Modeling Quality Assurance Project Plan

for

Clarks Creek Dissolved Oxygen TMDL and Implementation Plan

EPA Contract No. EP-C-08-004, Task Order 0061
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Prepared for:

U.S. Environmental Protection Agency, Region 10
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QAPP 250, Revision 1

November 29, 2010

This quality assurance project plan (QAPP) has been prepared according to guidance provided in *EPA Requirements for Quality Assurance Project Plans* (EPA QA/R-5, EPA/240/B-01/003, U.S. Environmental Protection Agency, Office of Environmental Information, Washington, DC, March 2001, [Reissued May 2006]) and *EPA Guidance for Quality Assurance Project Plans for Modeling* (EPA QA/G-5M, EPA/240/R-02/007, U.S. Environmental Protection Agency, Office of Environmental Information, Washington, DC, December 2002) to ensure that environmental and related data collected, compiled, and/or generated for this project are complete, accurate, and of the type, quantity, and quality required for their intended use. Tetra Tech will conduct the work in conformance with the quality assurance program described in the quality management plan for Tetra Tech's Fairfax Center and with the procedures detailed in this QAPP.

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Approvals:

11/30/10	12-1-10
Jennifer Wu — Date	Gina Grepo-Grove — Date
TMDL Project Manager	Quality Assurance Coordinator
U.S. Environmental Protection Agency, Region 10	U.S. Environmental Protection Agency, Region 10

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Approvals:

Dr. Jonathan Butcher Task Order Leader Tetra Tech, Inc.	12/7/10 Date	John O'Donnell QA Officer Tetra Tech, Inc.	12/06/2010 Date
John Craig Technical Monitor Tetra Tech, Inc.	12/6/10 Date	Greg Sousa Modeling QC Officer Tetra Tech, Inc.	2010-12-07 Date

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Approvals:

Cindy James 11/30/10

Cindy James Date
Task Leader
Washington Department of Ecology

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Acronyms and Abbreviations

AIH	American Institute of Hydrology
BOD	biochemical oxygen demand
CVS	concurrent version control system
DO	dissolved oxygen
DQO	data quality objective
EPA	U.S. Environmental Protection Agency
GIS	geographical information system
HSPF	Hydrologic Simulation Program FORTRAN
MS4	Municipal Separate Storm Sewer System
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
RAM	random access memory
SOD	sediment oxygen demand
TM	Technical Monitor
TMDL	Total Maximum Daily Load
TO	Task Order
TOL	Task Order Leader
TOM	Task Order Manager
USGS	U.S. Geological Survey

Distribution

This document will be distributed to the following personnel who will be involved in this project.

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1 Project Management

1.1 PROJECT/TASK ORGANIZATION

The U.S. Environmental Protection Agency (EPA) Region 10 has retained Tetra Tech, Inc., to provide consulting services to support the development of a dissolved oxygen (DO) Total Maximum Daily Load (TMDL) for Clarks Creek in Puyallup, Washington.

Completion of this work will involve using a series of analytical tools, most significantly mathematical models, to address the sources, fate, and transport of water, sediment, thermal loads, oxygen demanding waste, and nutrients in the creek. Simulation models will be used to determine appropriate loading targets and to help evaluate implementation options to achieve the TMDL.

This quality assurance project plan (QAPP) provides a general description of the modeling and associated analytical work to be performed for the project, including data quality objectives (DQOs) and quality control (QC) procedures to ensure that the final product satisfies user requirements. This QAPP also addresses the use of secondary data (data collected for another purpose or collected by an organization or organizations not under the scope of this QAPP) to support TMDL development.

The organizational aspects of the program provide the framework for conducting the necessary tasks. The organizational structure and function can also facilitate task performance and adherence to QC procedures and quality assurance (QA) requirements. Key task roles are filled by the persons who are leading the various technical phases of the project and the persons who are ultimately responsible for approving and accepting final products and deliverables.

The program organization chart, provided in Figure 1, illustrates the relationships and lines of communication among all participants and data users. The responsibilities of these persons are described below.

Jennifer Wu, EPA Region 10 TMDL Project Manager, will provide overall project/program oversight for this study for EPA as designee of the official Task Order Manager (TOM), Jayne Carlin. The EPA Region 10 Project Manager will work with the Tetra Tech Task Order Leader (TOL) to ensure that project objectives are attained. Ms. Wu will also have the following responsibilities:

- Providing oversight for model selection, data selection, model calibration, model validation, and adherence to project objectives
- Maintaining the official approved QAPP
- Facilitating participation of state, EPA, and other relevant participants on the project workgroup
- Coordinating with contractors, reviewers, and others to ensure technical quality and contract adherence

The EPA Region 10 QA Coordinator, Gina Grepo-Grove, will be responsible for reviewing and approving this QAPP. Her responsibilities will also include conducting external performance and system audits and participating in Agency QA reviews of the study.

The Tetra Tech Technical Monitor for this contract is John Craig. He will provide senior-level management oversight of the assigned TOL. Dr. Jonathan Butcher, P.H. will be Tetra Tech's TOL and will lead the large-scale model development. Additional responsibilities of the Tetra Tech TOL include the following:

- Coordinating project assignments, establishing priorities, and scheduling

- Ensuring completion of high-quality products within established budgets and time schedules
- Acting as primary point of contact for the EPA Region 10 Project Manager and TOM
- Providing guidance, technical advice, and performance evaluations to those assigned to the project
- Implementing corrective actions and providing professional advice to staff
- Preparing and reviewing preparation of project deliverables, including the QAPP, draft report, final report, and other materials developed to support the project
- Providing support to EPA in interacting with the project team, technical reviewers, workgroup participants, and others to ensure that technical quality requirements of the study design objectives are met

The Tetra Tech QA Officer is John O'Donnell, whose primary responsibilities include the following:

- Providing support to the Tetra Tech TOL in preparing and distributing the QAPP
- Reviewing and internally approving the QAPP
- Monitoring QC activities to determine conformance

Tetra Tech modeling staff will be responsible for developing model input data sets, applying the model, comparing model results to observed data, calibrating the model, and writing documentation. They will implement the QA/QC program, complete assigned work on schedule and with strict adherence to the established procedures, and complete required documentation. Other technical staff will perform literature searches; assist in secondary data gathering, compilation, and review; and help complete other deliverables to support the development of the draft and final report.

The Modeling QC Officer, Greg Sousa, will provide additional oversight. Mr. Sousa is familiar with the proposed model and will provide final QC review of the model setup and output. The Modeling QC Officer or his designees will be responsible for performing evaluations to ensure that QC is maintained throughout the data collection and analysis process. QC evaluations will include reviewing site-specific model equations and codes (when necessary), double-checking work as it is completed, and providing written documentation of these reviews to ensure that the standards set forth in the QAPP and in other planning documents are met or exceeded. Other QA/QC staff, including technical reviewers and technical editors selected as needed, will provide peer review oversight of the content of the work products and ensure that they comply with EPA's specifications.

Third-party technical review of the modeling application is anticipated to be provided by Washington Ecology staff. Jennifer Wu, as EPA TMDL Project Manager, will be responsible for coordinating with Ecology to arrange the third-party technical review.

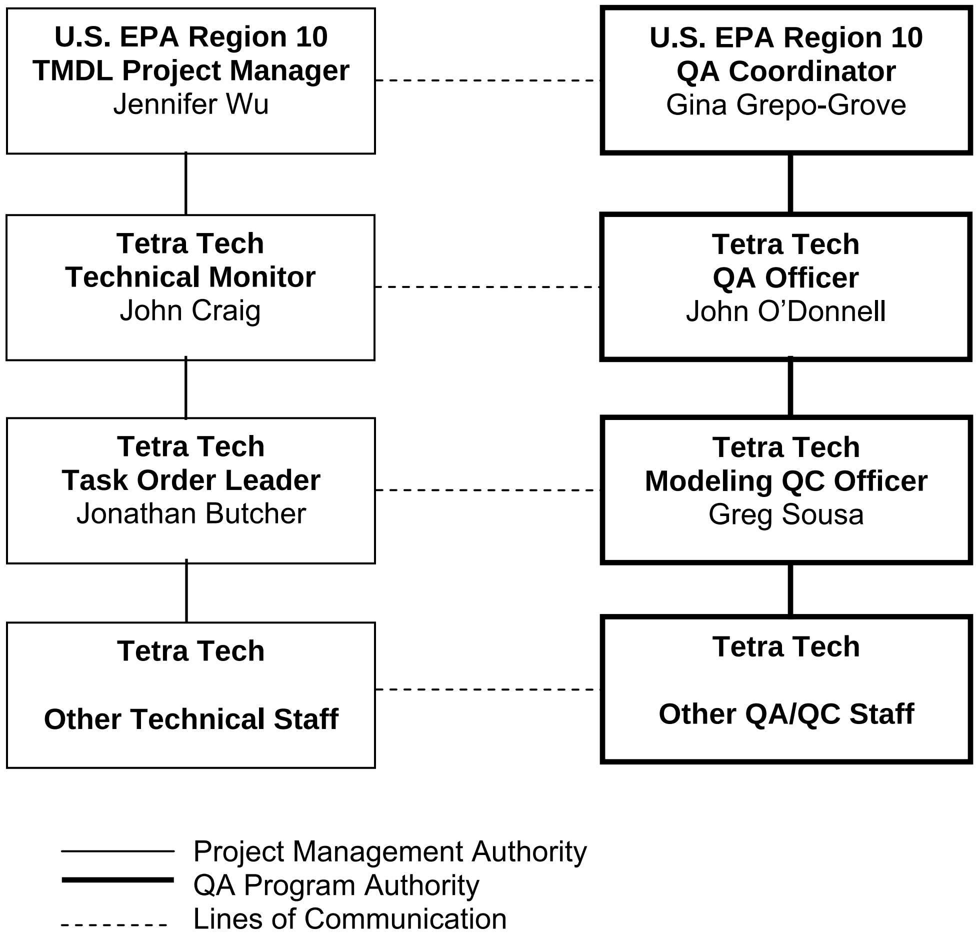

Figure 1. Project Organizational Structure

1.2 Problem Definition/Background

Clarks Creek, a spring-fed tributary of the Puyallup River in Pierce County, Washington, is an important spawning and rearing area for salmonids. Clarks Creek flows through the City of Puyallup and is subject to strong development pressure. The portion of Clarks Creek upstream of the tribal reservation (i.e., south of Tacoma Road) is designated as Core Summer Salmonid Habitat, while the downstream portion is designated for Salmonid Spawning, Rearing, and Migration. In addition, the entire length of Clarks Creek is designated for Primary Contact and Water Supply Uses. Recent monitoring in Clarks Creek (summarized in Tetra Tech, 2010) indicates that the stream is impaired for DO, threatening its designated uses. Sediment oxygen demand (SOD) and invasive macrophytes (American waterweed; *Elodea nuttallii*) are believed to play a role in this impairment. Secondary factors such as removal of riparian canopy and increased temperatures may also play a role.

The Task Order (TO) calls for the development of a TMDL and Implementation Plan to address the DO impairment in Clarks Creek. To create a useful Implementation Plan, it is essential that a linkage analysis be completed that evaluates and describes the relationship between the DO response and the ultimate sources of stressors, including both upland loading and instream processes, that ultimately lead to reduced DO and threat to salmonid health. The key to the success of this effort is the development of a conceptual model that describes the linkage between stressors and impacts. The conceptual model can be thought of as a graphical representation of a series of risk hypotheses. Data analyses and simulation modeling are then used to test and evaluate the risk hypotheses and identify options for intervention in the cycle of impairment. The ultimate goal is to identify the most cost-effective and feasible opportunities for implementation that will bring Clarks Creek into compliance with water quality standards for dissolved oxygen.

1.3 Project/Task Description

The TMDL project addresses DO conditions in the mainstem of Clarks Creek. To support the development of the TMDL water quality modeling is needed for the Clarks Creek mainstem, which commences approximately one-third of a mile south of Maplewood Springs and flows 3.6 miles through Pierce County, the City of Puyallup, and Puyallup Tribal lands before discharging into the Puyallup River. The geographic extent of the study is described in further detail below in Section 1.4.4 and accompanying Figure 4.

The modeling work in support of this project is generally described under Task 3.1 of the TO: "The Clarks Creek Team and the Contractor shall decide on the best modeling or technical approach to develop a dissolved oxygen TMDL."

To determine the appropriate modeling approach, Tetra Tech has completed a Data Review and Analysis Report (Task 2). Section 8 of this report describes the proposed modeling analysis as follows:

> It does appear that the sediment budget and stormwater impacts are only two among many processes that contribute to the DO impairment, and are likely not the critical pathways to developing the DO TMDL. As shown in the Conceptual Model (see Section 1.4.4), DO impairments in Clarks Creek are affected by a variety of interacting stressor sources and processes. It is important to note that solving DO impairment does not necessarily require intervention on all the many pathways that contribute to reduced DO. Rather, addressing impairment requires a reduction in contributions to DO deficit – from whichever source they are obtained – that will be sufficient to achieve DO criteria.
>
> Predicting the effects of potential management measures is made more difficult by the complex interlocking processes that determine DO concentrations in Clarks Creek. For this purpose a water quality response model is needed. The immediate need is for a waterbody response model that can help evaluate the relative importance of different stressor sources and processes (e.g., SOD versus lack of riparian cover) rather than a stormwater loading model. A watershed model (such as the proposed water-quality version of HSPF [Hydrologic Simulation Program FORTRAN]) would still be extremely useful for assessing the contributions of individual sources for those stressors that are directly related to upland land management – but the tool to understand sensitivity to instream processes and develop instream targets is of greater priority. Despite the data gaps noted…[in Section 8 of Tetra Tech, 2010 and summarized below in Section 1.4.1], it appears that there is sufficient information available to develop an instream response model that will be useful to help evaluate system sensitivities and the prospects for different types of management options.
>
> Key questions to be addressed by the response model should be focused on critical conditions of lower flow, higher temperatures, and elevated plant growth. The most important influences of watershed processes and stormwater loads on the DO balance appear to depend on long term loading of sediment and organic matter, and not on transient effects such as responses to individual storms. As a result, dynamic time-dependent models are of lesser utility and are not essential to completing the TMDL. Instead, quasi-steady state waterbody response models of the DO mass balance that assume constant external forcing during critical periods (but allow for diurnal cycles in DO kinetics, light, and temperature) appear appropriate. For this application, the QUAL2K stream water quality model (Chapra et al., 2008; an extension of the older QUAL2E model) is well suited as a general framework. Specifically, we will use the version known as QUAL2Kw (Pelletier and Chapra, 2008),

which is a version created for Washington Ecology (http://www.ecy.wa.gov/programs/eap/models.html) that contains routines for automated calibration and sensitivity analysis, as well as some process improvements.

The QUAL2Kw model does not explicitly simulate macrophytes, but does contain detailed routines for "bottom algae" that can be used to simulate submersed macrophytes such as elodea. Additional detailed analyses on specific topics, such as elodea growth or heat gain in the absence of riparian canopy, could complement the QUAL2Kw analysis.

This QAPP addresses the development of the QUAL2Kw model for Clarks Creek. It does not address development of the HSPF watershed model, which will be performed under a separate contract from the Puyallup Tribe.

1.4 Quality Objectives and Criteria for Model Inputs/Outputs

This section describes the quality objectives for the project and the general performance criteria to achieve those objectives. Specific quantitative tests are described further in Section 2.

EPA policy is to use a systematic planning process to define quality objectives and performance criteria. Systematic planning identifies the expected outcome of the modeling project, its technical goals, cost and schedule, and the criteria for determining whether the inputs and outputs of the various intermediate stages of the project, as well as the project's final product, are acceptable.

The Clarks Creek project is being planned consistent with EPA's DQO Process. A key component of the DQO Process is identifying and documenting the decision context for the project (the principal study questions). The general quality objectives for modeling are to provide information sufficient to answer each of the principal study questions. The principal study questions for this project are described below.

The quality of an environmental analysis program can be evaluated in three steps: (1) establishing scientific assessment quality objectives, (2) evaluating program design for whether the objectives can be met, and (3) establishing assessment and measurement quality objectives that can be used to evaluate the appropriateness of the methods used in the program.

Sections 1.4.1 through 1.4.6 describe DQOs and criteria for TMDL development for this project, written in accordance with the seven steps described in EPA's *Guidance for the Data Quality Objectives Process* (EPA QA/G-4) (USEPA, 2006).

1.4.1 State the Problem

The Washington Department of Ecology has determined that the mainstem of Clarks Creek, from the mouth to the headwaters, is impaired by low DO and requires the development of a TMDL (listing ID 35407). The applicable DO criteria are defined as follows: For the segment of Clarks Creek designated Core Summer Salmonid Habitat, the minimum allowable DO concentration is 9.5 mg/L. For the segment designated Salmonid Spawning, Rearing, and Migration, the minimum allowable DO concentration is 8.0 mg/L. DO concentrations should not drop below these criteria at a probability frequency of more than once every 10 years. If DO concentrations are naturally below these criteria, then human influences should not cause an additional decrease of more than 0.2 mg/L.

A detailed description of water quality and use assessment in Clarks Creek, along with information on land use, geology, vegetation, and so on is provided in the Clarks Creek Data Review (Tetra Tech, 2010). Depressed DO in Clarks Creek occurs as the net result of a series of complex processes. These are summarized in schematic form in Figure 2. Here, the central box represents the volume of a stream reach, while the various arrows represent potential gains and losses from the system.

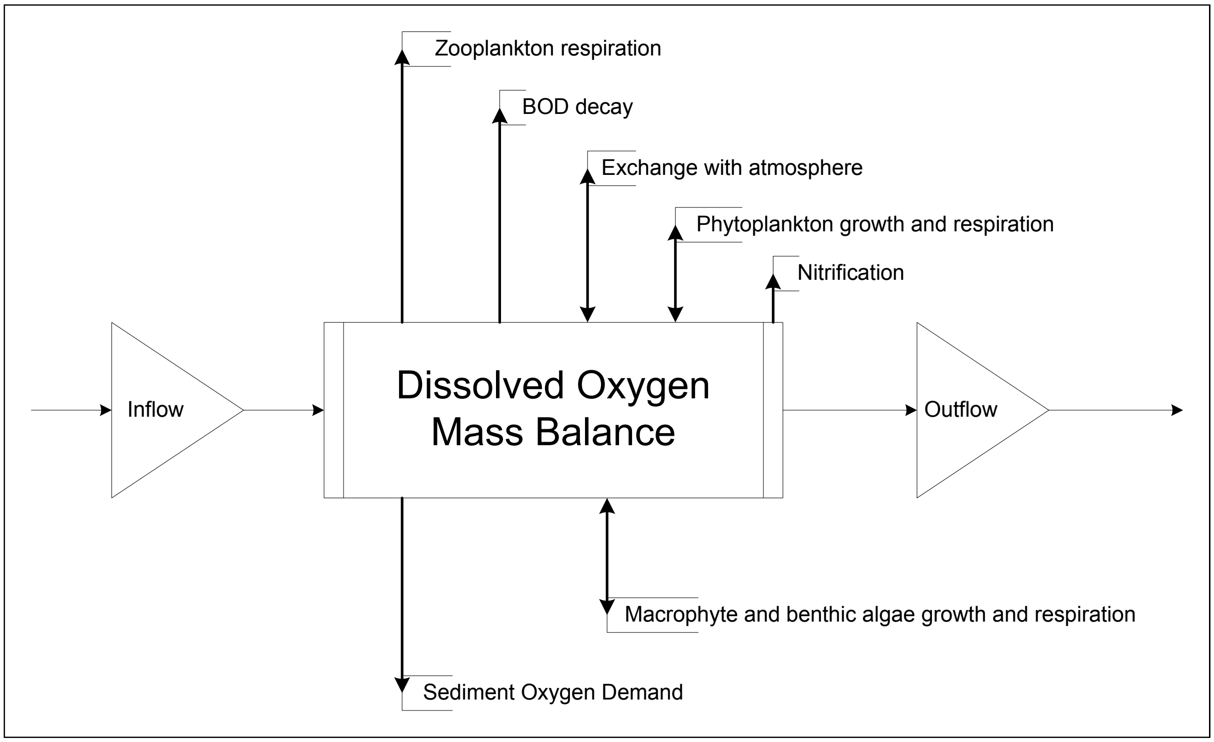

Figure 2. Process Diagram for Dissolved Oxygen Mass Balance in a Stream Reach

The oxygen mass balance depends on both advective and kinetic terms. The advective terms are inflow and outflow of oxygen mass, while the kinetic terms represent additions, losses, and transformations that occur in the stream reach. In simple terms, the oxygen in a stream reach is equal to the inflow mass minus the outflow mass, plus the net result of all the kinetic terms.

The advective terms tell us that DO concentrations in a reach depend in part on the concentrations present upstream (the inflow term). This is important because the kinetic terms that may add DO when it is depleted below saturation may act rather slowly, so conditions such as reduced DO in a spring-fed headwater may persist downstream.

There are seven kinetic terms, of varying degrees of importance:

1. *Zooplankton respiration* represents oxygen consumption by macroinvertebrates in the water column and on the bottom (fish could also be included here). This term is usually insignificant relative to other kinetic terms.

2. Biochemical oxygen demand *(BOD) decay* represents the process of decay of organic material by aerobic microorganisms, which consumes oxygen and produces CO_2.

3. *Exchange with atmosphere* may be either a source or sink of DO. In general, water will attempt to return the saturation concentration of DO, which, as noted below, is a function of water temperature. When DO is below saturation, oxygen will move from the atmosphere to the water (reaeration). The rate of reaeration is a function of the magnitude of the DO deficit and the velocity and turbulence of the water. When DO is present at supersaturation there will be net degassing to the atmosphere. Note that the saturation concentration varies with temperature; thus, changes in temperature can have an important effect on atmospheric exchanges.

4. *Phytoplankton growth and respiration* is also both a source and sink of DO. This represents contributions from planktonic algae that float in the water column. Algae produce DO during

photosynthesis and consume DO in respiration, thus typically producing DO during the day and reducing DO at night.

5. *Nitrification* represents the consumption of DO when ammonia (NH_3) is oxidized to nitrite (NO_2) and then to nitrate (NO_3). This can be an important part of the mass balance in streams with large ammonia loads.
6. *Macrophyte and benthic algae growth and respiration* represent the effects of attached, non-planktonic plant life, including both algae and macrophytes. As with planktonic algae, these produce DO during photosynthesis and consume DO in respiration.
7. *Sediment oxygen demand* (SOD) is a mechanism that removes DO from the water column at the sediment interface, primarily by the action of bacteria consuming and reducing organic material in the sediment, but also sometimes including chemical oxidation of compounds such as hydrogen sulfide that may bubble out of the sediment.

The extent of current knowledge about these kinetic processes in Clarks Creek varies considerably, despite the existence of a number of previous studies and data collection efforts (summarized in Tetra Tech, 2010). It seems safe to conclude first, however, that several of these processes are of limited importance at best in Clarks Creek, including (1), (4), and (5). As noted above, zooplankton respiration is rarely an important part of the DO mass balance in flowing streams. Planktonic algae are also of limited significance due to constant baseflow that tends to flush plankton out of the system. Nitrification is likely to be of minor importance because ammonia concentrations are generally low and the nitrification process generally proceeds slowly.

The remaining four kinetic processes are all potentially important; however, there is considerable variability in our knowledge about these processes. Most notably, for SOD – which is a major contributor to DO depletion in many streams – there are no quantitative data for Clarks Creek. It seems likely that the direct contribution of organic material from macrophyte litter and roots along with loading of organic material in runoff from the watershed (the settling of which may be enhanced by the presence of macrophytes) has resulted in an increase in SOD over background levels, but no direct measurement has been attempted to date. The fact that DO concentrations do not return to saturation following elodea removal is likely attributable in part to SOD in the system. (The QUAL2Kw model can help determine the potential magnitude of SOD, but, if this is estimated to be a significant contributor to DO impairment, it will likely need to be confirmed by subsequent measurements.)

The direct impacts of macrophytes on the DO balance in Clarks Creek are, in contrast, fairly well established. The City of Puyallup cuts and harvests elodea from Clarks Creek on an annual basis in late summer. As is described in the Data Review and Analysis Report (Tetra Tech, 2010), diurnal monitoring before and after harvesting of elodea suggests that the presence of extensive elodea mats depresses daily minimum DO by between 0.5 and 1.0 mg/L in the middle and lower sections of Clarks Creek.

In evaluating these numbers it is important to emphasize that the margin for error is small. At summer temperatures near 14 ºC the DO saturation concentration is 10.3 mg/L. This leaves only a margin 0.8 mg/L above the criterion concentration of 9.5 mg/L. As a result, DO in Clarks Creek will be sensitive to small increases in temperature, such as may be associated with the lack of riparian cover.

BOD is not particularly well characterized in the stream. Rough order-of-magnitude calculations suggest that BOD may contribute about 0.1 to 0.2 mg/L to the DO deficit. While this needs to be confirmed with a stream modeling exercise, the contribution of BOD appears to be relatively small.

The last kinetic process, exchange with the atmosphere, tends to drive DO back toward saturation concentrations. The key here is how fast the exchange may occur. This will determine, for example, how quickly the stream can correct for low DO concentrations in water emerging from Maplewood Springs at the headwaters. Reaeration in streams is largely a function of flow velocity. Therefore, factors such as increased impervious surfaces and decreased infiltration, or the withdrawal of water from Maplewood Springs, which decreases low flow volumes and velocities, will exacerbate DO problems. There is also a potential linkage to nuisance macrophyte growth, as dense stands of elodea can slow flow velocity and reduce atmospheric exchanges.

While there is considerable uncertainty in the overall oxygen mass balance, the review presented above suggests that elodea growth and (probably) SOD are two of the most important contributors to the DO impairment. The factors that contribute to excess elodea growth in turn appear to be elevated nutrient concentrations, which promote growth, and excess fine sediment, which provides a favorable substrate for elodea colonization. Because elodea is a rooted macrophyte that can obtain phosphorus from the sediment, observed elevated nitrate nitrogen concentrations in Clarks Creek (on the order of 2 to 3 mg/L, as described in Tetra Tech, 2010) may be of particular concern for promoting excess growth.

A conceptual model of the processes potentially leading to DO impairment is provided in Figure 3. The conceptual model diagram shows the linkage between stressor sources (at the top), instream processes (middle), and impacts on DO (at the bottom). Each pathway through the diagram can be regarded as a risk hypothesis that describes a theorized cause and effect relationship. The arrows with heavier weights indicate pathways that were estimated to be of potentially greater importance in Tetra Tech (2010).

The relative importance of the different pathways through the conceptual model is not fully known at this time. However, some tentative suggestions as to pathways that may be of greater importance is shown with heavier weighted lines.

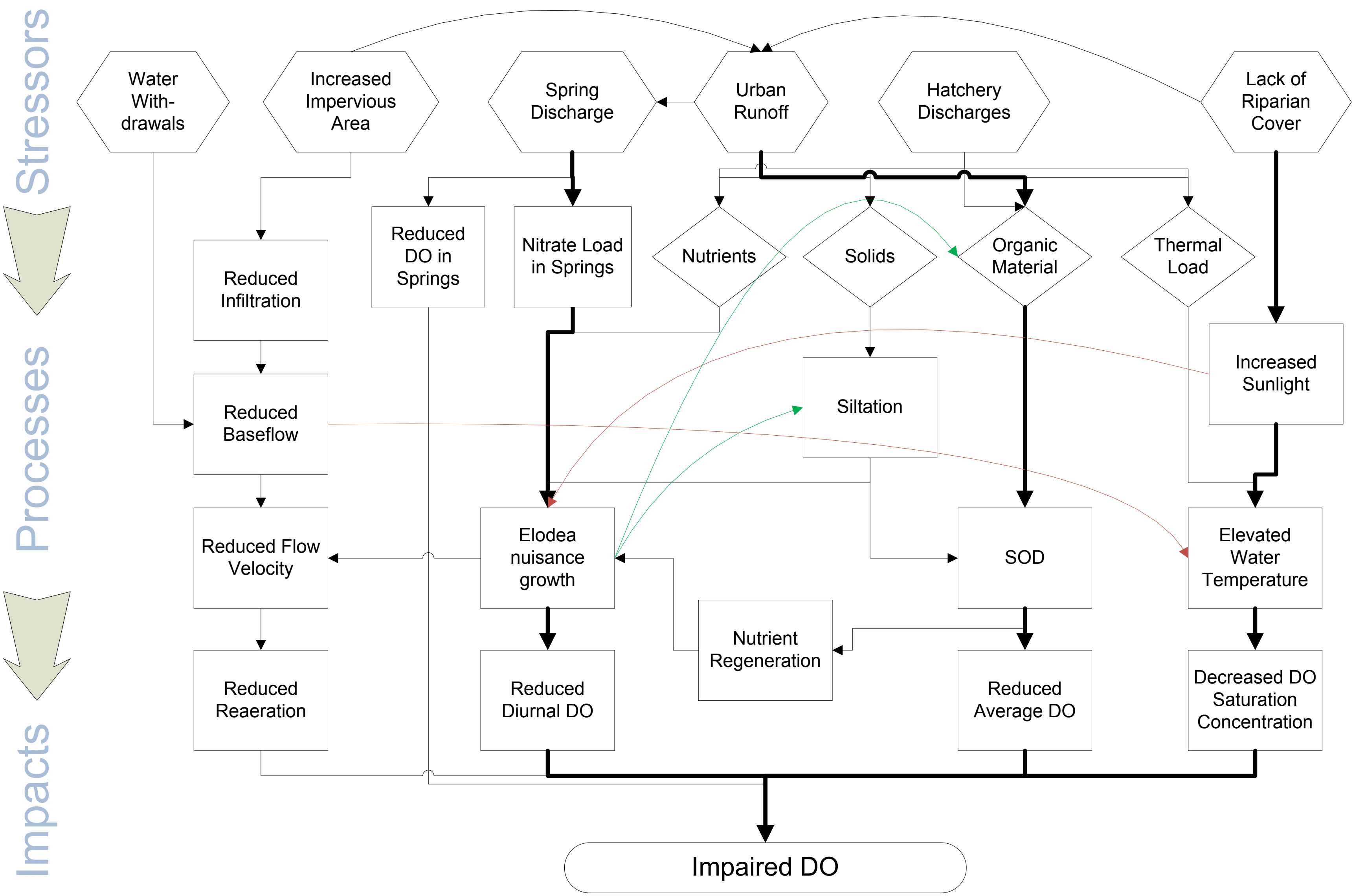

Figure 3. Conceptual Model of DO Impairment in Clarks Creek

One of the most significant cause and effect relationships (risk hypothesis) in the conceptual model may be the linkage to elevated nitrate in Maplewood Springs (Jones et al., 1999) and other groundwater discharges to Clarks Creek headwaters, which leads to increased elodea growth, which reduces diurnal DO, and causes excursions of the DO criterion. This stressor source may reflect long-term increases in groundwater nitrate concentrations, likely due in large part to onsite wastewater disposal. While improvements may be possible through better management of household wastewater and fertilizers, there might be significant lag times to see the benefits of such efforts.

Two other important pathways are also highlighted in the draft conceptual model. The first is the contribution of organic material in urban runoff to SOD, which has a subsidiary impact of providing a substrate that enhances elodea growth. The second is the role of poor riparian cover in both increasing elodea growth and elevating instream temperatures. Both of these risk pathways are largely speculative at present and, in particular, there are no data available on SOD. However, the stressor sources associated with these pathways are amenable to the types of planning and implementation typically carried out by MS4 programs.

In sum, the Principal Study Questions to be addressed by modeling in this project are:

1. What is the sensitivity of DO in Clarks Creek to each of the potential risk pathways described in the Conceptual Model?
2. What levels of reductions in controllable stressors are needed to achieve DO standards?
3. What implementation options will best achieve the needed reductions?

1.4.2 Identify the Decision

The intended end product of this Task Order is the development of a TMDL and an associated implementation plan to achieve DO standards in Clarks Creek. The nature of these final products will depend strongly on the evaluation of the linkages between stressor sources and impacts described above in Figure 3.

1.4.3 Identify the Inputs to the Decision

The primary input to the decision to be addressed by modeling is an evaluation of the DO concentration sensitivity to the various stressor sources identified in the Conceptual Model and their relative importance to the DO deficit. The role of the QUAL2Kw model is thus to provide a framework for evaluating and testing the multiple risk hypotheses that are contained within the Conceptual Model. TMDL allocations and an implementation strategy will then be developed by focusing on those stressor sources that are significant contributors to DO deficit and amenable to control.

1.4.4 Define the Boundaries of the Study

The focus of the study is DO in the Clarks Creek mainstem; however, conditions in the mainstem are largely determined by loads derived from the contributing watershed. The boundaries of the study are thus generally coincident with the extent of the Clarks Creek watershed, which occupies an area of 10.4 square miles of glacial deposits, foothill ridges, and flat valley land along the Puyallup River (Figure 4). It should be noted, however, that flow from the springs at the headwaters of Clarks Creek, which contribute significant amounts of nitrate load, appears to be derived from an area larger than the surface drainage area. The study area may thus also encompass the larger area that contributes to groundwater base flow in Clarks Creek.

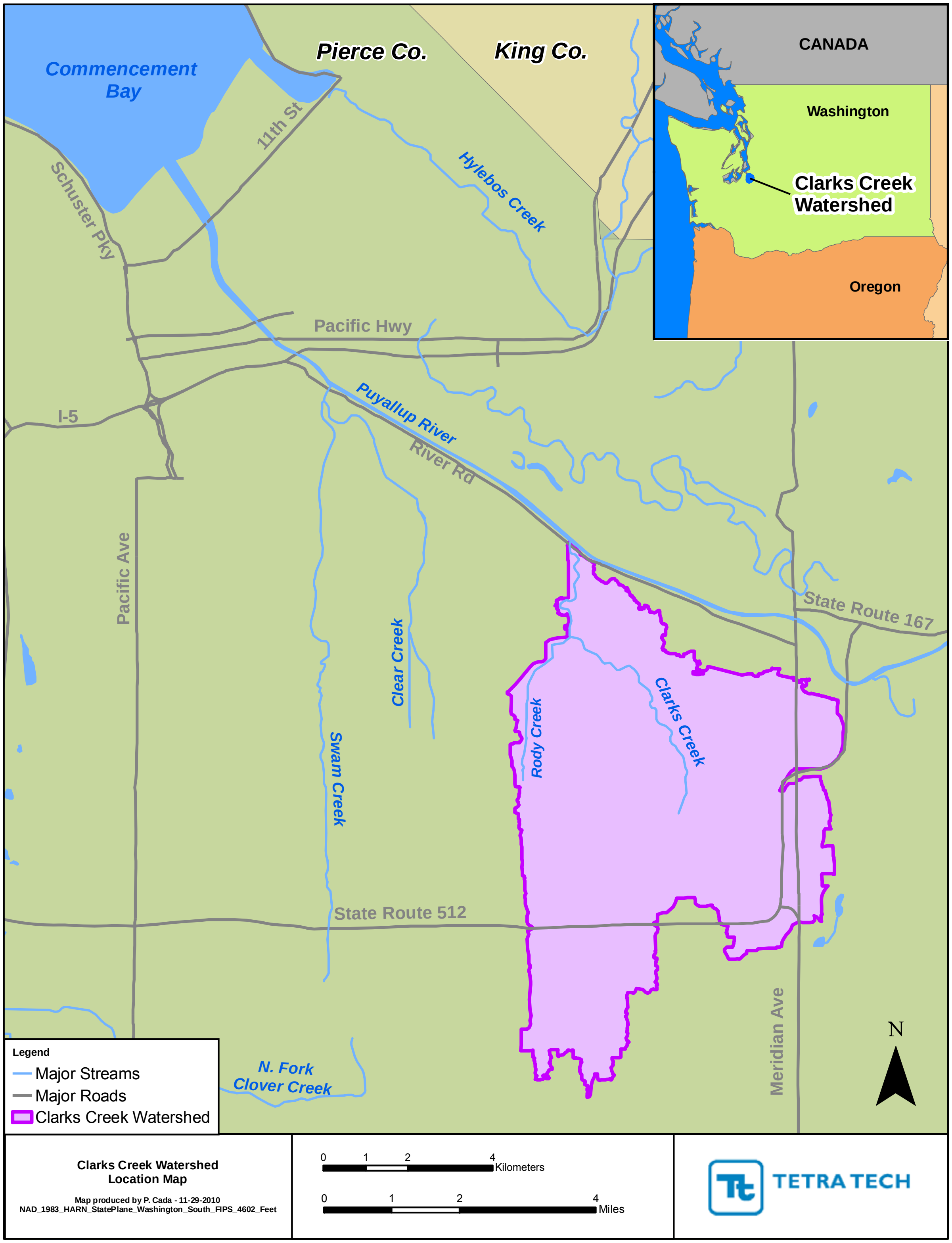

Figure 4 Location Map of Clarks Creek Watershed

1.4.5 Develop a Decision Rule for Information Synthesis

The purpose of a decision rule is to integrate the outputs from the study into a single statement that describes the logical basis for choosing among alternative actions. Output from the previous DQO steps will be used to guide decision makers to choose from among alternative actions. The decision rule for this project is:

> To achieve DO criteria and support uses in Clarks Creek it is necessary to control a variety of factors that contribute – either directly or indirectly – to reduced DO in the creek. An instream response model will be used to evaluate the contributions of different potential sources to the DO balance and to determine load reductions necessary to achieve standards. The evaluation of the sensitivity and importance of different stressor sources will be used to identify, evaluate, and test potential implementation strategies that will achieve the TMDL. Tetra Tech will provide technical evaluations of implementation strategies, while Washington Ecology and EPA will be responsible for integrating the policy, regulatory, and stakeholder components and promulgating the final strategy.

1.4.6 Specify Tolerance Limits on Decision Errors

To help guide the interpretation of the technical information provided by the water quality model, general performance targets for the modeling are described in Section 2.2.5. The performance targets are based on generally accepted values from the literature and experience with previous projects.

Specific numeric acceptance criteria are not specified for the model. Instead, appropriate uses of the model will be determined by the project team based on assessment of the types of decisions to be made, the model performance, and the available resources.

1.5 Special Training Requirements/Certification

Tetra Tech staff involved in developing model input data sets and model application have experience in numerical modeling gained through their work on numerous similar projects. The Tetra Tech TOL, who has extensive experience managing similar projects, will provide guidance to the modeling. The TOL will ensure strict adherence to the project protocols.

Mr. John O’Donnell is the QA Officer for this project. He is the QA Manager for Tetra Tech’s Fairfax Center offices. He has over 20 years environmental laboratory and QA experience and has been QA Officer for several contracts, including EPA contracts with the Office of Science and Technology; Office of Wastewater Management; and Office of Wetlands, Oceans, and Watersheds.

Dr. Jonathan Butcher, P.H., will be Tetra Tech’s TOL. Dr. Butcher is a water quality modeler and Professional Hydrologist (AIH) with over 20 years’ experience supporting EPA, state, and local governments throughout the US in TMDL and water supply protection studies. He is a nationally recognized expert in the application of the watershed and waterbody response models.

Dr. Butcher will be supported by a range of qualified Tetra Tech staff.

1.6 Documentation and Records

Thorough documentation of all modeling activities is necessary to be able to effectively interpret the results. All records and documents relevant to the application, including electronic versions of data and input data sets, will be maintained at Tetra Tech’s offices in the central file. The central repository for the model will be Tetra Tech’s Research Triangle Park, North Carolina, office. Tetra Tech will deliver a copy of the records and documents in the central file to EPA at the end of the task. Unless other arrangements are made, records will be maintained at Tetra Tech's offices for a minimum of 3 years following task completion.

The Tetra Tech TOL and designees will maintain files, as appropriate, as repositories for information and data used in models and for preparing reports and documents during the task. Electronic project files are maintained on network computers and are backed up weekly. The Tetra Tech TOL will supervise the use of materials in the central files. The following information will be included in the hard copy or electronic task files in the central file:

- Any reports and documents prepared
- Contract and task order information
- QAPP and draft and final versions of requirements and design documents
- Electronic copies of models
- Results of technical reviews, internal and external design tests, quality assessments of output data, and audits
- Documentation of response actions during the task to correct problems
- Input and test data sets
- Communications (memoranda; internal notes; telephone conversation records; letters; meeting minutes; and all written correspondence among the task team personnel, suppliers, or others)
- Studies, reports, documents, and newspaper articles pertaining to the task
- Special data compilations

Records of receipt with information on source and description of documentation will be filed along with the original data sheets and files to ensure traceability. Records of actions and subsequent findings will be kept during additional data processing.

All data files, source codes, and executable versions of the computer software will be retained for internal peer review, auditing, or post-task reuse in the electronic task files in the administrative record. These materials include the following:

- Versions of the source and executable code used
- Databases used for model input, as necessary
- Key assumptions
- Documentation of the model code and verification testing for newly developed codes or modifications to the existing model

The Tetra Tech Modeling QC Officer and other experienced technical staff will review the materials listed above during internal peer review of modified existing models or new codes or models. The designated QC Officers will perform QC checks on any modifications to the source code used in the design process. All new input and output files, together with existing files, records, codes, and data sets, will be saved for inspection and possible reuse.

Any changes in this QAPP required during the study will be documented in a memo sent by Tetra Tech's QA Officer to each person on the distribution list following approval by the appropriate persons. The memo will be attached to the revised QAPP.

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2 Model Selection, Calibration, and Supporting Data Acquisition and Management

2.1 Model Selection

The work described in this QAPP does not involve the creation of new simulation modeling software. Rather, it involves the development and application of an existing model, QUAL2Kw (Chapra et al., 2008; Pelletier and Chapra, 2008). The rationale for the selection of QUAL2Kw is described above in Section 1.3.

2.2 Model Calibration and Validation

Environmental simulation models are simplified mathematical representations of complex real world systems. Models cannot accurately depict the multitude of processes occurring at all physical and temporal scales. Models can, however, make use of known interrelationships among variables to predict how a given quantity or variable would change in response to a change in an interdependent variable or forcing function. In this way, models can be useful frameworks for investigations of how a system would likely respond to a perturbation from its current state. To provide a credible basis for prediction and the evaluation of mitigation options, the ability of the model to represent real world conditions should be demonstrated through a process of model calibration and corroboration (CREM, 2009).

2.2.1 Objectives of Model Calibration Activities

The principal study questions for this project address the following:

1. What is the sensitivity of DO in Clarks Creek to each of the potential risk pathways described in the Conceptual Model?
2. What levels of reductions in controllable stressors are needed to achieve DO standards?
3. What implementation options will best achieve the needed reductions?

Model calibration is designed to ensure that the models are adequate to provide appropriate input to answer the study questions. The work covered under this Task Order is proceeding in parallel (but not synchronously) with a separate contract to be issued by the Puyallup Tribe to complete an HSPF watershed model that will address sediment, nutrient, and bacterial loads to Clarks Creek. The HSPF model will enable a dynamic (time-varying) simulation of DO in Clarks Creek. The Tribe's project will also collect significant amounts of new data.

The QUAL2Kw application described in this QAPP can be viewed as a preliminary modeling exercise that will inform the subsequent HSPF modeling by identifying the significant risk pathways and sensitivities of the DO response, while the HSPF watershed model will allow for a more refined estimate of upland loading sources and implementation opportunities. The two project schedules are not fully synchronized and it will be necessary to develop TMDL allocations and implementation plans under this current project well before the Tribe's modeling project is completed. It is anticipated that a separate QAPP will be developed for the HSPF watershed modeling work.

The QUAL2Kw modeling will form the initial basis for identifying the TMDL allocations for achieving DO standards in Clarks Creek; however, the implementation planning that arises from this project is anticipated to be refined through adaptive management as the Tribe's modeling effort is completed.

As a result of these considerations, model calibration will focus on decision needs relative to the first two principal study questions. These require that the calibration activities establish a credible representation of the components and relationships contained in the Conceptual Model (Figure 3).

2.2.2 Model Calibration/Corroboration Procedures

Calibration consists of the process of adjusting model parameters to provide an appropriate representation of observed conditions and underlying processes. Calibration is necessary because of the semi-empirical nature of water quality models. Although these models are formulated from mass balance principles, most of the kinetic descriptions in the models are empirically derived. These empirical derivations contain a number of coefficients that are usually determined by calibration of the model to observed water quality data that have been collected in the waterbody of interest.

Calibration tunes the models to represent conditions appropriate to the waterbody and watershed under study. However, calibration alone is not sufficient to assess the predictive capability of the model, or to determine whether the model developed via calibration contains a valid representation of cause and effect relationships, especially those associated with the principal study questions. To help determine the adequacy of the calibration and to evaluate the uncertainty associated with the calibration, the model is subjected to a validation or corroboration step. The terminology of corroboration is preferred by CREM (2009), and "includes all quantitative and qualitative methods for evaluating the degree to which a model corresponds to reality. The rigor of these methods varies depending on the type and purpose of the model application." In a traditional validation step, the model is applied to a set of data independent from that used in calibration to test its performance. However, the reality is that the "validation" test often indicates the need for further adjustments, resulting in an iterative process, potentially followed by another validation test.

The QUAL2Kw model to be used in this project is a steady-state (but diurnally variable), critical conditions model. Observed DO problems do not appear to be sensitive to flow, but are sensitive to temperature. Therefore, steady-state analyses at typical summer baseflow conditions are appropriate. Tetra Tech will identify at least three periods of relatively intensive data availability from the existing monitoring record (see Tetra Tech, 2010) for calibration, corroboration, and potential further testing of the model performance.

The model will be calibrated through a sequential process, beginning with the flow balance and hydrology, followed by water temperature, chemical water quality, and algal/macrophyte response.

The simulated water balance is determined almost entirely by boundary conditions, which will be specified based on best available data. The calibration of hydrology in QUAL2Kw is focused on ensuring that depths, flow velocities, and travel times are well-represented in the model. Dye studies for velocities and travel time have not been done; however, there is a HEC-RAS hydraulic model of the mainstem (CH2MHill 2003) that will be used to establish channel dimensions and estimated travel times. These will be checked against field measurements of velocity at the USGS gage.

The temperature simulation will depend on boundary conditions and riparian shading. Quantitative data on riparian shading are not yet available; thus, this aspect of the simulation will consist primarily of sensitivity analysis.

The water quality calibration will begin by attaining a general representation of total N and total P concentrations. This will be followed by calibration for nutrient species, which must be done simultaneously with model development of macrophyte growth. For the macrophytes (elodea), the model representation of benthic algae will serve as a surrogate for elodea. This may require reducing the sensitivity of the "attached algae" in the model to water column phosphorus concentrations, as elodea can obtain phosphorus via its roots from the sediment. Dissolved oxygen calibration then occurs as the final step, as the DO balance depends on all the other components of the calibration.

After the model is adequately calibrated, the quality of the calibration will be further evaluated through corroboration tests on additional data sets. In the past, this has typically been described as a validation test, where model validation is defined as, “subsequent testing of a pre-calibrated model to additional field data, usually under different external conditions, to further examine the model’s ability to predict future conditions” (USEPA, 1997). In fact, extension of the model to new data sets often requires some further adjustments and assumptions, resulting in an iterative process of model development that is more appropriately termed corroboration. The corroboration step helps to ensure that the calibration is robust, and that the quality of the calibration is not an artifact of over-fitting to a specific set of observations. Corroboration tests can also provide evidence as to the degree of uncertainty that may be expected when the model is applied to conditions outside of the calibration series.

It is unreasonable to expect that the model will exactly predict all spatial and temporal variations in concentrations. Therefore, it is important to evaluate the water quality calibration through use of statistical tests of equivalence between observed and simulated data in addition to qualitative graphical comparisons.

To conduct the calibration and validation process, a set of basic statistical methods will be used to compare model predictions and observations for average, minimum, and maximum DO, nutrient concentrations, and temperature, including the mean error statistic, the absolute mean error, the root-mean-square error, and the relative error. Because QUAL2Kw is a steady-state (diurnal) model, other statistics that are commonly applied to dynamic models, such as the coefficient of determination, and the Nash-Sutcliffe coefficient of model fit efficiency, will not be applied here.

Mean Error Statistic. The mean error between model predictions and observations is defined as

$$E = \frac{\sum (O - P)}{n},$$

where

E = mean error
O = observations
P = model prediction at the same time as the observations
n = number of observed-predicted pairs

A mean error of zero is ideal. A non-zero value is an indication that the model might be biased toward either over- or under-prediction. However, an important consideration of the mean error approach is that it can severely penalize the model for small phase shifts in timing. One approach that can be used to address this is to establish a time window, calculate the range of model predictions for the time window, then count a deviation from prediction only if the observation falls outside this range.

Absolute Mean Error Statistic. The absolute mean error between model predictions and observations is defined as

$$E_{abs} = \frac{\sum \left|(O - P)\right|}{n},$$

where

E_{abs} = absolute mean error.

An absolute mean error of zero is ideal. The magnitude of the absolute mean error indicates the average deviation between model predictions and observed data. Unlike the mean error, the absolute mean error cannot give a false zero.

Root-Mean-Square Error Statistic. The root-mean-square error (E_{rms}) is defined as

$$E_{rms} = \sqrt{\frac{\sum (O - P)^2}{n}} ,$$

A root-mean-square error of zero is ideal. The root-mean-square error is an indicator of the deviation between model predictions and observations. The E_{rms} statistic is an alternative to (and is usually larger than) the absolute mean error.

Relative Error Statistics. The relative error statistics (*RE*) between model predictions and observations can be calculated by dividing the mean error and absolute mean error statistics by the mean of the observations. A relative error statistic of zero is ideal. When it is non-zero, it represents the percentage of deviation between the model prediction and observation.

2.2.3 Uncertainty Analysis for Calibrated Models

From a decision context, the primary function of the calibrated water quality model will be to predict the response of instream DO to changes in external loads and management. As such, an important input to the decision-making process is information on the degree of uncertainty that is associated with model predictions. In some cases, the risks or *costs* of not meeting water quality standards could be substantially greater than the costs of over-protection, creating an asymmetric decision problem in which there is a strong motivation for risk avoidance. Therefore, an uncertainty analysis of model predictions is essential.

As with any mathematical approximation of reality, a water quality model is subject to significant uncertainties. Direct information on the aggregate prediction uncertainty will arise from the model validation exercise; however, further diagnostics are needed to understand the sources and implications of uncertainty.

The major sources of model uncertainty include the mathematical formulation, boundary conditions data uncertainty, calibration data uncertainty, and parameter specification. In many cases, a significant amount of the overall prediction uncertainty is due to boundary conditions (e.g., uncertainty in estimation of ungaged tributary flows) and uncertainty in the observed data used for calibration and validation. These sources of uncertainty are largely unavoidable, but do not invalidate the use of the model for decision purposes. Uncertainties in the mathematical formulation and model parameters are usually of greater concern for decision purposes as these describe the cause and effect relationships in the calibrated model.

The QUAL2K/QUAL2Kw model code has a long history of testing and application, so outright errors in the coding of the models are unlikely. A simulation model, however, is only a simplified representation of the complexities of the real world. The question is not whether the model is "right" in the sense that it represents all processes, but rather whether it is useful, in the sense that it represents the important processes to a sufficiently correct degree to be useful in answering the principal study questions.

The most widely applied parameter uncertainty analysis approach for complex simulation models is sensitivity analysis. Sensitivity analysis is implemented by perturbing model parameter values one at a time (or in combination) and evaluating the model response. This method is useful in identifying key parameters and processes in a water quality system, and the interpretation of the result is straightforward and meaningful. Sensitivity analysis, however, is limited in its ability to evaluate nonlinear interactions among multiple parameters.

2.2.4 Acceptance Criteria for Model Calibration

The model development and evaluation process culminates in a decision to accept (or not accept) the model for use in decision making (CREM, 2009).

The intended uses of the model focus on the ability to understand and quantify the contribution of different risk pathways to depressed DO in Clarks Creek. As such, the abilities of the model to replicate observed DO concentrations (particularly daily minima) and to represent the relative contributions of different stressor sources are of greatest importance. Ideally, the models should attain tight calibration to observed data; however, a less precise calibration can still provide useful information.

In light of these uses of the models, it is most informative to specify performance target ranges of precision that characterize the model results as "very good," "good," "fair," or "poor." These characterizations inform appropriate uses of the model: Where a model achieves an excellent fit it can assume a strong role in evaluating management options. Conversely, where a model achieves only a fair or poor fit it should assume a much less prominent role in the overall weight-of-evidence evaluation of management options.

Specific numeric acceptance criteria are not specified for the model. Instead, appropriate uses of the model will be determined by the project team based on assessment of the types of decisions to be made, the model performance, and the available resources.

2.2.5 Performance Targets for QUAL2Kw

General performance targets for QUAL2Kw based on past model experience are summarized in Table 1.

Table 1. Performance Targets for QUAL2Kw Simulation (Magnitude of Spatially Averaged Relative Mean Error (*RE*))

Model Component	Very Good	Good	Fair	Poor
1. Error in water temperature	≤ 5%	5 - 10%	10 - 15%	> 15%
2. Error in DO concentration	≤ 5%	5 - 10%	10 - 20%	> 20%
3. Suspended Sediment	≤ 20%	20 - 30%	30 - 45%	> 45%
4. Nutrients	≤ 15%	15 - 25%	25 - 35%	> 35%

2.3 Nondirect Measurements (Secondary Data Acquisition Requirements)

Nondirect measurements (also referred to as secondary data) are data previously collected under an effort outside this contract that are used for model development and calibration. Sources of key secondary data are summarized in Details regarding how relevant secondary data will be identified, acquired, and used for this task are provided below.

Table 2. Sources of Key Secondary Data

Data Type	Source
Tributary and Mainstem Flow	USGS gaging (NWIS system); City of Puyallup 2002-2003 data.
Tributary and Mainstem Water Quality	Monitoring by Puyallup Tribe, Washington Ecology, USGS, Pierce County, City of Puyallup, and others (summarized in Tetra Tech, 2010)
Reach Hydraulics	HEC-RAS model (CH2MHill, 2003); USGS field measurements (NWIS system)
Meteorology	National Climatic Data Center
Point Source Loads	Discharge Monitoring Reports (Washington Ecology); Self-monitoring (Puyallup Tribe)
Stream Shading	Qualitative Observation, sensitivity analyses
Sediment Oxygen Demand	Sensitivity Analyses

2.3.1 Flow Data

Reliable streamflow data are important to model development and calibration and validation. The U.S. Geological Survey (USGS) maintained a streamflow gage on Clarks Creek at Tacoma Road through 2008. Data from this gage are readily available through the USGS National Water Information System, accompanied by useful QC information. USGS also provides a small number of field measurements at other sites on Clarks Creek and has developed information on ground water-surface water interactions in the area (Savoca et al., 2010). Some additional flow measurements were collected by URS during 2002-2003 monitoring and are available from the City of Puyallup. Additional information on ungaged flows will need to be inferred from existing HEC-RAS hydraulic models of the creek developed for Pierce County (CH2MHill, 2003). When flow data from sources other than USGS gaging and field measurements are used a review of the relevant quality assurance protocols will be undertaken and the results documented in the project report.

An HSPF watershed model of the watershed has been developed for flow only (CH2MHill, 2003). This model will be evaluated for potential use in estimating unmonitored tributary flows for the QUAL2Kw application.

2.3.2 Meteorological Data

QUAL2Kw requires meteorological data to simulate water temperature and light limitation on plant growth. Diurnal data for air temperature, dewpoint temperature, wind speed, and cloud cover will be obtained from the National Climatic Data Center (NCDC) records for Tacoma Narrows Airport (WBAN 94274).

Incident solar radiation at the water surface is calculated by QUAL2Kw using edge-of-atmosphere solar radiation (a function of latitude and time of year), cloud cover, and shading. Information on riparian shading of Clarks Creek is limited at this time. However, the intention for the initial application of the model is to undertake sensitivity analyses to test whether attaining compliance with DO criteria is sensitive to riparian shading and consequent temperature effects. If model results for DO are sensitive to variations in shading, then it would be appropriate to invest extra effort to assemble detailed LIDAR data and collect additional field data on tree canopy to provide a more accurate estimate of shading, potentially using Ecology's SHADE model.

2.3.3 Water Quality Observations

As part of this task order, Tetra Tech (2010) has already compiled and reviewed water quality monitoring data for Clarks Creek. These data have been variously collected by USGS, Washington Department of Ecology, the Puyallup Tribe, the City of Puyallup, Pierce County, and others. Data collected and provided by USGS and Ecology will be assumed to have undergone appropriate QA/QC procedures. When data from other sources are used, a review of the relevant quality assurance protocols will be undertaken and the results documented in the project report.

2.3.4 Point Source Discharges

Two hatcheries discharge to Clarks Creek: The Washington State Department of Fisheries operates a hatchery at Maplewood Springs under NPDES permit WA0039748 while the Puyallup Tribe operates a small hatchery on Diru Creek and a rearing pond that discharges to Clarks Creek near Diru Creek. (The Puyallup Tribal Hatchery currently falls under the regulatory threshold of the NPDES general permit for tribal fish hatcheries.) Both hatcheries are believed to discharge only small amounts of pollutants, although data are sparse. Tetra Tech will assemble available monitoring data from Washington Ecology and the Puyallup Tribe. However, it is anticipated that significant uncertainty regarding these discharges will remain. This will be addressed through sensitivity analyses.

2.3.5 Additional Loading Sources

Additional thermal and pollutant loads derive from groundwater discharges, small unmonitored tributaries, and direct loading from riparian areas. Loading via groundwater discharges from unsewered portions of the watershed may include contributions from onsite wastewater disposal. Information on these potential sources is extremely limited and will be initially addressed through reasonable assumptions and sensitivity analyses. While the Puyallup Tribe is developing an HSPF water quality model of the watershed it is not anticipated that results of this model will be available in time to inform the QUAL2Kw modeling effort described in this QAPP. As with other sources of uncertainty, recommendations for additional data collection and watershed modeling will be made if results appear to be sensitive to these assumptions.

2.3.6 Quality Control for Nondirect Measurements

The majority of the nondirect measurements will be obtained from quality assured sources. Tetra Tech will assume that data obtained from USGS, Washington Ecology, or EPA documents and databases have been screened and meet specified measurement performance criteria. These criteria might not be reported for the parameters of interest in the documents or databases. Tetra Tech will determine how much effort should be made to find reports or metadata that might contain that information. Tetra Tech will perform general quality checks on the transfer of data from any source databases to another database, spreadsheet, or document.

Where data are obtained from sources lacking an associated quality report, Tetra Tech will evaluate data quality of such secondary data before use. Additional methods that might be used to determine the quality of secondary data include:

- Verifying values and extracting statements of data quality from the raw data, metadata, or original final report

- Comparing data to a checklist of required factors (e.g., analyzed by an approved laboratory, used a specific method, met specified DQOs, validated)

If it is determined that such searches are not necessary or that no quality requirements exist or can be established, however these data must be used in the task, Tetra Tech will add a disclaimer to the deliverable indicating that the quality of the secondary data is unknown.

2.4 Data Management and Hardware/Software Configuration

No sampling (primary data collection) will be conducted by Tetra Tech for this task. Secondary data collected as part of this task will be maintained as hard copy only, both hard copy and electronic, or electronic only, depending on their nature.

The modeling software to be used for this project consists primarily of the QUAL2Kw model, for which both code and executables are publicly available from Washington Ecology <http://www.ecy.wa.gov/programs/eap/models.html>. The current release is version 5.1b52.

The Tetra Tech TOL will maintain and provide the final version of the model input, output, and executables to EPA and Ecology for archiving at the completion of the task. Electronic copies of the data, GIS, and other supporting documentation will be supplied to EPA with the final report. Tetra Tech will maintain copies in a task subdirectory (subject to regular system backups) and on disk for a maximum period of 3 years after task termination, unless otherwise directed by the client.

Most work conducted by Tetra Tech for this task requires the maintenance of computer resources. Tetra Tech's computers are either covered by onsite service agreements or serviced by in-house specialists. When a problem with a microcomputer occurs, in-house computer specialists diagnose the problem and correct it if possible. When outside assistance is necessary, the computer specialists call the appropriate vendor. For other computer equipment requiring outside repair and not currently covered by a service contract, local computer service companies are used on a time-and-materials basis. Routine maintenance of microcomputers is performed by in-house computer specialists. Electric power to each microcomputer flows through a surge suppressor to protect electronic components from potentially damaging voltage spikes. All computer users have been instructed on the importance of routinely archiving work assignment data files from hard drive to compact disc or server storage. The office network server is backed up on tape nightly during the week. Screening for viruses on electronic files loaded on microcomputers or the network is standard company policy. Automated screening systems have been placed on all of Tetra Tech's computer systems and are updated regularly to ensure that viruses are identified and destroyed. Annual maintenance of software is performed to keep up with evolutionary changes in computer storage, media, and programs.

3 Assessments and Response Actions

3.1 Assessment and Response Actions

The QA program under which this task order will operate includes surveillance and internal and external testing of the software application. The essential steps in the QA program are as follows:

- Identify and define the problem
- Assign responsibility for investigating the problem
- Investigate and determine the cause of the problem
- Assign and accept responsibility for implementing appropriate corrective action
- Establish the effectiveness of and implement the corrective action
- Verify that the corrective action has eliminated the problem

Many technical problems can be solved on the spot by the staff members involved; for example, by modifying the technical approach, correcting errors in input data, or correcting errors or deficiencies in documentation. Immediate corrective actions are part of normal operating procedures and are noted in records for the task. Problems not solved this way require formalized, long-term corrective action. If quality problems that require attention are identified, Tetra Tech will determine whether attaining acceptable quality requires short- or long-term actions. If a failure in an analytical system occurs (e.g., performance requirements are not met), the appropriate QC Officer will be responsible for corrective action and will immediately inform the Tetra Tech TOL or QA Officer, as appropriate. Subsequent steps taken will depend on the nature and significance of the problem.

The Tetra Tech TOL (or designee) has primary responsibility for monitoring the activities of this task and identifying or confirming any quality problems. Significant quality problems will also be brought to the attention of the Tetra Tech QA Officer, who will initiate the corrective action system described above, document the nature of the problem, and ensure that the recommended corrective action is carried out. The Tetra Tech QA Officer has the authority to stop work if problems affecting data quality that will require extensive effort to resolve are identified.

Corrective actions may include the following:

- Reemphasizing to staff the task objectives, the limitations in scope, the need to adhere to the agreed-upon schedule and procedures, and the need to document QC and QA activities
- Securing additional commitment of staff time to devote to the task
- Retaining outside consultants to review problems in specialized technical areas
- Changing procedures

The assigned QC Officer (or designee) will perform or oversee the following qualitative and quantitative assessments of model performance to ensure that models are performing the required tasks while meeting the quality objectives:

- Data acquisition assessments
- Secondary data quality assessments
- Model testing studies
- Model evaluations
- Internal peer reviews

3.1.1 Model Development Quality Assessment

This QAPP and other supporting materials will be distributed to all personnel involved in the work assignment. The designated QC Officer will ensure that all tasks described in the work plan are carried out in accordance with the QAPP. Tetra Tech will review staff performance throughout each development phase of each case study to ensure adherence to task protocols.

Quality assessment is defined as the process by which QC is implemented in the model development task. All modelers will conform to the following guidelines:

- All modeling activities including data interpretation, load calculations, or other related computational activities are subject to audit or peer review. Thus, the modelers are instructed to maintain careful written and electronic records for all aspects of model development.
- If historical data are used, a written record on where the data were obtained and any information on their quality will be documented in the final report. A written record on where this information is on a computer or backup media will be maintained in the task files.
- If new theory is incorporated into the model framework, references for the theory and how it is implemented in any computer code will be documented.
- Any modified computer codes will be documented, including internal documentation (e.g., revision notes in the source code), as well as external documentation (e.g., user's guides and technical memoranda supplements).

The QC Officer will periodically conduct surveillance of each modeler's work. Modelers will be asked to provide verbal status reports of their work at periodic internal modeling work group meetings. The Tetra Tech TOL or his assigned deputy will make detailed modeling documentation available to members of the modeling work group on a monthly basis.

3.1.2 Software Development Quality Assessment

New software development is not anticipated for this project. If any such development is required, the QC Officer (or designee) will conduct surveillance on software development activities to ensure that all tasks are carried out in accordance with the QAPP and satisfy user requirements. Staff performance will be reviewed throughout the life cycle to ensure adherence to task procedures and protocols.

3.1.3 Surveillance of Project Activities

Internal peer reviews will be documented in the project file and QAPP file. Documentation will include the names, titles, and positions of the peer reviewers; their report findings; and the project management's documented responses to their findings. The Tetra Tech TOL may replace a staff member if it is in the best interest of the task to do so.

Performance audits are quantitative checks on different segments of task activities. The Tetra Tech QC Officer or his designees will be responsible for overseeing work as it is performed and for periodically conducting internal assessments during the data entry and analysis phases of the task. The Tetra Tech TOL will perform surveillance activities throughout the duration of the task to ensure that management and technical aspects are being properly implemented according to the schedule and quality requirements specified in the data review and technical approach documentation. These surveillance activities will include assessing how task milestones are achieved and documented, corrective actions are implemented, budgets are adhered to, peer reviews are performed, and data are managed, and whether computers, software, and data are acquired in a timely manner.

3.2 Reports to Management

The TOL (or designee) will provide monthly progress reports to EPA. As appropriate, these reports will inform EPA of the following:

- Adherence to project schedule and budget
- Deviations from approved QAPP, as determined from project assessment and oversight activities
- The impact of these deviations on model application quality and uncertainty
- The need for and results of response actions to correct the deviations
- Potential uncertainties in decisions based on model predictions and data
- Data Quality Assessment findings regarding model input data and model outputs

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4 Output Assessment and Model Usability

4.1 Departures from Acceptance Criteria

The model developed for the project will be used to assess a series of study questions, as summarized in Section 1.3, associated with the project goals and objectives. Acceptance criteria for the model are described in Section 2.2.4.

Written documentation will be prepared under the direction of the relevant QC Officer addressing the calibrated model's ability to meet the specified acceptance criteria and provided to the TOL and QA Officer for review. If a model does not meet acceptance criteria, the QC Officer will first direct efforts to bring the model into compliance. If, after such efforts, the model still fails to meet acceptance criteria, a thorough exposition of the problem and potential corrective actions (e.g., additional data collection or modification of model code) will be provided to EPA. Tetra Tech will also provide an analysis of the degree to which any model that does not fully meet acceptance criteria may still be useful for addressing study questions.

4.2 Model Corroboration Methods

Simulation models used to support implementation planning will be corroborated using data sets separate from those used in model calibration, as described in Section 2.2.2. Results of model corroboration will be documented in writing and provided to EPA.

4.3 Third-Party Peer Review

The calibrated model and accompanying model report will be subject to third-party technical peer review at the discretion of the EPA TMDL Project Manager. It is anticipated that such reviews will include a technical review by staff from Washington Ecology. Tetra Tech will provide a response to technical review comments and perform any needed modifications to the model and report.

4.4 Reconciliation with User Requirements

Quality objectives for modeling are addressed in Section 1.4. Specific numeric acceptance criteria are not specified for the model (Section 2.2.2). Instead, appropriate uses of the model will be determined by the project team based on assessment of the types of decisions to be made, the model performance, and the available resources.

If the project team determines that the quality of the model calibration is insufficient to address the principal study questions, Tetra Tech will consult with EPA and other team members, as appropriate, as to whether the levels of uncertainty present in the models can allow user requirements to be met, and, if not, the actions needed to address the issue.

A detailed evaluation of the ability of the modeling tools to meet user requirements will be provided in the modeling report.

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