved oxygen will be estimated and removed from the outputs of the natural conditions model run.

All human-caused impacts must be accounted for and removed from the current condition model(s), using all existing, readily available, and credible information, to develop the natural conditions scenarios. After all sources of anthropogenic pollution have been removed, natural conditions criteria are determined (Step 9). All data used to address anthropogenic sources of pollution must meet data credibility requirements.

Model outputs

Modeling outputs and subsequent analyses must represent the natural variability of marine DO (such as the range of values). This includes, but is not limited to:

- Description of short-term (e.g., daily) variability of marine DO.
- Description of long-term (e.g., multi-week, intra-annual) range and variation in marine DO.

[17] For example, Section 2.1 Process Description of the Puget Sound Dissolved Oxygen Modeling Study (https://apps.ecology.wa.gov/publications/SummaryPages/1203049.html) describes kinetics simulated in the intermediate-scale water quality model.

- Demonstration of how variability of selected key inputs (e.g., freshwater flows, temperature) impact the magnitude of marine DO.[18]

Model outputs that estimate natural conditions represent the potential conditions of the site. The model output resolution will vary by project design (as described in the QAPP), data availability, and model choice(s). The model outputs of the site must:

- Abide by the data and modeling requirements in this performance-based approach chapter, and
- Protect designated and existing aquatic life uses by removing all human-caused impacts and pollution to the water of interest.

If various model outputs are used in analysis (such as from using multiple runs), then the model runs chosen must best reflect the natural conditions of the site and capture the range of conditions.

Other considerations

Freshwater hydrology as it was reflected in a hindcast year modeled may be used, and if used, freshwater hydrology must fall within the expected natural condition variability. Water quality conditions (e.g., concentrations) must be set at estimated natural conditions. The methods used and any assumptions made must be documented. Finally, all feasible and practicable steps to achieve representativeness of the model(s) used to estimate natural conditions must be taken, and the model must meet any quality assurance, quality control, and performance minimum requirements outlined in the project QAPP (see Step 7).

Human structural changes

The performance-based approach will not be used to derive criteria for specific assessment units (i.e., defined water body sections) of waters that contain human structural changes that cannot be effectively remedied (as determined consistent with the federal regulations at 40 CFR 131.10; see WAC 173-201A-260(1)(b)).

[18] For example, see the analyses performed and reported in Volume 1 of the Puget Sound Nutrient Source Reduction Project (https://apps.ecology.wa.gov/publications/SummaryPages/1903001.html) and Puget Sound Nutrient Source Reduction Project Volume 2: Model Updates and Optimization Scenarios, Phase 2 (https://apps.ecology.wa.gov/publications/SummaryPages/2503003.html).

Step 9: Determining natural conditions criteria values

Criteria magnitude

Step 8 estimates the natural conditions of marine dissolved oxygen at a site. These model outputs are then used to determine natural conditions criteria for the site. Natural conditions criteria must reflect the natural water quality of the system without any human impacts; see Step 8 for further details and requirements.

Once estimates of natural conditions are produced, then outputs are aggregated. First, volume-weighted horizontal aggregations are performed on model results across the assessment unit. The assessment unit must reflect Washington's CWA Section 303(d) assessment units as defined in Section 1C of *Water Quality Program Policy 1-11 Chapter 1: Washington's Water Quality Assessment Listing Methodology to Meet Clean Water Act Requirements*.[19] Horizontal aggregations use the mean value for concurrent temporal outputs across the assessment unit at each depth layer in the model.

Second, the time series of model outputs (e.g., time series of hourly DO values at each cell or node) within each assessment unit *and* each depth layer are reduced to daily minimum DO values for each day of the simulation.

The results of this aggregation process determine criteria values for marine DO for each day within the temporal window of the model (e.g., summer growing season), each assessment unit, *and* each depth layer within each assessment unit. There is no vertical aggregation of model output (e.g. model vertical layers) allowed. The aggregation process used to calculate criteria values must be documented.

Criteria duration and frequency

Any developed natural conditions criteria must include duration and frequency components in addition to magnitude values. The duration and frequency components must match the duration and frequency of the biologically-based numeric marine DO criteria at WAC 173-201A-210(1)(d).

Criteria evaluation and application

Developed natural conditions criteria must only include the periods of the year when natural conditions were estimated. For example, the criteria values may only be applicable for the summer period if the natural conditions were estimated using such bounds (e.g., seasonal). Any developed natural condition criteria values have the same bounds or restrictions as the methods used for estimation. For all other times when natural conditions were not estimated, all existing and applicable biologically-based numeric criteria continue to apply.

[19] https://apps.ecology.wa.gov/publications/SummaryPages/1810035.html

Step 10: Documentation and use

Once the natural conditions criteria values (including magnitude, duration, frequency) are determined, these values are applicable for use in state and federal CWA actions. If used, all evaluations, analyses, data, and decision points from this approach must be documented. Any reports generated from the use of the PBA must follow accepted agency templates or protocols.

Documentation must include sources of model uncertainty in summarized form. Further, documentation must show how the model outputs were used to establish natural conditions criteria, and also include information on natural condition estimates, including but not limited to:

- Summary tables
- Cumulative relative frequency tables
- Natural variation and central tendencies for simulated waters
- Spatial and temporal considerations
- Amendments to the project QAPP.
    - Any amendments to the project QAPP must be consistent with the PBA requirements.
- Sources of data, approaches, and references not previously documented and used in the analysis

All documentation (including, but not limited to, the project specific QAPP, model outputs, and determined natural conditions criteria) must be made available to the public when using the natural condition criteria in subsequent state and federal CWA actions.