DEPARTMENT OF THE ARMY
SEATTLE DISTRICT, CORPS OF ENGINEERS
P.O. BOX 3755
SEATTLE, WASHINGTON 98124-3755

REPLY TO
ATTENTION OF

Water Management Section

November 21, 2007

Robert Steed
Idaho Department of Environmental Quality
2110 Ironwood Parkway
Coeur d'Alene, ID 83814

Marcie Mangold
Washington Department of Ecology
4601 N. Monroe St.
Spokane, WA 99205

Donald Martin
U.S. Environmental Protection Agency
1910 Northwest Blvd., Suite 208
Coeur d'Alene, ID 83814

Michele Wingert
Kalispel Tribe of Indians
P.O. Box 39
Usk, WA 99180

SUBJECT: Pend Oreille River TMDL for Temperature Draft August 2007, COE review comments

Dear Mr. Steed, Ms. Mangold, Mr. Martin, and Ms. Wingert:

Enclosed are the Seattle District Corps of Engineers' comments on the August 2007 *Draft Pend Oreille River Total Maximum Daily Load for Temperature* (Draft TMDL) prepared by Tetra Tech, Inc for the Tri-State Water Quality Council. These comments include the following sections:

- General comments and recommended corrections on the August 2007 Draft TMDL

- Attachment A: Comments on the August 2007 Draft TMDL and an alternative assessment of thermal impacts and the effects of travel time, prepared by Mike Schneider, U.S. Army Engineer Research and Development Center

- Attachment B: Technical assessment of predictive errors of model estimates, prepared by Mike Schneider, U.S. Army Engineer Research and Development Center.

The Seattle District is aware that the temperature model used to develop the Draft TMDL had a water budget error and that new model runs have been generated that may change certain aspects of the Draft TMDL. The Seattle District is providing comments on the August 2007 Draft TMDL with the understanding that there will be further opportunities to comment on the revised Draft TMDL once the new model runs have been evaluated.

The Seattle District is committed to being an active participant in the Pend Oreille River TMDL and is providing the enclosed comments with intent of strengthening the temperature model and Draft TMDL. If you have any questions concerning our information, please do not hesitate to contact me by phone at (206) 764-3595 or by e-mail at edwin.t.zapel@usace.army.mil.

Sincerely,

Ed Zapel
Chief, Water Management Section
Seattle District Corps of Engineers

Cc: Rudd Turner, CENWD

Enclosures

November 9, 2007

MEMORANDUM FOR: Robert Steed, Idaho Department of Environmental Quality
Paul Picket / Jon Jones, Washington Department of Ecology
Don Martin, Environmental Protection Agency
Michele Wingert, Kalispel Tribe of Indians

SUBJECT: Pend Oreille River TMDL for Temperature Draft August 2007, COE review comments

The following memorandum contains comments and corrections from the Seattle District Corps of Engineers (Seattle District) regarding the August 2007 *Draft Pend Oreille River Total Maximum Daily Load for Temperature* prepared by Tetra Tech, Inc for the Tri-State Water Quality Council. Comments were provided by Kent Easthouse, Seattle District Corps of Engineers and Mike Schneider, U.S. Army Engineer Research and Development Center.

Attached are two documents by Mike Schneider, U.S. Army Engineer Research and Development Center.

- Attachment A: Comments on the August 2007 *Draft Pend Oreille River Total Maximum Daily Load for Temperature* and an alternative assessment of thermal impacts and travel time
- Attachment B: Technical assessment of predictive errors of model estimates

Overview

The CE-QUAL W2 model used for the August 2007 Draft TMDL analysis was developed by Portland State University and documented in the following reports: *Idaho Pend Oreille River Model: Model Development and Calibration Technical Report EWR-02-06* and the March 2007 DRAFT *Idaho Pend Oreille River Model: Model Scenario Simulations Technical Report EWR-01-07*. The Seattle District discovered a substantial error with the water budget in the CE-QUAL W2 model used to develop the August 2007 *Draft Pend Oreille River Total Maximum Daily Load for Temperature* which required Portland State University to re-run the model and generate updated model results. Until the results of the new model runs are seen and the new TMDL load allocations are developed, the Seattle District will focus comments on the general methodology of the approach and on the modeling issues rather than on the specific loading data presented in the TMDL.

The Seattle District is providing comments on the Draft TMDL with the understanding that there will be another opportunity to comment on the specific details outlined in the revised Draft TMDL once the temperature model has been fixed, re-calibrated, and the newer model results are analyzed and evaluated.

General Comments

The Seattle District is committed to being an active participant in the Pend Oreille River TMDL process and will assist the state of Idaho in the development and implementation of the Pend Oreille River TMDL. The Seattle District believes that the temperature data collection programs by various entities and CE-QUAL W2 model development for the Pend Oreille River is an important part of understanding the physical, chemical, and biological processes occurring in the Pend Oreille River under existing and simulated natural conditions. However, modeling a hypothetical natural river for which little historical data exists, is a complicated process and model error and uncertainty must be considered when interpreting data and drawing conclusions regarding compliance with state water quality statues. At a minimum uncertainty and sensitivity tests need to be conducted to determine the impacts on predicted temperatures. In addition, rigorous statistical analysis of model scenario temperature data is required to provide a comprehensive summary of study findings. It is critical that the model contain the best information in representing the current and natural Pend Oreille River environment, especially in light of the highly specific water quality metrics identified in this study. Lastly, the water quality metrics used for compliance determination need to be representative of river conditions and must account for both the thermal source and differences in travel time between modeling scenarios.

The Seattle District believes that the current CE-QUAL W2 model and data interpretation of the model needs to be improved before the final TMDL process moves forward. Comments provided below will focus on the following issues:

- Model Uncertainty and Error
- Existing Errors in Model
- Water Quality Compliance Metrics
- Travel Time and Lag Time
- TMDL Analysis

I. Model Uncertainty

There are many challenges associated with the application of the CE-QUAL W2 model to the Pend Oreille River with and without Albeni Falls Dam for the purpose of determining compliance with Idaho and Washington water quality standards. Simulated temperatures generated from model scenarios representing “natural” conditions and “existing” conditions form the basis for determination of compliance. The Seattle District believes that both model uncertainty and error need to be reevaluated and accounted for when comparing “natural” and “existing” simulations to assess compliance. Modeling errors identified by the Seattle District in the current Pend Oreille River TMDL study involving boundary conditions for flow and temperatures have resulted in erroneous conclusions of non-compliance and load allocations. Comments in the following section will focus on (1) The Level of Uncertainty, and (2) Errors Introduced at the Boundary Propagate through Model.

Level of Uncertainty

Comment: There is little discussion of role of model uncertainty in drawing conclusions on water quality compliance in the Draft TMDL. The assumption of the certainty of model estimates for both “natural” and “existing” conditions is implied in this TMDL. This assumption of model certainty in the TMDL is a concern to the Seattle District because the TMDL bases compliance criteria on comparisons of simulated model temperatures for the existing river with Albeni Falls Dam to a theoretical “natural” river without Albeni Falls Dam. The detection tolerance of the model to determine temperature differences down to 0.3 °C or less between model scenarios for “natural” and “existing” conditions is not supported by a quantitative evaluation of the predictive error of the model, sensitivity analyses of critical but uncertain model inputs for the “natural” conditions scenario, or the cumulative errors compounded from both factors.

The predictive errors of model estimates of temperature at a specific point in time and space will be much larger than predictive errors of simulated temperatures averaged over time and space. The confidence level associated with claims of non-compliance using narrowly defined water quality metrics that are based on a singular response at a specific point or model cell location, need to consider the much larger uncertainty associated with numerical model simulations. For example, the predictive errors associated with the maximum daily surface temperatures in the Pend Oreille River at Riley Creek were found to be over twice as large as the predictive errors for determining the daily average cross sectional temperatures. A more detailed discussion of these observations can be found in the attached Appendix.

There was no discussion of observed temperatures in Pend Oreille River system prior to the construction of Albeni Falls Dam in 1951 in the TMDL. As a result, this study cannot directly quantify the models predictive capability of reproducing “natural” conditions. The CE-QUAL W2 model attempts to simulate temperature for pre-dam conditions by removing Albeni Falls Dam from the model and altering critical input parameters such as flow, lake elevation, river elevation, and river bathymetry. Each of these input parameters for pre-dam conditions are individual sources of uncertainty to the model. A sensitivity analysis should be performed to determine the impacts of these critical model input parameters on model results and on the cumulative impact of all parameters on model results. In addition, other source of estimate uncertainty can be associated with modeling errors that include poorly defined flow and temperature boundary conditions, forcing functions, model parameters and channel/structural features. All of these factors contribute to model estimates deviating from the observations of the real world resulting in model error.

The Seattle District does not believe that the model can accurately predict temperatures in the Pend Oreille River down to less than about 0.5 °C at a sufficient confidence level[1]. The concept that model error and uncertainty is not important when comparing two model scenarios is not a reasonable approach when comparing the "natural" vs. "existing" conditions scenarios. These two model scenarios have different travel times, boundary conditions, channel configurations, model mesh setups and other differences in order to simulate the Pend Oreille River with and without Albeni Falls Dam. Model error needs to be accounted for between two such different model scenarios. Clear justification, along with confidence limits assumed, for using a detection tolerance of 0.3 °C between modeling results should be presented in the TMDL.

Recommendations:

A simple sensitivity analysis should be performed to verify the range of simulated thermal properties. A quantitative analyses of model uncertainty should be conducted and realistic/verifiable detection limits should be determined and applied to assessments of compliance. An effective compliance tolerance commensurate with the reasonable limits determined in the sensitivity analysis should be used to account for model uncertainty and model error in the final determination of water quality compliance. The best information should be used to estimate natural conditions with the model. It has been demonstrated that critical model input like river flows are important in characterizing the thermal properties in the Pend Oreille River. Other model inputs like pre-dam Lake Pend Oreille stage are publicly available and should be consistent with model input conditions. The imposed natural channel bathymetry, hydrology, hydraulics should be reviewed and compared with available data.

Comment:

The location of the upstream boundary condition at the railroad bridge and the decision not to model the large shallow basin of Lake Pend Oreille that flows into the Pend Oreille River or the influence of Clark Fork discharges, has resulted in considerable model uncertainty and error at

[1] The position that model error is similar between scenarios and does not need to be accounted for was shown to be incorrect when evaluating the influence of an error introduced at the upstream temperature boundary condition on compliance determination at the Washington State Line on May 1, 2004. The Draft TMDL states that Albeni Falls impaired water quality at the state line on May 1, 2004 and a heat load was calculated. However, the Seattle District analyzed the CE-QUAL W2 model input data and determined that the differential transport of an erroneous cold water inflow at the boundary condition resulted in large temperature differences at the Washington State Line that were identified as violations of Washington State water quality standards. The boundary condition cold water was introduced the same day at the upstream end of the Pend Oreille River for both "existing" and "natural" scenarios, but timing and duration of this cold water inflow as observed at a distance downstream compliance location were quite different because of the different travel times associated with difference conditions. The erroneous cold water input to the model was the direct result of model uncertainty and error at the upstream boundary condition.

the boundary. Portland State University stated in the *Idaho Pend Oreille River Model: Model Development and Calibration Technical Report EWR-02-06* report:

Model error for temperature was greatest nearest the upstream boundary condition, but improved at sites closer to Albeni Falls Dam. The larger error near the upstream boundary condition was due to data reflecting seiching action in Lake Pend Oreille. Only a small portion of the lake is simulated by the model. Sites downstream towards the dam were not affected by seiching and thus model predictions improved downstream….The Model was very sensitive to the upstream boundary conditions. Differences between model predictions and data were often due to the sparseness of data measured at the upstream boundary condition.

The location of the upstream boundary at the railroad bridge effectively excludes the interaction of Lake Pend Oreille and the Clark Fork River with flows in the Pend Oreille River. Temperature development in Lake Pend Oreille controls the input temperatures to the Pend Oreille River. By not coupling a model of the large shallow basin of Lake Pend Oreille together with the river model, the model cannot accurately model input temperatures into the Pend Oreille River resulting from atmospheric changes that create seiching action in the lake. In addition to seiching activity, coupling a lake model to the existing river model would improve temperature simulations for “natural” conditions. Currently, existing Lake Pend Oreille temperatures are assumed to represent temperatures that would have existed under “natural” conditions. However, under “natural” conditions the lake would have been up to 5 meters shallower during August than under “existing” conditions causing a different thermal regime in the basin. As an example, the need for coupling of a river model to a lake model to improve temperature simulations in the Spokane River was identified as an important component in determining the influence of Post Falls Dam (Golder 2004; HDR 2005).

Recommendation: The Pend Oreille River temperature model should be coupled together with a Lake Pend Oreille temperature model to reduce uncertainty and error at the boundary condition and increase the confidence in model simulated temperatures entering the Pend Oreille River from Lake Pend Oreille.

Errors Introduced at Boundary Propagate Through Model

Comment: The Seattle District disagrees with the position presented in the TMDL that “*The absolute accuracy (AME) of the model is not critically important when comparing scenarios, because any error in the model results would be similar between scenarios”*. Although such a position may be true for comparing model scenarios where vegetative cover is changed or point sources are added/removed, such logic is flawed when applied to comparisons of modeling scenarios where travel time is significantly different. Scenarios for “natural” and “existing” conditions have significantly different travel times because of the influence of Albeni Falls Dam on the hydrology of the Pend Oreille River. Therefore, any model uncertainty or error introduced at the boundary condition will propagate through the model at different rates due to travel time differences. Consequently, comparison of model data from a single cell at an instant in time from two model runs with different travel times without accounting for model uncertainty and error is not valid because errors introduced into the model will not be the same at that instant in time for the two scenarios.

Recommendations: Model uncertainty and model error need to be accounted for when comparing scenarios with different travel times. Statistical methods to account for model error and uncertainty should be incorporated into the assessment of model data for compliance. If the Seattle District had not found the model error responsible for the May 1, 2004 violation at the Washington State Line, the Draft TMDL would have applied erroneous heat load determinations to the Pend Oreille River for the TMDL.

II. Existing Errors in Model

The Seattle District has found several errors in the CE-QUAL W2 model used for the current Draft TMDL evaluation that need to be addressed before the TMDL can be finalized. It is likely that these errors will impact the determination of compliance and load allocation.

Hydrologic Budget

Comment: The CE-QUAL W2 model used for the TMDL evaluation has an error in the hydrologic budget for the "existing" scenario. During 2004 and 2005, the summer flows in the model for existing conditions were much higher than observed flows at Albeni Falls Dam. The "natural" conditions scenario hydrologic budget did not exhibit this problem.

Recommendation: Portland State University should fix the hydrologic budget in the model for the "existing" conditions scenario. The model will likely need to be recalibrated and re-run. New model results should be used for all TMDL analysis. The results currently outlined in the TMDL may or may not be relevant under the updated model runs.

Lake Pend Oreille Elevation

Comment: The current model used for the TMDL evaluation has an error in the simulated Lake Pend Oreille elevations for the "natural" conditions scenario. The model Lake Pend Oreille elevations that are too low during the summer, most notably the months of July and August, compared to historic lake elevation data. The "natural" scenario simulates lake elevations in August that are less than 2046.3 feet, the minimum recorded lake elevation between 1914 and 1950. Considerable amounts of heat are introduced or lost in the shallow region of the Pend Oreille River at the boundary condition with the current version of the CE QUAL W2 "natural" conditions model, and sources of uncertainty or error that may impact this shallow region need to be corrected.

The Seattle District developed a lake elevation rating curve using publicly available data from the United States Geological Survey comparing lake elevations measured at Hope, Idaho with Pend Oreille River flows measured at Newport, Washington between 1930 and 1950 (**Figure 1**). Based on the Seattle District's rating curve, the "natural" scenario lake elevations actually range from 2 to 3 feet higher than lake elevations used by Portland State University in the simulation model.

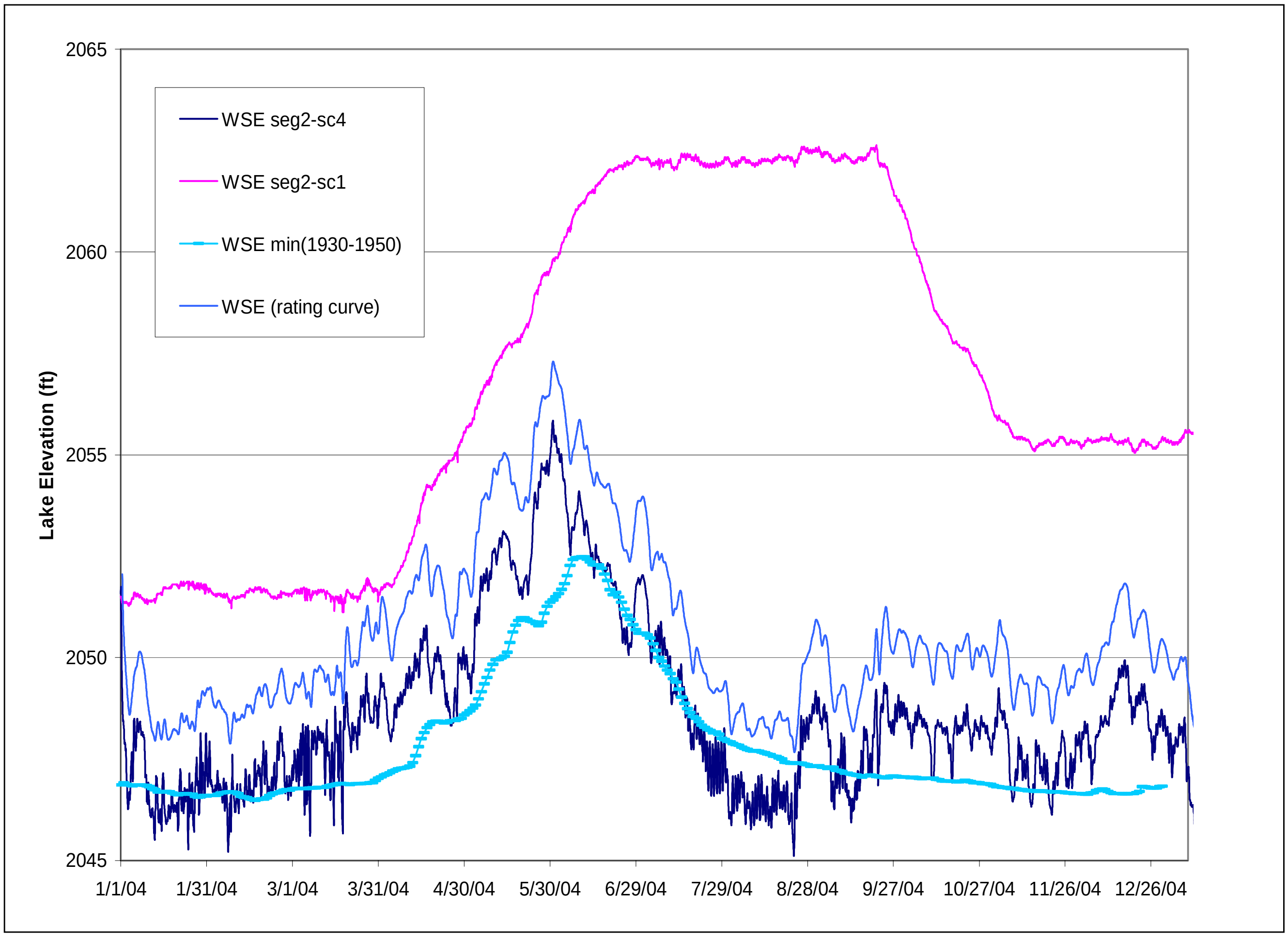


Figure 1. Lake elevation sensitivity analysis showing the current modeled "natural" lake elevation (WSE Seg2-sc4) the revised "natural" lake elevation using the Corps rating curve (WSE rating curve), the "existing" conditions lake elevation (WSE seg2-sc1), and the minimum recorded lake elevation from 1930-1950 (WSEmin 1930-1950).

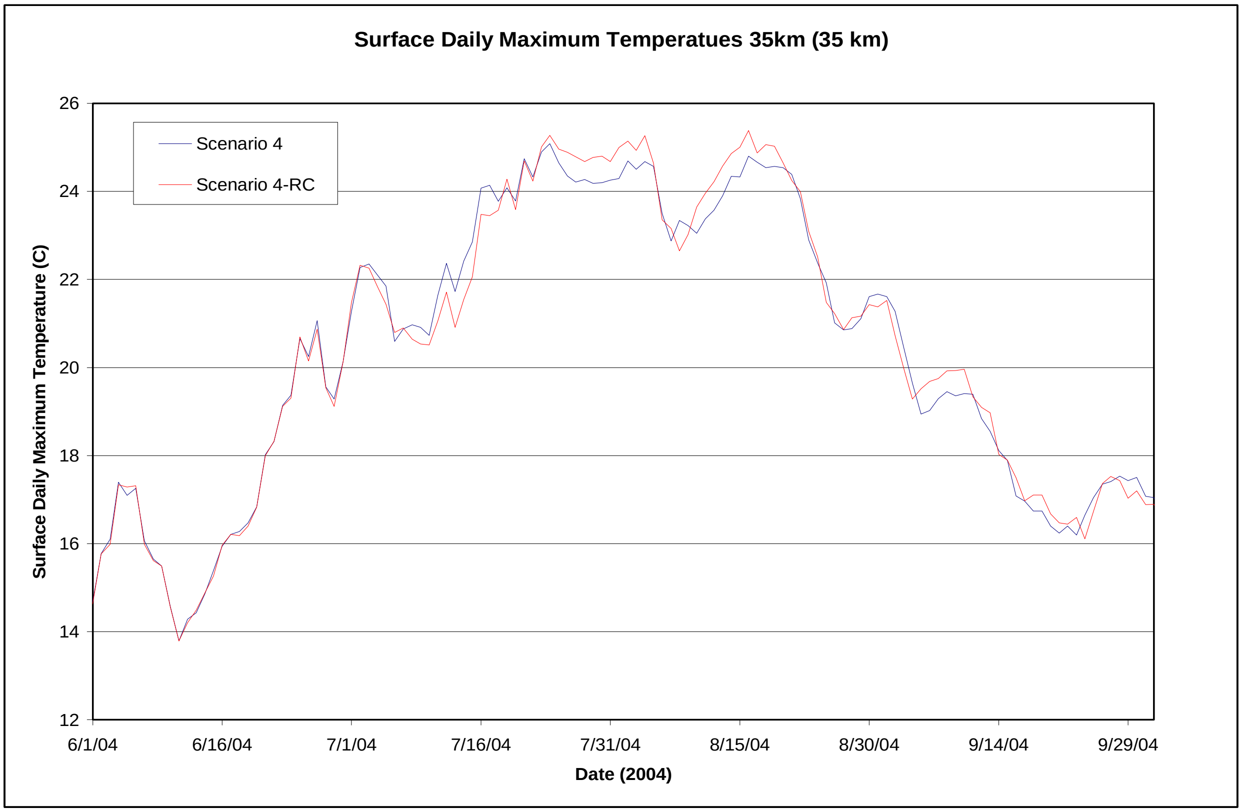
The Seattle District performed a sensitivity analysis on lake elevations for the "natural" condition scenario using the current modeled natural lake elevations (Scenario 4) and revised natural lake elevations (Scenario 4-RC) determined from the Corps' lake elevation rating curve (**Figure 2**). Results showed that during the critical time period of June through September, differences in predicted daily surface maximum temperatures between the "natural" scenarios using the current (Scenario 4) and revised (Scenario 4-RC) lake elevations were ± 0.8 °C at Segment 138 (35km) and ± 1.1 °C at Segment 95 (23.4 km). During the critical June through September time period a difference in daily maximum surface temperature of ± 0.8 to 1.1 °C is significant when compliance metrics are being proposed on 0.3 °C differences.

Recommendation: The Seattle District recommends that a lake elevation sensitivity analysis be performed on the "natural" scenario model runs to determine the impact of changing lake elevations by 2 to 3 feet during the low flow summer months. Additionally, the Seattle District recommends re-running the model using the Seattle Districts lake elevation rating curve that more accurately simulates lake elevations during the entire year and boundary condition depths during the critical time period of July and August. This rating curve was sent to IDEQ on September 27, 2007.

III. Compliance Metrics

A critically important component of the TMDL analyses involves the application of water quality compliance metrics for temperature. The Seattle District believes that compliance metrics that are based upon single surface and bottom cell temperatures are not representative of water quality conditions in the Pend Oreille River, are not consistent with previously completed temperature TMDL's or guidance documents issued by the state of Idaho, and only represent the extremum in the river at that location. Additionally, compliance metrics comparing two model scenarios at an instance in time and space, do not accurately reflect meaningful changes to the thermal loading of the Pend Oreille River.

The Seattle District questions the validity of a compliance metric that require no measurable temperature change above "natural conditions" when it is the applicable criteria, at any time or place throughout the Pend Oreille River. We feel that Idaho Department of Environmental Quality is setting a precedent on the Pend Oreille River regarding compliance with temperature standards that is impractical, unreasonable, and not achievable, The Seattle District does not believe that any river system that has experienced some level of hydrologic development could meet this rigid criteria. This compliance metric makes no distinction between sources of pollution within or outside of the river reach of interest. The presence of small differences in transport rates of temperature between existing and "natural" conditions will result in a non-compliance determination using this metric that have little to do with meaningful changes to thermal regimes.



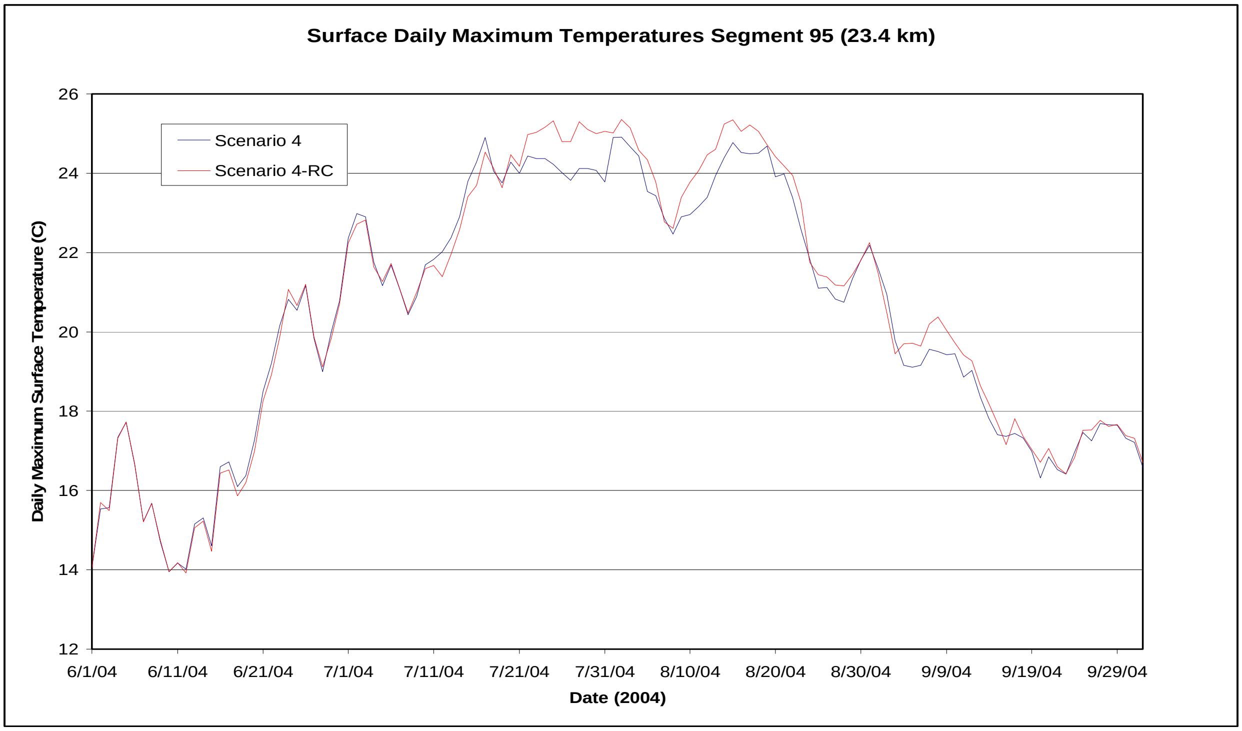


Figure 2. Daily maximum surface temperatures at segment 138 (35km) and segment 95 (23.4 km) from June 1 to September 30, 2004 using the existing "natural" condition lake elevations (Scenario 4) and the Corps' rating curve for "natural" condition lake elevations (Scenario 4-RC).

Idaho DEQ has conducted considerable research on temperature regulation and produced numerous thoughtful papers discussing how temperature compliance should be addressed for Idaho rivers. However, the Seattle District sees little evidence in the TMDL that this guidance has been followed. The state of Idaho has also completed many temperature TMDL's that have been approved by the EPA. The Seattle District can find no example where some of the compliance metrics used in this TMDL have been recommended or previously applied.

There is a lack of statistical analysis of the temperature data generated by the model and QA/QC to determine if the numbers generated by modeling scenarios are valid. There is a need for more rigorous statistical analysis of the data including determining the frequency, magnitude and duration of violations, a comparison of the frequency and duration of temperatures over 22 °C under "natural" and "existing" scenarios, determining 95th percentiles for data and other analysis.

Use of Surface and Bottom Cells for Compliance

Comment: The use of surface and bottom cells as compliance points are not representative of water quality in the Pend Oreille River and should be removed from the TMDL. In particular, the use of bottom cells should not be used in the TMDL analysis because simulations of the Pend Oreille River have generated physically unrealistic temperatures near the channel bottom. Isolated grid cells can retain constituent properties for artificially long periods of time and can result in erroneous results. The segments corresponding to the 10K (segment 39) and 35K stations (segment 138) have isolated cells near the channel bottom through which little or no flow is passed in the model. Diffusion is the only transport mechanism available in the model for water quality constituents of interest in these isolated cells located near the channel bed.

The use of surface cells to represent daily maximum temperatures does not truly represent the river condition. Surface cells represent an extreme conditions that are highly influenced by atmospheric inputs as well as by tributary inputs. Surface cells do not represent the dominant aquatic habitat in the Pend Oreille River for which this TMDL is being developed. The simulated surface temperatures with mechanistic water quality models contain much higher predictive errors than estimates of daily average cross sectional temperatures (see Appendix). If one was manually collecting temperatures in the Pend Oreille River to determine compliance with water quality standards, temperatures collected at the surface of the river would not be used in a determination of compliance.

Idaho DEQ has set forth guidelines for the collection and interpretation of temperature data from rivers that clearly states that temperatures should be collected from representative locations in the river (IDEQ 2000). The collection of temperature in rivers should be in well mixed location not influenced by localized ground water sources, point sources, or direct sunlight (IDEQ 2000). The same recommendations should apply to model results in characterizing the thermal conditions in a river or stream.

Recommendation: The Seattle District Corps of Engineers recommends using volume weighted or flow weighted temperatures at a model segment for compliance determinations. Volume weighted temperatures represent the entire water column of the river and are more representative of the water quality in the river and of the dominant aquatic habitat compared to surface and bottom cells. This type of integration should also be used to characterize daily maximum temperatures.

Use of Instantaneous Metric for Compliance

Comment: The use a metric requiring no measurable increase in temperature above natural conditions when it is the applicable criteria, at any location and at any instance in time is not valid and has not been used in previous TMDL analyses by Idaho DEQ. When the model is used to simulate temperatures in the river with and without Albeni Falls Dam there is typically a difference in travel time of about 3 days or greater between the two scenarios from the entrance to the dam. Temperatures introduced at the entrance will travel down river at different rates and generate instantaneous differences in temperature between the two cases. These temperature gradients in most cases are caused by the differential transport of externally generated temperature loads. To have an instantaneous point and time compliance metric for two modeling scenarios that have significantly different travel times is not justified and has little merit in characterizing the thermal budget of the Pend Oreille River.

Recommendation: The Seattle District recommends that the TMDL remove the instantaneous point and time compliance metric. Use of the daily maximum and daily average temperatures are a more accurate and comprehensive metric for assessments of compliance. Furthermore, use of the 7 day average of the daily maximum is a better assessment of compliance for CE QUAL W2 model scenarios with different travel times.

Frequency Analysis

Comment: Frequency analysis of modeled temperature data should be performed to better understand the thermal impact of Albeni Falls Dam on the Pend Oreille River. An analysis of the frequency, magnitude and duration of exceedances of the 22 °C standard for the "natural" and "existing" scenarios would provide valuable information pertaining to Albeni Falls impact (positive or negative) on the thermal regime in the river. Additionally, the Willamette TMDL utilized frequency analysis to assess temperature data between modeling scenarios with travel time differences. Frequency analysis will remove temporal shifts between modeling scenarios to allow a more meaningful interpretation of the modeling data and a determination of thermal impacts to a river.

Recommendation: Frequency analysis should be conducted on the "natural" and "existing" modeling scenarios to determine the frequency, magnitude, and duration of exceeding 22 °C and to account for temperature differences due to travel time or lag time.

Use of the Idaho 10 Percent Procedure and Air Temperature Exemption in the TMDL

Comment : Idaho DEQ has published two technical documents that should be addressed in the TMDL and discussed in the context of temperature compliance. First, the January 3, 2002 *Temperature Frequency of Exceedance Calculation Procedure*, and Second the *Regional Application of the Idaho Water Quality Standards Temperature Exemption*. The temperature frequency of exceedance calculation procedure states that the 10 percent frequency of exceedance policy is for 303(d) listing and de-listing decisions. The document states that if a frequency of exceedance is less than 10 percent and there is no other evidence of thermal impairment, then it is possible to move for de-listing from the 303(d) list rather than proceed with a temperature TMDL. The Draft Pend Oreille TMDL needs to assess the frequency of temperature exceedances to determine if the 10 percent procedure is valid for use on the Pend Oreille River.

The second document deals with the temperature exemption for Idaho. Information from this document is shown in Table 7 of the TMDL but is not addressed in the TMDL. The temperature exemption states that the numeric temperature criteria is exempt when air temperature exceeds the 90^{th} percentile of the annual maximum weekly maximum temperatures as determined from the historical record of a nearby weather station. For the Idaho Panhandle region including Sandpoint, this 90^{th} percentile temperature is calculated as 92.6 °F or 33.67 °C. During 2004, which is the basis year of model simulations, air temperatures exceeded 92.6 °F several times in July and August at either Sandpoint or Priest River. There is little mention in the TMDL of this rule or how it is applied.

Recommendation: The TMDL analysis needs to inform readers of these two provisions of the Idaho DEQ water quality standards and to explain the exemptions and how they may or may not be used in the Pend Oreille River TMDL and the justification for the decision. For the 10 percent rule, a simple frequency analysis of the data should be performed in the TMDL to better quantify temperature exceedances outlined in the TMDL.

IV. Travel Time and Lag Time

Mike Schneider, U.S. Army Engineer Research and Development Center has provided a detailed report outlining the Seattle District's concerns regarding travel time as well as an alternative assessment of thermal impacts and travel time differences between the "natural" scenario and the "existing" scenario. This report is attached.

V. TMDL Analysis

The Seattle District understands that Portland State University has re-run the CE-QUAL-W2 model used to develop the Draft TMDL and has generated updated model results. Until the results of the new model runs are seen, new compliance metrics developed, and the new TMDL load allocations are presented, the Seattle District will limit comments on the loading data presented in the TMDL.

General

Comment: The Draft TMDL presented little technical data either in the report or in an Appendix to justify how compliance metrics were determined and how water quality standard compliance was decided. Few figures or tables of results from modeling scenarios are presented for the Idaho section of the report. Rigorous statistical analysis of the determinations of compliance or non-compliance was not presented in the TMDL or included as an appendix.

Comment: Analysis of the temperature data shows that the existing water temperatures in the Pend Oreille River exhibit a net cooling when compared to the hypothetical natural conditions. However, the Draft TMDL does not mention the overall thermal enhancement of Albeni Falls Dam to the Pend Oreille River and instead focuses on the few simulated non-compliance locations. Any rigorous assessment of risk to aquatic life caused by changes in the thermal loading of the Pend Oreille River would need to address all the thermal impacts, positive and negative, to the aquatic environment.

A quantitative review of study results shows existing conditions have significantly reduced the extent and duration of temperature extrema when compared to natural conditions. The main event noted as not complying with Idaho water quality standards in the Draft TMDL (Cross Section on August 8, 2004) is associated with seiching in Lake Pend Oreille and a cold front causing a greater heat loss in the shallow natural system compared to the deeper existing conditions, and the different transport rate in these two systems. As a result, the absolute temperatures triggering the non-compliance event does not fall in the upper range of extreme temperatures naturally occurring in the Pend Oreille River. Non compliance is being based on a pulse of cold water moving at different rates through the two models.

Recommendation: The TMDL should present statistics, figures and tables of the data used by Idaho DEQ for making compliance determinations. The thermal impacts of Albeni Falls Dam on the Pend Oreille River should be addressed. This impact analysis should present both the positive and negative thermal impacts. Compliance should not be based on a pulse of cold water being transported at different rates in the two systems.

Loadings Analysis

Comment: The Draft TMDL presents loading capacity calculations that appear to be in error and should be corrected in the next Draft of the TMDL. Errors in the way temperature and flow are used by the TMDL in the heat load equation shown on page 71 may result in erroneous loading analysis. Data show the Pend Oreille River to be stratified and to have diurnal temperature cycles. Heat load needs to be calculated from the entire water column for the entire day and not from single cell at an instance in time.

VI. References

Golder 2004. Phase 2 Spokane River water temperature report Spokane River hydroelectric project. Prepared for Water Resources Work Group Spokane River Project Relicensing by Golder Associates and HDR Engineering.

HDR 2005. Spokane River hydroelectric project, current operations water quality report.. Prepared for Water Resources Work Group Spokane River Project Relicensing and Avista Utilities by HDR Engineering, Bellevue WA.

IDEQ 2000. Protocol for placement and retrieval of temperature data loggers in Idaho streams. Water Quality Monitoring Protocols Report No. 10. Prepared by Donald W. Zaroban, Idaho Division of Environmental Quality.

Kent Easthouse
Water Management Section
Seattle District, US Army Corps of Engineers

Cc: Schneider, ERDC
Zapel, CENWS

Attachment A

Comments on the August 2007 *Draft Pend Oreille River Total Maximum Daily Load for Temperature* and an alternative assessment of thermal impacts and travel time

DEPARTMENT OF THE ARMY
ENGINEER RESEARCH AND DEVELOPMENT CENTER, CORPS OF ENGINEERS
COASTAL AND HYDRAULICS LABORATORY
WATERWAYS EXPERIMENT STATION, 3909 HALLS FERRY ROAD
VICKSBURG, MISSISSIPPI 39180-6199

CEERD-HF-HE (1110-2-1403b) November 7, 2007

MEMORANDUM FOR Commander, US Army Engineer District, Seattle, ATTN: CENWS-EC-TB-WM (Mr. Kent Easthouse),

Subject Comments on the August 2007 *Draft Pend Oreille River Total Maximum Daily Load for Temperature* and an alternative assessment of thermal impacts and travel time

Background The current draft TMDL for temperature in the Pend Oreille River in the State of Idaho concludes that the existence and operation of Albeni Falls Dam is the primary source of temperature impairment in this system. The basis for the TMDL analysis involves the application of a hydrodynamic, water quality model CE-QUAL-W2 from the outlet of Lake Pend Oreille at the railroad bridge to Albeni Falls Dam. This model was used to simulate existing and pre-dam "natural" conditions for the years 2004 and 2005. The comparison of existing and natural conditions was used to identify occurrences of non-compliance with Idaho State water quality regulations. A set of water quality compliance metrics and locations were outlined in the TMDL and provide the basis for identifying Albeni Falls Dam as the prominent source for thermal pollution in the Pend Oreille River. The specific compliance metrics and locations used by the state of Idaho in determining non-compliance have not been clearly identified at this time due in-part to a major revision of the modeling analyses. Furthermore, the TMDL has identified waters entering the state of Washington do not comply with Washington State water quality regulations.

Purpose The purpose of this document is to identify several short-coming in the methodology used in the draft TMDL to determine water quality compliance for temperature in the states of Idaho and Washington. An alternative analysis is presented that provides a means of distinguishing between internal and external thermal sources of heat and differential transport that contributes to the thermal characteristics of the Pend Oreille River. This alternative assessment provides critical information needed to make decisions regarding compliance with state water quality standards.

Problem Statement The current TMDL for temperature in the Pend Oreille River is based upon the identification of differences in water quality metrics between natural and existing conditions without clearly identifying the source or significance of these differences. The thermal loading introduced from Lake Pend Oreille into the Pend Oreille River is the primary determinant of the thermal regime given that the travel time through the entire study area during the summer months ranges from 2 to 10 days. The time of travel from the entrance of the Pend Oreille River to Albeni Falls Dam for existing conditions was typically 2-3 times as long as the travel time through the pre-impoundment "natural" conditions simulation. The differential transport of thermal loads external to the Pend Oreille River provides a mechanism for generating temperature differences between simulations of existing and natural conditions that have nothing to due with changes to the thermal loading of the Pend Oreille River by Albeni Falls Dam. The differences in temperature caused by differential transport of external thermal loads have been inappropriately designated as non-compliance events caused by Albeni Falls Dam.

The exchange of heat with the atmosphere is an active process during passage through the Pend Oreille River. The influence of warm and cold weather events will cause river temperatures to warm up or cool down during passage through the Idaho reach of the Pend Oreille River. The source of changes to the heat content of the Pend Oreille River during passage will be referred to as "internal thermal loads" throughout this document and can be associated with existence and operation of Albeni Falls Dam. The central question regarding the impacts of Albeni Falls Dam on Pend Oreille River temperatures will involve the nature of these internal thermal loads for existing and natural conditions.

A second major concern of the methodology employed by the TMDL involves the significance of changes to the thermal regime of the Pend Oreille River. The term significance refers to two different aspects of this analysis: significance of the risks to the aquatic life and significance of temperature differences based on the detection threshold of the modeling approach. The presentation of model results in the TMDL was decidedly one sided with great significance being placed on periods when existing temperatures were warmer than the simulated "natural" conditions. What was not presented in a meaningful way in the TMDL was the net reduction in thermal loading caused by the presence of Albeni Falls Dam. A comprehensive risk assessment of beneficial uses in the Pend Oreille River would consider both the beneficial and detrimental changes to the thermal regime. A formal recognition of the enhancements to the thermal regime of the Pend Oreille River by Albeni Falls Dam should be considered in the form of thermal credits as allowed under the Pollution Trading statues of Idaho State regulations.

There is a need to recognize that the model only provides an approximation of the real world that will be deficient at some level of application. It is import to characterize what is the detection threshold of the model so that informed decisions can be made from the simulation results. Can the model differentiate temperature differences on the order of 0.3 ^{o}C given the uncertainty associated with model error and inputs? What is the required confidence level in model output to conclude state water quality standards have been violated? These are important question that have not been adequately addressed in the current draft TMDL.

Results

Alternative Assessment of Thermal Impacts

One recommendation for improving the TMDL for Temperature in the Pend Oreille River is to include a comprehensive quantitative summary of the thermal characteristics. A quantitative summary would involve descriptive statistics of daily average and daily maximum temperatures during the critical summer months. The volume weighted daily average temperatures were summarized at segments 2, 39, 91, 136, and 183 for the period from June 21 – September 21 for the years 2004 and 2005 for natural and existing conditions as shown in Figure 1. The box plots identify the 10, 25, 50, 75, and 90th percentile temperatures for a given location and flow scenario (whiskers identify 10 and 90 percentile, box identifies 25, 50, 75 percentile). The dotted line in each box represents the average temperature and observations outside the 10th and 90th percentile are shown as individual symbols. The temperatures introduced into the Pend Oreille River through the upstream boundary with Lake Pend Oreille at segment 2 were on average 0.5 ^{o}C warmer for the natural conditions when compared with existing conditions. The temperatures entering the Pend Oreille River during the natural conditions exceeded the daily average 19 ^{o}C numeric criteria over 75 percent of the time. This observation demonstrates the importance of defining natural condition for compliance determination in the TMDL. In all cases, with exception of segment 39, the natural conditions were warmer than existing conditions. The change in the temperature distribution during the summer months from upstream to downstream was small indicating little systemic change in the thermal loading was present.

An alternative approach of quantifying how much cooler the present day thermal conditions are in comparison to the modeled natural conditions involves calculating the cumulative exceedance frequencies for both cases. The presentation of the frequency of exceedance of volume-weighted daily average temperatures in the Pend Oreille River for existing and natural conditions at the entrance of the Pend Oreille River and at Albeni Falls Dam are shown in Figure 2. This presentation of simulated results at the entrance to the Pend Oreille River (dashed lines) indicates that the frequency of temperatures greater than 19 ^{o}C has been reduced from 82 percent for natural conditions to about 70 percent for existing conditions. The size of the reduction in frequency of temperatures exceeding 22 ^{o}C was slightly less at the river entrance changing from 33 percent under natural conditions to about 24 percent for existing conditions. At Albeni Falls Dam (solid lines) the frequency of exceeding daily average volume-weighted temperatures above 19 ^{o}C is always smaller for existing conditions compared to natural conditions by 5 to 10 percent. For instance, the temperatures exceeded 23.6 ^{o}C almost 10 percent of the time under natural conditions at Albeni Falls Dam. The simulations of current conditions at Albeni Falls Dam do not show any temperatures exceeding 23.6 ^{o}C.

The simulated temperatures for natural conditions were much warmer than existing conditions during the first half of the critical summer time period at the entrance to the Pend Oreille River. The time history of calculated temperatures introduced into the Pend Oreille River from Lake Pend Oreille for existing and natural conditions are shown in Figure 3. The upstream temperatures were identical for natural and existing conditions from August 22 through Sept. 21. The deepening of the thermocline in Lake Pend Oreille during the summer is the cause for diminishing differences in temperatures introduced into the Pend Oreille River between these two scenarios. Another important aspect of the inflowing temperatures to the Pend Oreille River is the presence of large fluctuations of temperature over time. These variations in temperatures result in thermal “fronts” that when propagated at different rates through the Pend Oreille River results in temperature differences when natural and existing simulations are compared at a designed location and time.

External Thermal Loading

A demonstration of the magnitude of the influence of differential transport of externally generated thermal loading was explored through conducting a simulation excluding the influence of heat exchange. The existing and natural conditions model of the Pend Oreille River was executed excluding the heat exchange processes for 2004 and 2005. The only source of heat accounted for in these simulations were externally generated thermal loads introduced from Lake Pend Oreille, the tributaries, and other point discharges. The model simulated the dispersion, mixing, and transport of external sources of thermal energy which does result in subtle changes to river temperatures, but the total amount of thermal energy was conserved in these simulations.

The calculated water temperature characteristics at Albeni Falls Dam were nearly an exact copy of temperatures at the upstream boundary conditions for the natural conditions simulation with no heat exchange as shown in Figure 4. The time history of temperatures at Albeni Falls Dam simply lagged the response at the upstream boundary by the travel time between these two locations. The travel time was determined by adding a generic constituent to the calculation tracking the age of water introduced into the river from external sources. The travel time ranged from only two days during June 21 to five days in late August. The total thermal loading of the Pend Oreille River is conserved in this simulation.

The existing conditions scenario with no heat exchange was generated and the travel time was determined as described above. The time history of calculated water temperatures at Albeni Falls Dam and at the upstream boundary for existing conditions with no heat exchange is shown in Figure 5. The time history of water temperatures at Albeni Falls Dam is lagged in time from boundary conditions by the travel time which ranged from 3.5 days to almost 12 days during the critical summer period. The total thermal load was conserved but the temporal response at the dam has been altered from the pattern at the upstream boundary due to the added dispersion of the longer travel time, and deeper flow conditions.

The comparison of conservative transport of external thermal sources for the existing and natural conditions results in long periods of time where the existing conditions are warmer than natural conditions by over 0.3 C and warmer than the applicable numeric criteria of 19 C for daily average conditions as shown in Figure 6. A total of 21 days out of a possible 93 days from June 21 – September 21 would have fallen into this category of exceeding the applicable water quality standards for temperature. These events were generated from differential transport of externally generated thermal loads. The processes resulting in internal changes to the thermal load were removed from this evaluation. This exercise demonstrates the importance of distinguishing the thermal source of differences between natural and existing conditions. Under these conditions, it would be inappropriate to associate these differences in temperatures with changes to the thermal loading of the Pend Oreille River.

Internal Thermal Loading

The two simulations excluding heat exchange between the Pend Oreille River and the atmosphere provide a means of estimating the internal thermal loading during transport through the study area. The difference in temperatures at a specified location and time between the simulation of existing conditions with and without heat exchange with the atmosphere will provide an estimate of the net change in temperature during passage from the upstream boundary to the reference location. The time history of calculated daily average volume weighted temperatures of existing conditions with and without heat exchange at Albeni Falls Dam are shown in Figure 7 for the time period of June 21-September 21, 2004. A net increase in heat during transit to the Pend Oreille River is indicated when the existing temperature (blue) is greater than the existing with no heat exchange temperature (pink). A net reduction in temperature was indicated during much of August and all of September. It is interesting to note that the existing temperatures in late August and September at Albeni Falls Dam are similar to the temperatures at the upstream boundary (black) even though the travel time is over one week. The time history of the calculated internal temperature change is shown in Figure 8 for existing conditions. The net temperature change at Albeni Falls Dam ranged from +2 .1 ^{o}C to -2.3 ^{o}C during the study period. The large variance in temperature exchange is caused by the presence of both hot and cold weather systems passing over this area.

The determination of internal temperature change for the natural conditions simulations was conducted by comparing the temperatures at Albeni Falls Dam for simulations with and without atmospheric heat exchange as shown in Figure 9. This figure shows Pend Oreille River temperatures warming up above entrance temperatures from June 21-August 4 and consistently cooling down from August 21-September 21. The shallow flow conditions present during the natural conditions simulations results in average river temperatures that respond quickly to changes in atmospheric heat flux. However, the relative short time of travel or exposure to atmospheric conditions provides a limit on the degree of temperature change experienced in the Pend Oreille River under natural conditions. The time history of calculated internal temperature change is shown in Figure 10 for natural conditions. The net temperature change at Albeni Falls Dam ranges from 1.9 to -2.2 ^{o}C.

The change in thermal characteristics to the Pend Oreille River directly resulting from the existence and operation of Albeni Falls Dam can be evaluated by considering the properties of the calculated internal thermal changes as shown in Figure 11 for existing and natural conditions. The time history of changes to Pend Oreille River Temperatures from internal sources were similar with differences in the timing of synoptic events related to the different travel times in the two scenarios. The mean value (dotted line) of temperature change over the critical summer period from June 21-September 21 for 2004 and 2005 were nearly zero for both the existing and natural conditions as shown in Figure 12. The range in internal temperature changes was slightly greater for existing conditions compared with natural conditions. The greater range in response of internal temperature change for existing conditions is likely attributed to the longer travel time of this scenario. In general, the change in temperatures at the noted percentiles for existing and natural conditions ranged from 0.1 to 0.3 ^{o}C and generally fall below the detection threshold of the model and are thereby not significantly different.

Time of Travel

The difference in travel time between the two scenarios complicates the interpretation of temperature comparisons at a given location and time. As noted earlier, this type of comparison will involve water with different histories. If the difference in travel time between the two scenarios is 3 days, then the comparison of temperature for the day in question will involve parcels of water that entered the river reach three day apart. The temperature of water entering the Pend Oreille River three days apart maybe significantly different and be the primary source for the difference in release temperatures at the Dam. One means of estimating the change in temperature of a distinct parcel of water entering the river is to apply the difference in travel time between the two scenarios when comparing temperature at a downstream location. If the difference in travel time between the natural and existing conditions is three days, then the calculated temperature for the existing condition on the reference day would be compared to the calculated temperature for the natural condition three days earlier. This comparison of temperatures lagged by the difference in travel time does provide a means of estimating the change in temperature of a parcel of water entering the river at the same time for both conditions.

The difference in travel time for the existing and natural conditions scenarios were calculated for each day and this duration was added to the current date of the natural conditions results. The shifting of natural condition temperatures in time allows the comparison of temperatures of a distinct parcel of water. The calculated daily average volume weighted temperatures at Albeni Falls Dam for existing and natural conditions are shown in Figure 13 for the period of June 21 – September 21, 2004. The natural condition is generally warmer than existing conditions during the first half of this time period and colder than natural condition during the second half of this time period. If the determination of compliance is based on these results, a total of 8 days exhibit temperature warmer than 19 ^{o}C where the existing temperature is warmer than natural conditions by over 0.3 ^{o}C. The frequency of days where the existing temperature is warm that natural conditions by at least 0.3 ^{o}C is about 9 percent during the critical time period which happens to fall below the threshold identified as a thermal impairment in Appendix D of the WBAG II. It should be noted that external sources of temperature contribute to many of these daily average temperature differences.

The temperature difference in a unique parcel of water was estimated by subtracting the temperature calculated for the existing conditions at time T1 from the corresponding temperature from the natural conditions scenario at time T1-T_{ref} where T_{ref} is equal to the difference in travel time between the two conditions. The time history of the change in temperature in a parcel of water between the entrance and Albeni Falls Dam for natural and existing conditions is shown in Figure 14 along with the unadjusted temperature difference between these two conditions. The two estimates of temperature difference are similar for the first half of the study period and indicate existing conditions are consistently cooler than natural conditions. The two estimates of temperature change are quite different during the second half of the study period. The estimated temperature in the same parcel of water is warmer for natural conditions Tmp(adjusted natural) than existing conditions Tmp(existing). The temperature difference in the unadjusted calculation shows existing conditions trending warmer than natural conditions. The frequency distributions in the form of box plots for these two data sets are shown in Figure 15. The temperatures in a parcel of water for natural conditions were warmer than existing conditions 75 percent of the time. It was very infrequent that the parcel temperature for existing conditions was warmer than natural conditions by 0.3 ^{o}C.

Conclusions

The current TMDL for temperature in the Pend Oreille River has not appropriately identified the source or significance of non-compliance events in the states of Idaho and Washington. Without clearly establishing the linkage between the thermal sources and the events that have been identified as exceeding criteria, it is not appropriate to apportion thermal loads to rectify these events. This paper outlines a methodology for establishing a clearer linkage between sources of thermal load and the thermal characteristics in the Pend Oreille River. Distinguishing the influences of both external and internal thermal sources and the time of travel of these loads is central to these analyses. Alternative methods of statistically quantifying the thermal characteristics for existing and natural conditions was also presented. These statistical measures clearly indicate that the existence and operation of Albeni Falls Dam has resulted in a net cooling of the Pend Oreille River. These enhancements to the thermal properties of the Pend Oreille River should be recognized in the TMDL and means of accounting for these thermal credits explored.

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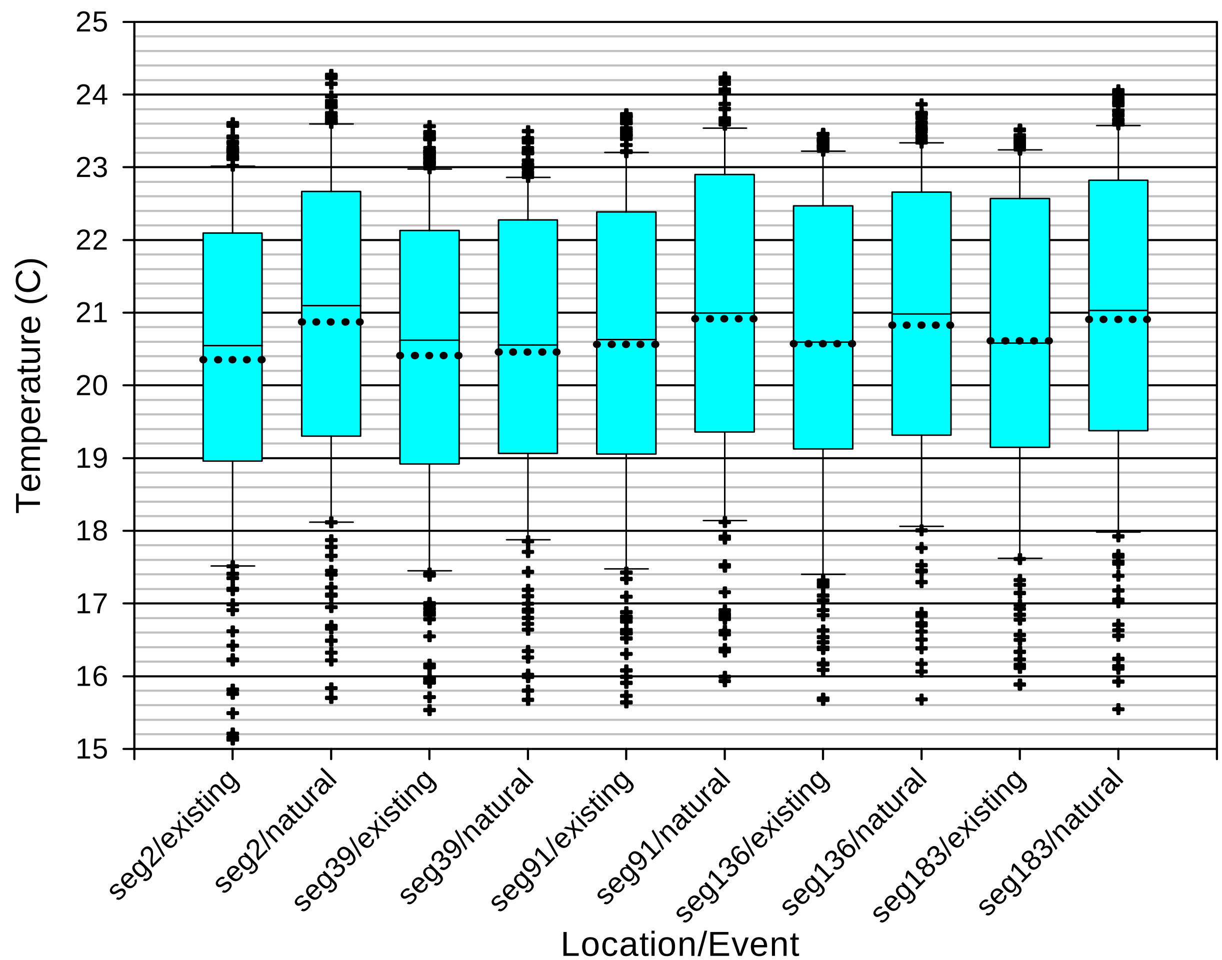

Figure 1 Statistical Summary of Daily Average Volume Weighted Temperatures in the Pend Oreille River, Idaho for Existing and Natural Conditions (Seg 2 entrance POR, Seg 39–10K from entrance, Seg 136–30K from entrance, Seg 183–Albeni Falls Dam)

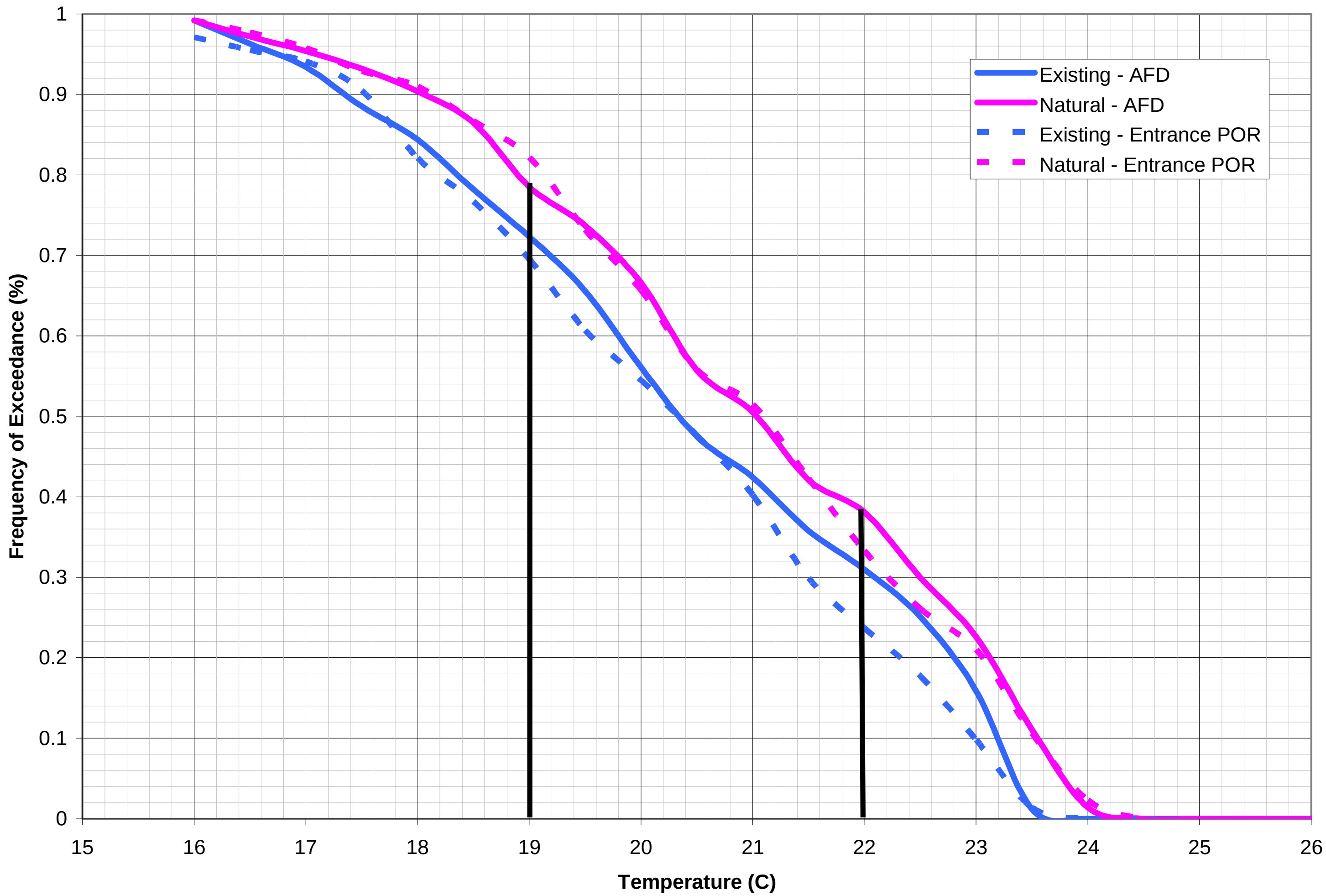

Figure 2. Frequency of Exceedance of Daily Average Volume-Weighted Temperatures in the Pend Oreille River at Albeni Falls Dam and at the Entrance for Existing and Natural Conditions, June 21-September 21, 2004 and 2005

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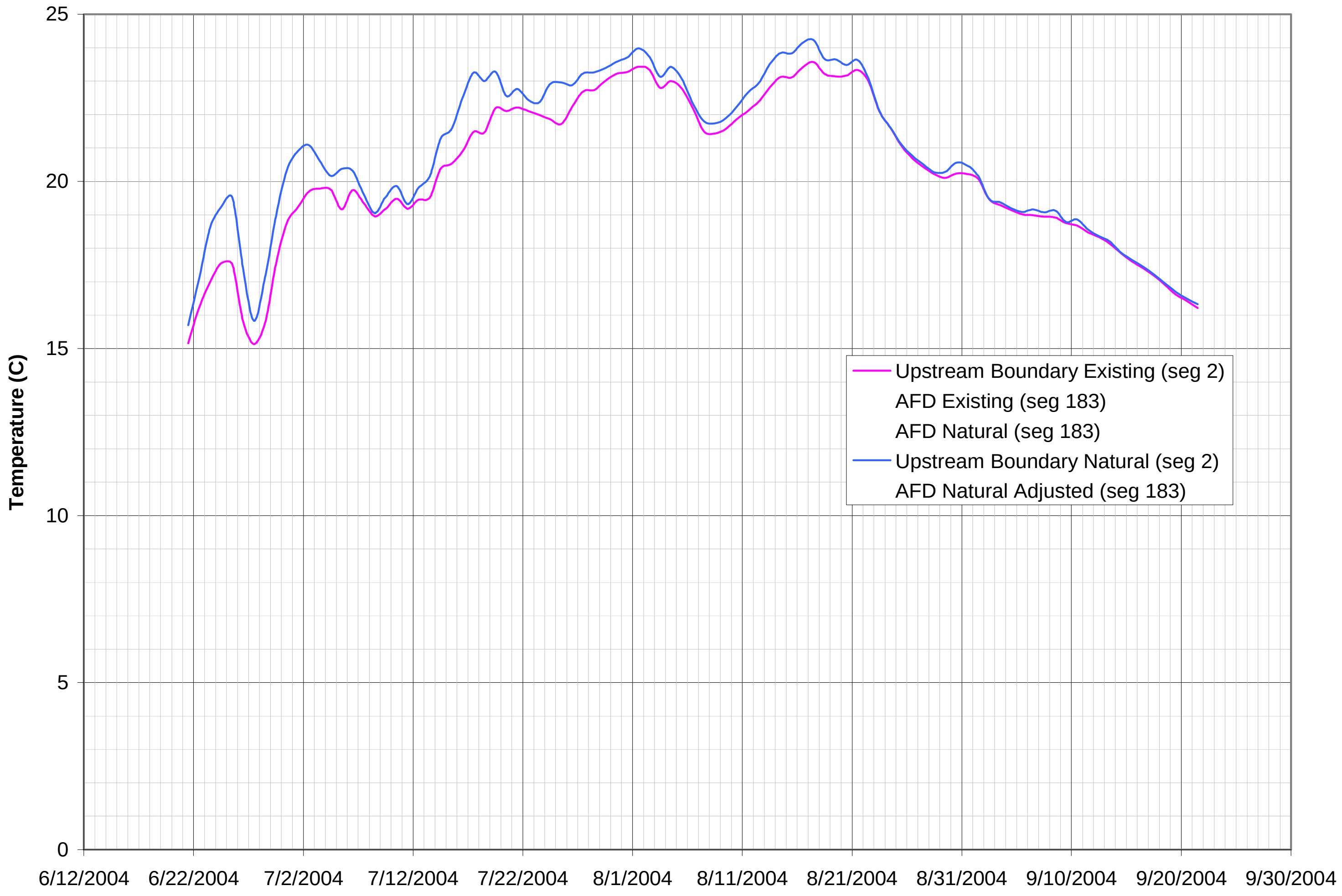

Figure 3. Temperature Time History of Daily Average Volume Weighted Temperatures in the Pend Oreille River Idaho at the Upstream Boundary with Lake Pend Oreille for Existing and Natural Conditions, June 21 – Sept 21, 2004.

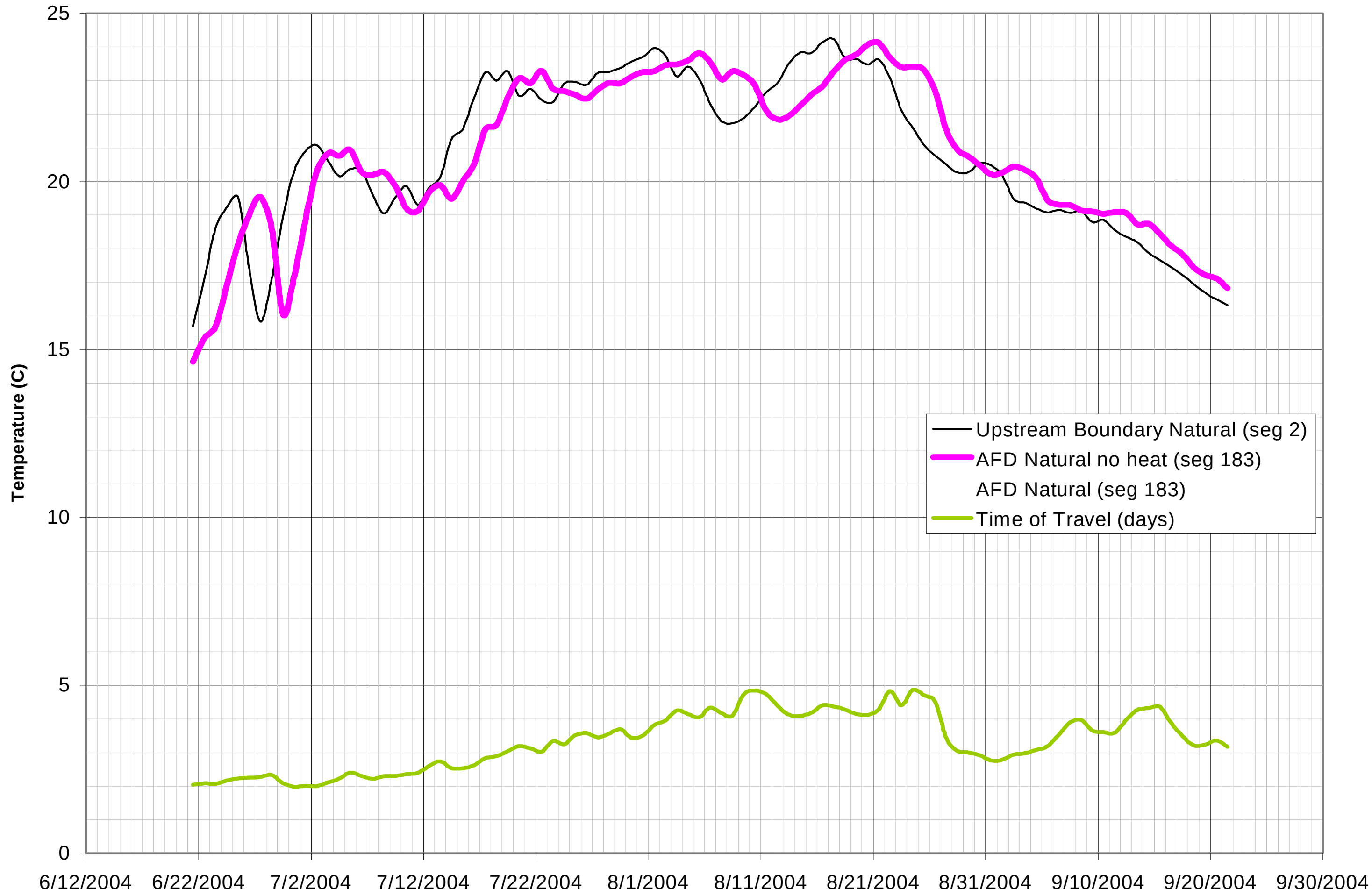

Figure 4. Temperature Time History of Daily Average Volume Weighted Temperatures in the Pend Oreille River, Idaho for Natural Conditions with No Heat Exchange, June 21-Sept 21, 2004.

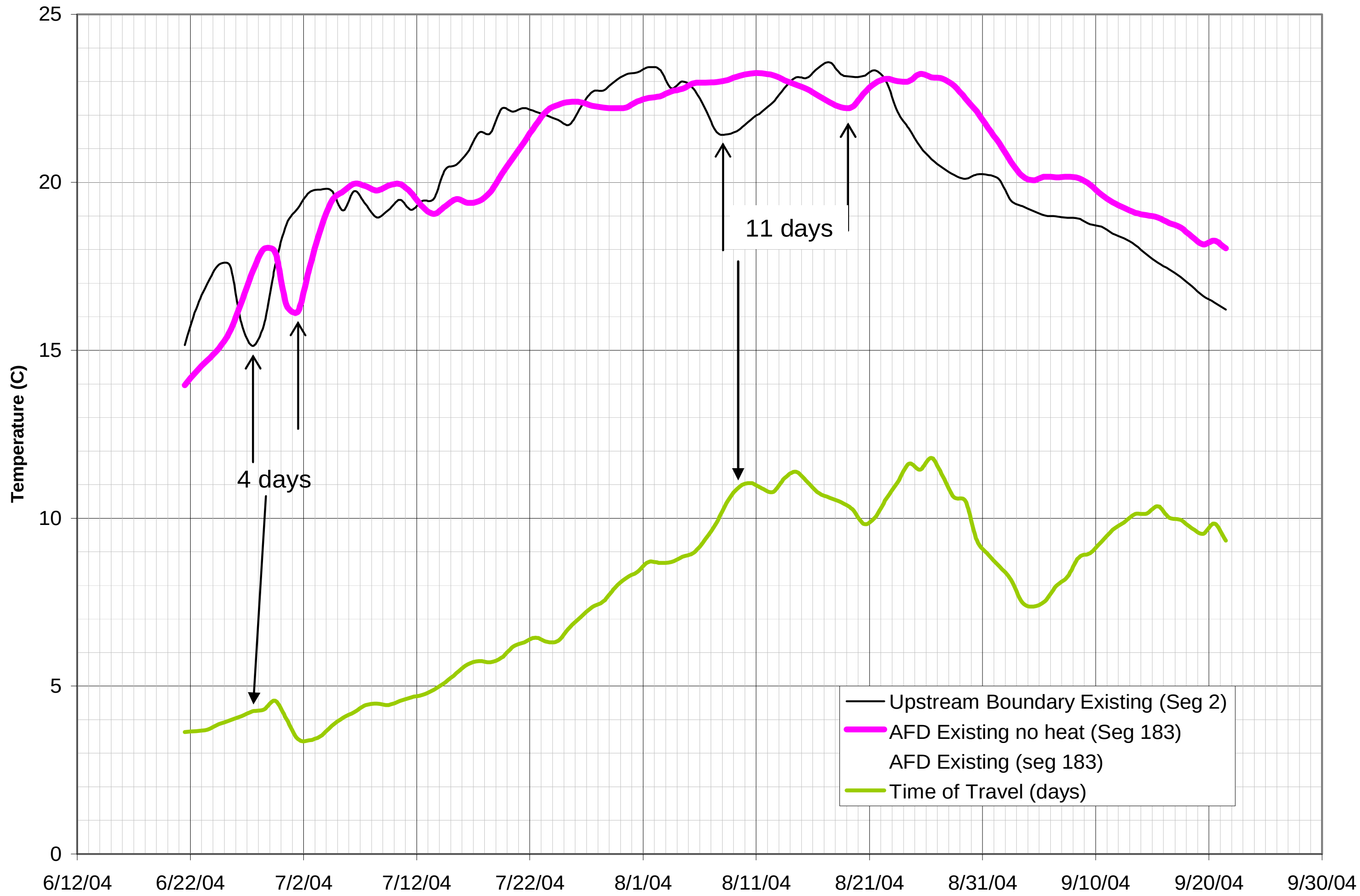

Figure 5. Temperature Time History of Daily Average Volume Weighted Temperatures in the Pend Oreille River, Idaho for Existing conditions with No Heat Exchange, June 21-Sept 21, 2004.

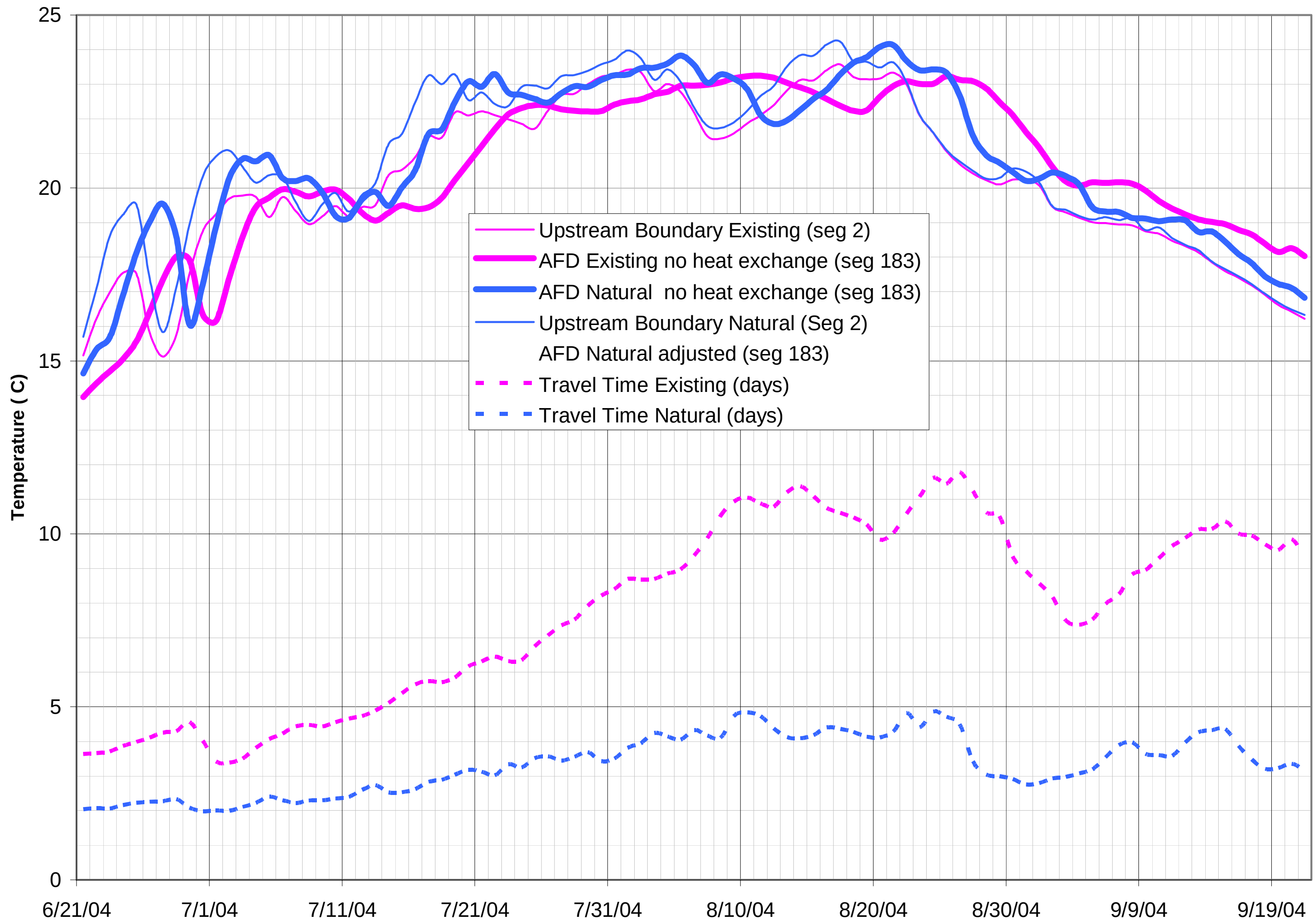

Figure 6. Time of Travel and Temperature Time History of Daily Average Volume Weighted Temperatures in the Pend Oreille River at the Upstream Boundary and Albeni Falls Dam for Existing and Natural Conditions with no heat exchange, June 21-Sept 21, 2004.

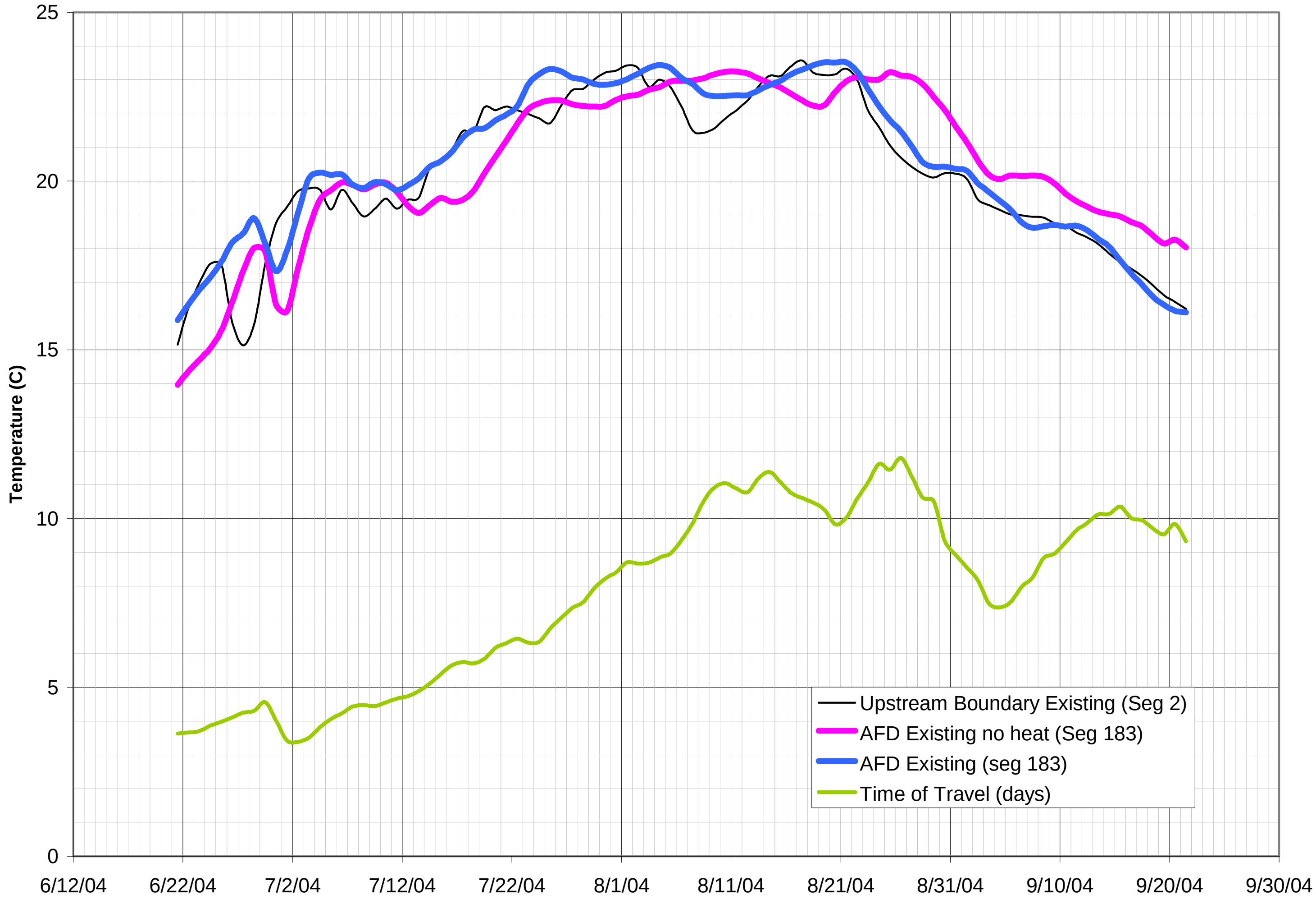

Figure 7. Temperature Time History of Daily Average Volume Weighted Temperatures in the Pend Oreille River, Idaho for Existing conditions with and without Heat Exchange, June 21-Sept 21, 2004.

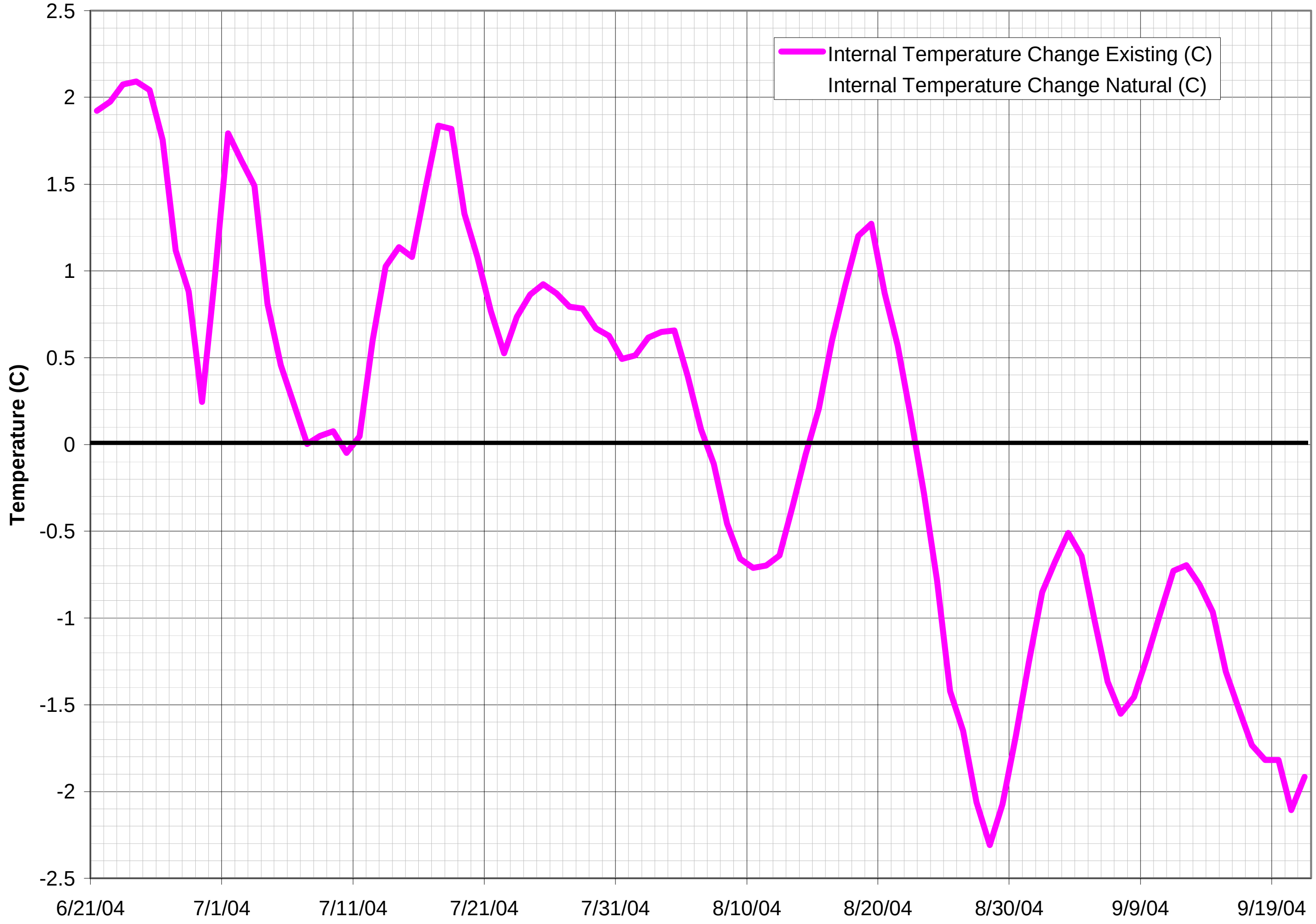

Figure 8. Temperature Time History of Internal Temperature Change in the Pend Oreille River from Longs Bridge to Albeni Falls Dam for Existing Conditions, June 21-Sept. 21, 2004

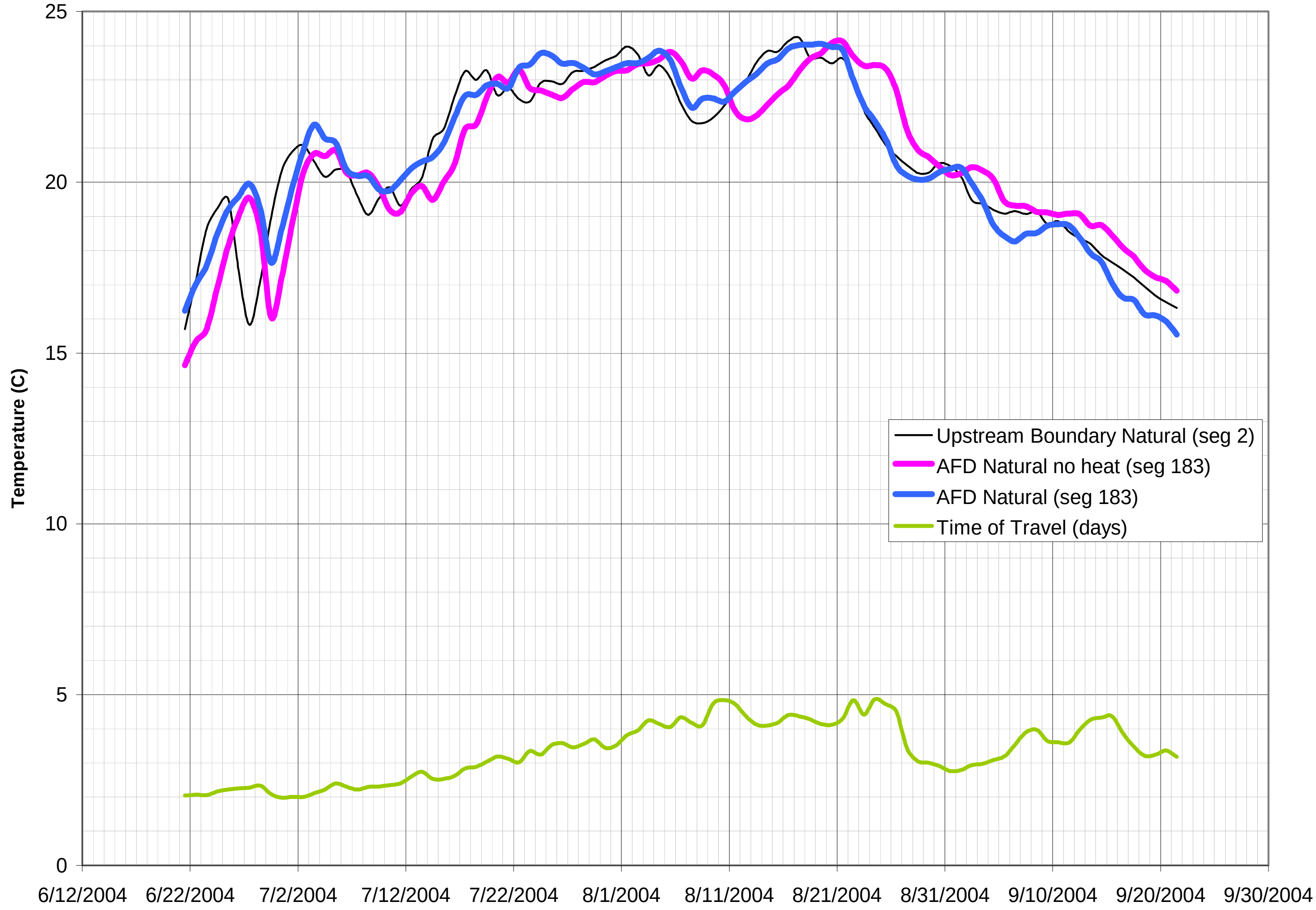

Figure 9. Temperature Time History of Daily Average Volume Weighted Temperatures in the Pend Oreille River, Idaho for Natural conditions with and without Heat Exchange, June 21-Sept 21, 2004.

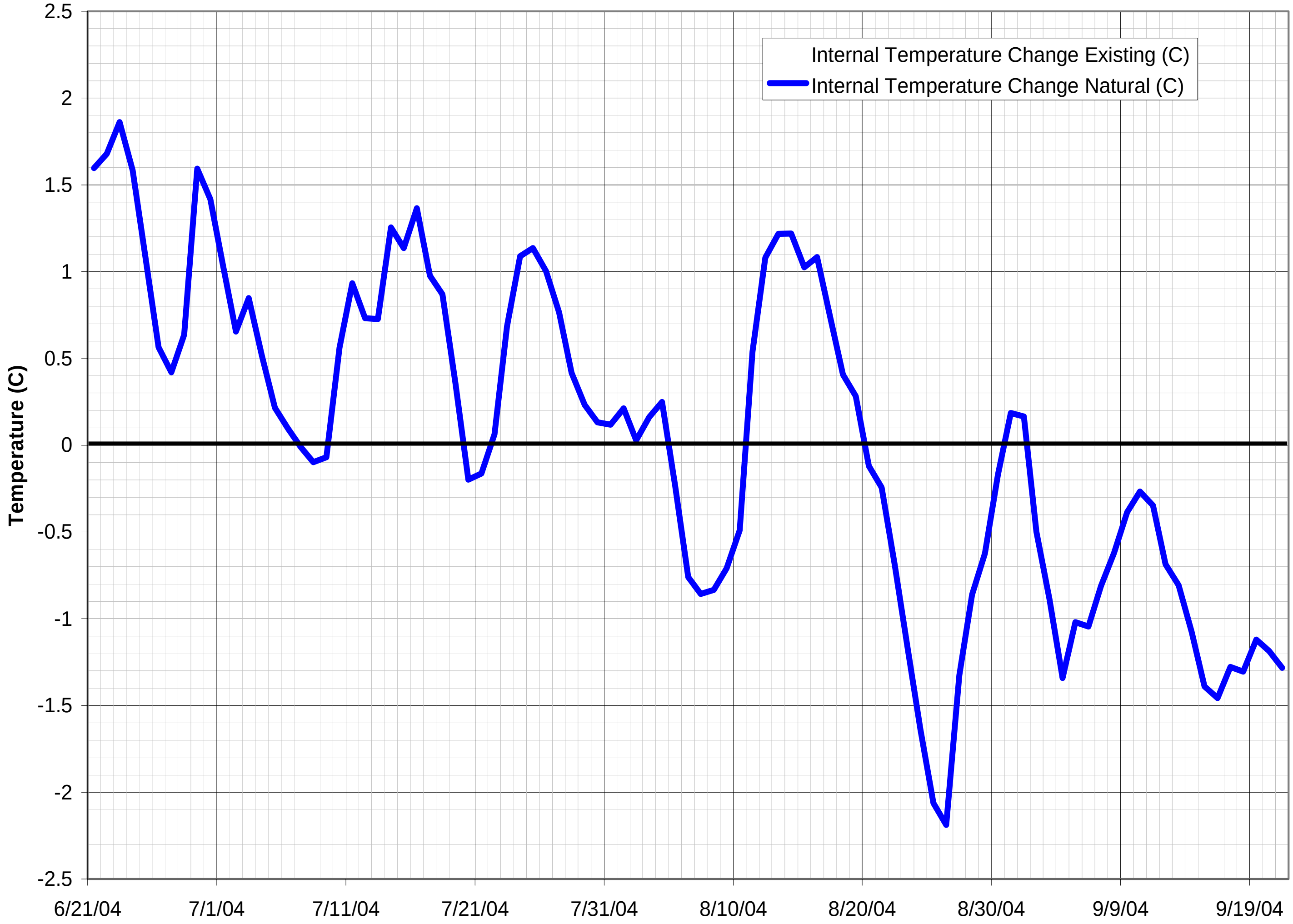

Figure 10. Temperature Time History of Internal Temperature Change in the Pend Oreille River from Longs Bridge to Albeni Falls Dam for Natural Conditions, June 21-Sept. 21, 2004

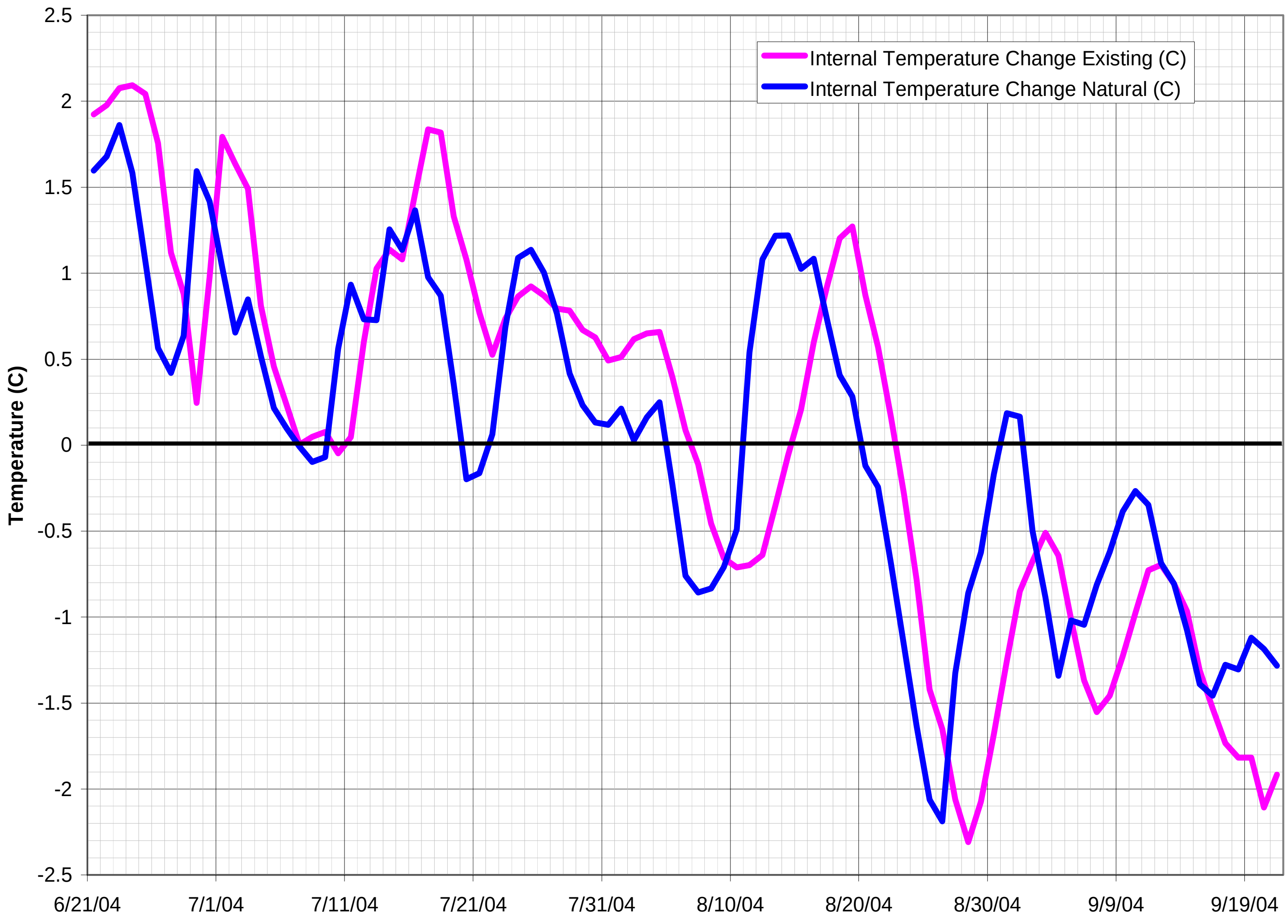

Figure 11. Temperature Time History of Internal Temperature Change in the Pend Oreille River from Longs Bridge to Albeni Falls Dam for Existing and Natural Conditions, June 21-Sept. 21, 2004.

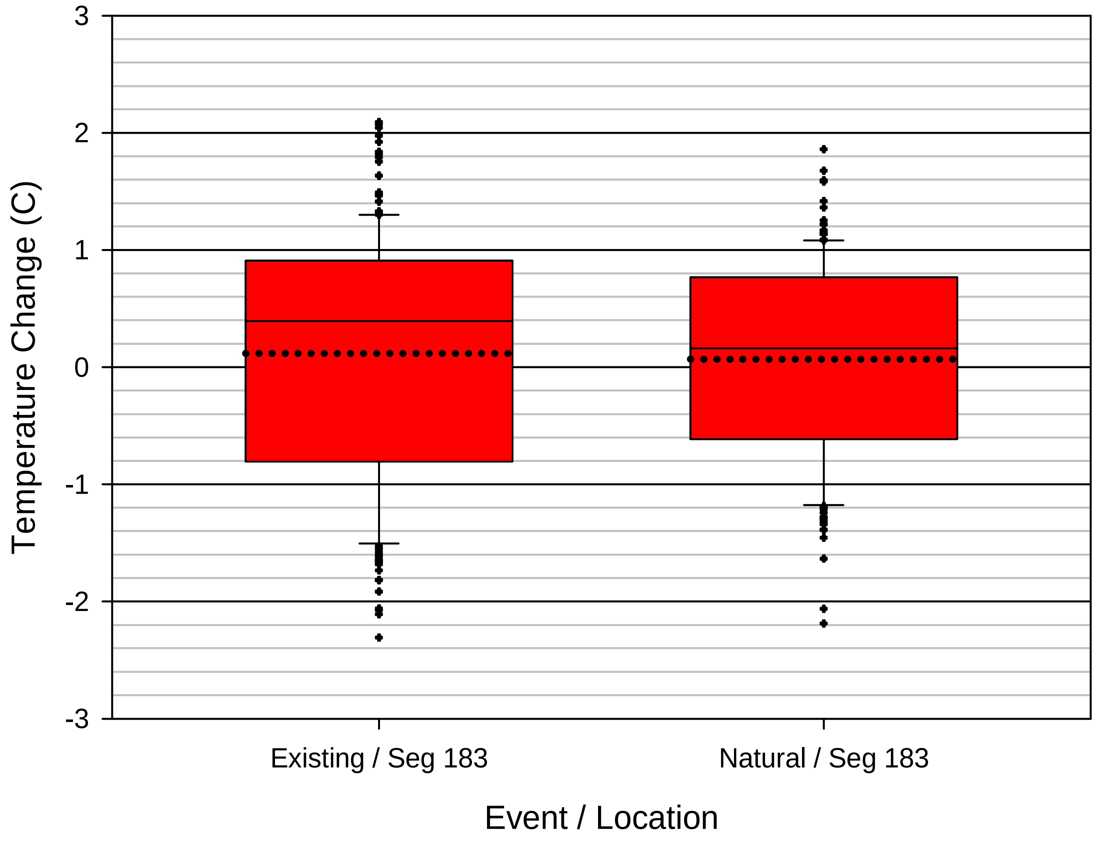

Figure 12. Statistical Summary of the Internal Change in Daily Average Flow Weighted Temperatures at Albeni Falls Dam for Existing and Natural Conditions, June 21-September 21, 2004 and 2005 (Seg 183=Albeni Falls Dam)

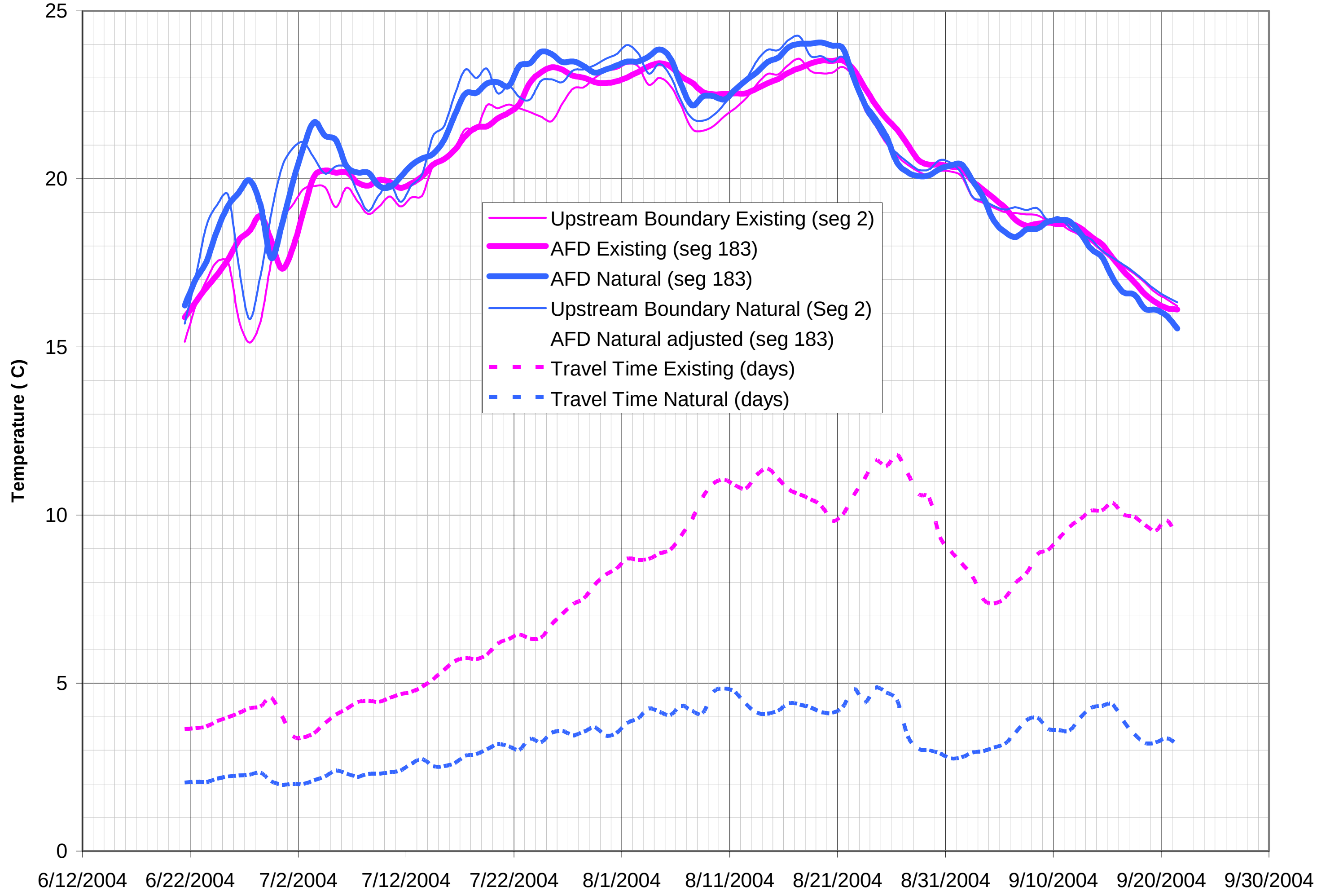

Figure 13. Time of Travel and Temperature Time History of Daily Average Volume Weighted Temperatures in the Pend Oreille River at the Upstream Boundary and Albeni Falls Dam for Existing and Natural conditions, June 21-Sept 21, 2004.

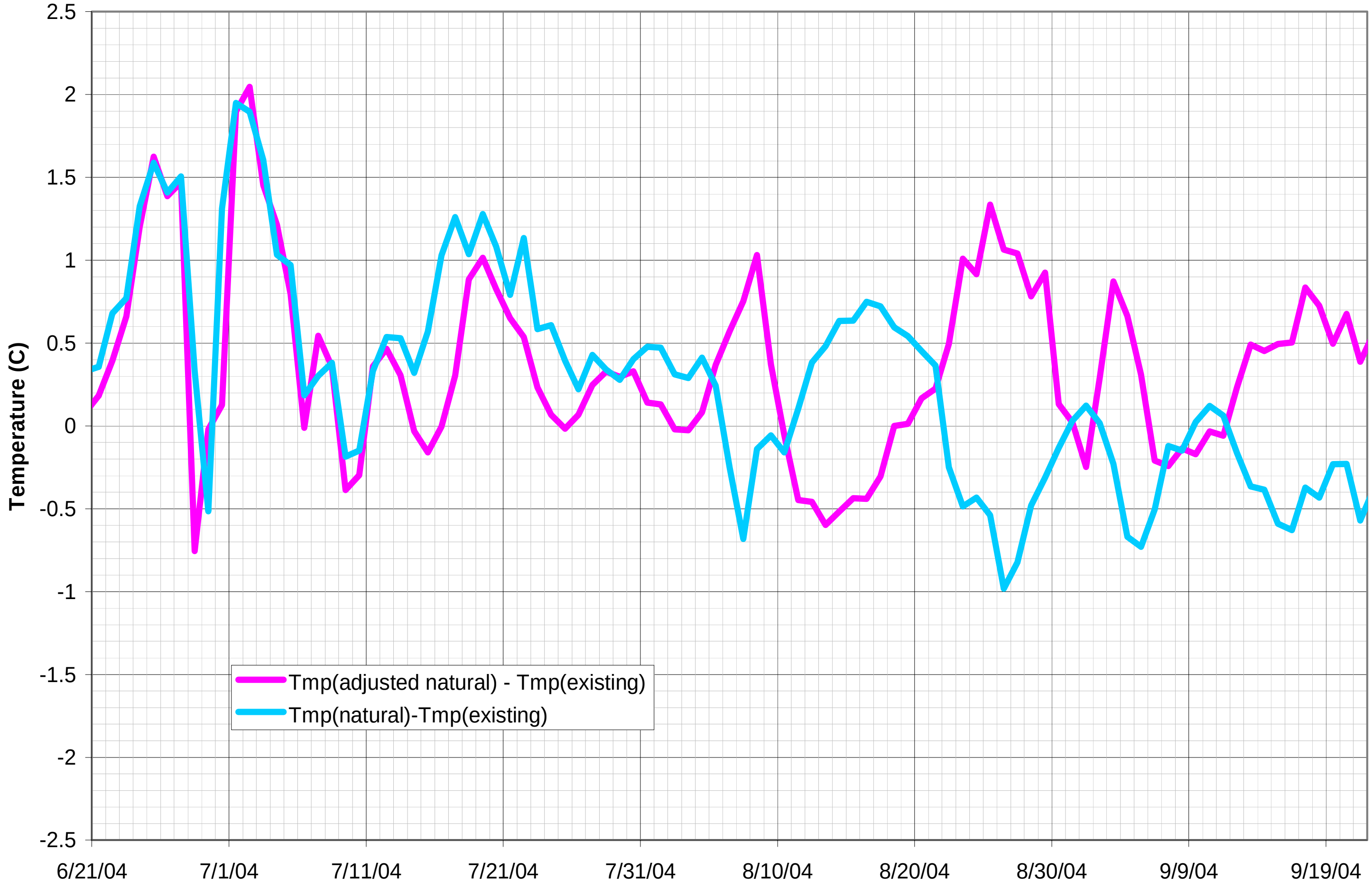

Figure 14. Time History of Temperature Difference between Natural and Existing Conditions at Albeni Falls Dam, June 21-September 21, 2004 (adjusted natural accounts for difference in travel time)

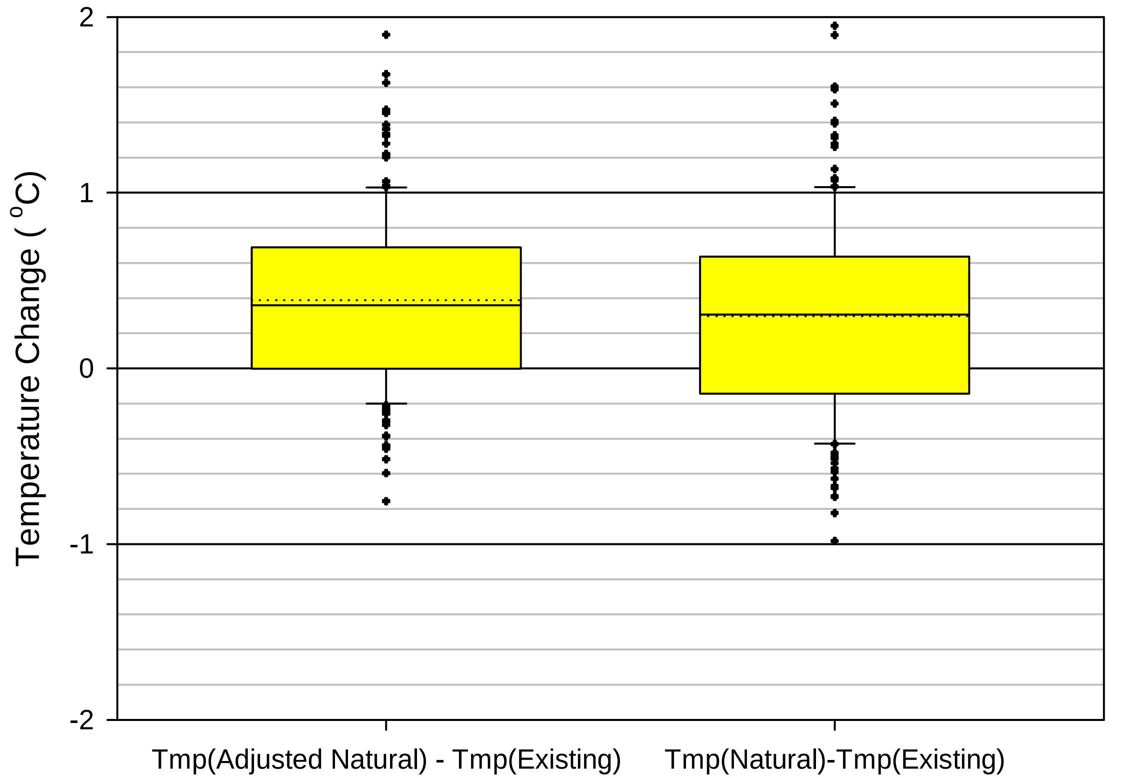

Figure 15. Frequency Summary of Daily Average Volume-Weighted Temperature Difference between Natural and Existing Conditions at Albeni Falls Dam, June 21-Sept 21, 2004 and 2005

Attachment B

Technical assessment of predictive errors of model estimates

DEPARTMENT OF THE ARMY
ENGINEER RESEARCH AND DEVELOPMENT CENTER, CORPS OF ENGINEERS
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CEERD-HF-HE (1110-2-1403b) November 15, 2007

MEMORANDUM FOR Commander, US Army Engineer District, Seattle, ATTN: CENWS-EC-TB-WM (Mr. Kent Easthouse),

Subject Technical assessment of prediction errors of model estimates of temperatures in the Pend Oreille River, Idaho

Background

Numerical simulations of water temperature for existing and natural conditions in the Pend Oreille River, Idaho were used to identify occurrences of non-compliance with Idaho State water quality regulations. A set of water quality compliance metrics and locations were outlined in the TMDL and provide the basis for identifying Albeni Falls Dam as the prominent source for thermal pollution in the Pend Oreille River. A temperature compliance tolerance of 0.3 ^{o}C was used to determine if an excursion above the applicable temperature criteria was evident. The specific compliance metrics included the daily average volume-weighted temperature by river segment, daily average temperatures in surface and bottom cells, daily maximum temperatures in surface cells, and instantaneous temperatures on August 8 and 16 in any cell. The following analyses will quantify the prediction error properties of the two-dimensional model of the Pend Oreille River, Idaho at the Riley Creek sampling station during the summer of 2004.

Problem Statement

The current TMDL for temperature in the Pend Oreille River is based upon simulated differences in temperature metrics for natural and existing conditions at a tolerance of 0.3 ^{o}C without clearly identifying the source or significance of these events. The ability of the model to reproduce certain thermal attributes of existing conditions in the Pend Oreille River is highly variable. The prediction errors of model estimates of temperature at a specific point in time and space can be much larger than prediction errors of simulated temperatures averaged over time and space. There is a need to recognize the variation in the predictive capability of the model to support decisions regarding compliance with water quality standards at meaningful confidence levels. The basis for making a determination of non-compliance based on simulated temperature differences of 0.3 ^{o}C is not strongly supported when the detection tolerance of the model to observed conditions is several times greater than 0.3 ^{o}C.

Approach

The natural conditions simulation of the Pend Oreille River, Idaho was conducted with the corrected hydrology for 2004. The calculated water temperatures at a depth of 3 ft, 20 ft, and 40 ft were output on a frequency of 0.02 days at segment 107. Segment 107 corresponds with the location of a COE sampling station at Riley Creek containing hourly observations of temperatures at these three depths from June 15 through November 3, 2004. The Riley Creek station provided the most comprehensive temperature data set quantifying the observed surface and subsurface temperature characteristics in the Pend Oreille River during the summer of 2004. The calculated and observed temperatures were compared each hour from June 21-September 21, 2004. This time period corresponds with the “critical time” period during the warm summer months defined by the State of Idaho for determination of 303D listing as outlined in WBAG II Appendix D. This time period is inclusive of all temperature excursions in the Pend Oreille River above the Idaho numerical criteria for maximum temperature of 22 ^{o}C, and daily average temperature of 19 ^{o}C.

Results

The model estimates of surface temperature consistently over-estimated the observed temperatures at a depth of 3 ft through much of the study period at the Riley Creek station as shown in **Figure 1**. The prediction error of surface temperatures are larger during periods of increasing river temperatures in June and July and smaller during extended periods of cooling in August and September where the vertical gradients in temperature were small (surface temperature = depth integrated average temperature). A statistical summary of the prediction errors are listed in **Table 1**. The mean prediction error of hourly temperatures at a 3 ft depth was -0.7 ^{o}C and ranged from -3.3 to 0.5 ^{o}C. The absolute mean error for hourly surface temperatures at Riley Creek for the summer of 2004 was 0.7 ^{o}C. The detailed hourly responses of calculated and observed temperatures at Riley Creek are shown in **Figure 2**. The variability of subsurface temperatures were much smaller than the surface response for both observed and calculated conditions. The observed temperatures at 20 and 40 ft of depth were nearly identical throughout the time period whereas the calculated temperatures at these two depths remained different by as much as 0.8 ^{o}C.

If should be noted that the model error statistics listed in Table 1 are much larger than those listed in the Idaho Pend Oreille River Model, Model Scenario Simulations report (PSU, 2007). The statistics listed in Table 19 of the Model Scenario Simulations report for the mean, absolute mean, and root mean square errors were 0.436, 0.522, and 0.736 ^{o}C, respectively for all the temperature observations at the Riley Creek station at a depth of 3 ft. The error statistics listed in Table 1 correspond only to the critical period from June 21-September 21, 2004 and therefore are a more appropriate measure of model error when determining water temperature compliance with Idaho standards.

The calculated and observed maximum daily surface temperatures at Riley Creek at a depth of 3 ft were determined and the prediction error statistics computed as listed in **Table 1**. The mean error of the maximum daily surface temperature was -1.0 ^{o}C and the corresponding standard deviation was 0.8 ^{o}C, both of which were larger than the prediction error of the hourly data. The prediction error statistics for the mean daily surface temperatures listed in **Table 1** were similar to the hourly surface error statistics. The vertically integrated daily maximum temperature error statistics were similar to the vertically integrated daily average error statistics with a small mean error (0.00 ^{o}C) and a standard deviation of 0.43 ^{o}C.

Table 1. Summary Statistics of Prediction Errors of Observed Temperatures in the Pend Oreille River at Riley Creek for Existing Conditions, June 21-September 21, 2004

Temperature Prediction Error Parameters (Temp-observed minus Temp-calculated) (^{o}C)		Hourly Surface Temperature	Daily Maximum Surface Temperature	Daily Average Surface Temperature	Daily Average Vertically Integrated Temperature	Daily Maximum Vertically Integrated Temperature
N*		2234	93	93	93	93
Mean		-0.69	-0.99	-0.69	-0.04	0.00
Absolute Mean		0.75	1.00	0.72	0.32	0.32
Maximum		0.52	0.23	0.30	0.93	1.06
Minimum		-3.26	-2.93	-2.54	-1.51	-1.18
Standard Deviation		0.71	0.75	0.63	0.44	0.43
Percentile	.01	-2.58	-2.79	-2.14	-1.32	-1.16
	.05	-2.03	-2.19	-1.83	-0.74	-0.74
	.10	-1.74	-2.03	-1.49	-0.61	-0.60
	.25	-1.17	-1.52	-1.16	-0.23	-0.16
	.50	-0.56	-0.97	-0.56	-0.01	0.01
	.75	-0.11	-0.34	-0.17	0.21	0.29
	.90	0.12	-0.04	0.01	0.50	0.50
	.95	0.22	0.01	0.10	0.58	0.63
	.99	0.37	0.22	0.23	0.82	0.75

* N = number of observations.

The vertical temperatures at Riley Creek were integrated to estimate a daily average vertically-integrated temperature for the observed and calculated data in the Pend Oreille River from June 21-September 21, 2007. The mean prediction error of the vertically integrated daily average temperature was -0.04 ^{o}C, and the corresponding standard deviation was 0.4 ^{o}C (**Table 1**), both of which were considerably smaller than the prediction errors for the daily maximum surface temperature metric. The ability of the model to predict the daily maximum surface temperature was considerably poorer than the corresponding vertically-integrated daily average temperature. The predicted surface temperatures were consistently over-estimated (error bias of -1.0 ^{o}C) and could contribute to erroneous conclusions of non-compliance when compared with surface temperatures simulated for natural conditions. The likelihood of a comparable prediction error bias in surface temperatures during the natural conditions simulations is highly unlikely due to the differences in vertical mixing and transport between natural and existing river environments. Even in the case of daily average vertically-integrated temperatures, the standard deviation of the predictive error (0.44 °C) was considerably greater than the compliance temperature tolerance of 0.3 °C.

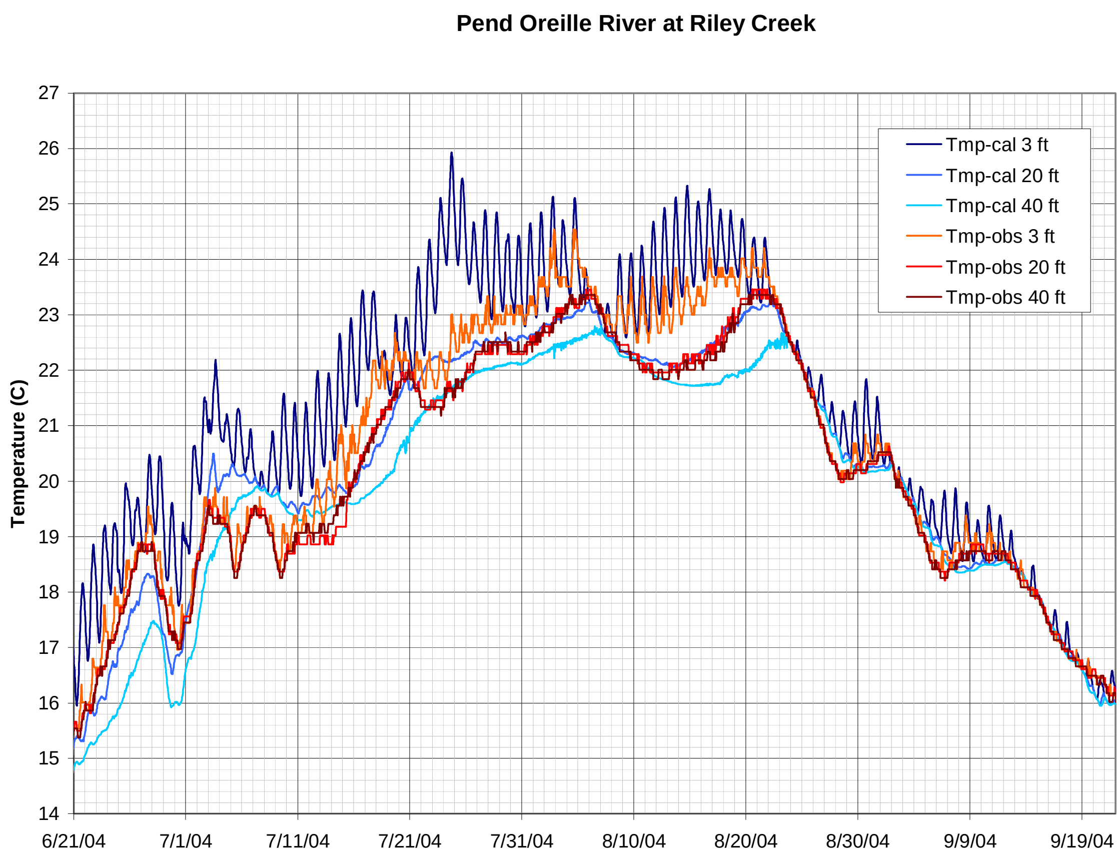

Figure 1. Time history of hourly observed and calculated temperatures in Pend Oreille River near Riley Creek. (Tmp-cal 3 ft = calculated temperature at a depth 3 ft, Tmp-obs 3 ft=observed temperature at a depth 3 ft)

The ability of model estimates to effectively reproduce different observed thermal conditions in the Pend Oreille River was quantified as a function of a parameter called the temperature detection tolerance. The temperature detection tolerance is another means of quantifying the confidence limits about model estimates. A model estimate was determined to successfully capture the observed thermal conditions if the estimated temperature plus or minus the temperature detection tolerance bounded the observed temperature. The percent of observations falling within the temperature detection tolerance of the calculated temperature was determined for four temperature metrics. The four temperature metrics used in this analysis were: the daily maximum surface temperatures, the daily average surface temperatures, the daily average depth-integrated temperatures and the daily maximum depth-integrated temperatures. The calculated and observed data in the Pend Oreille River at Riley Creek during June 21-September 21, 2007 were used in this analysis.

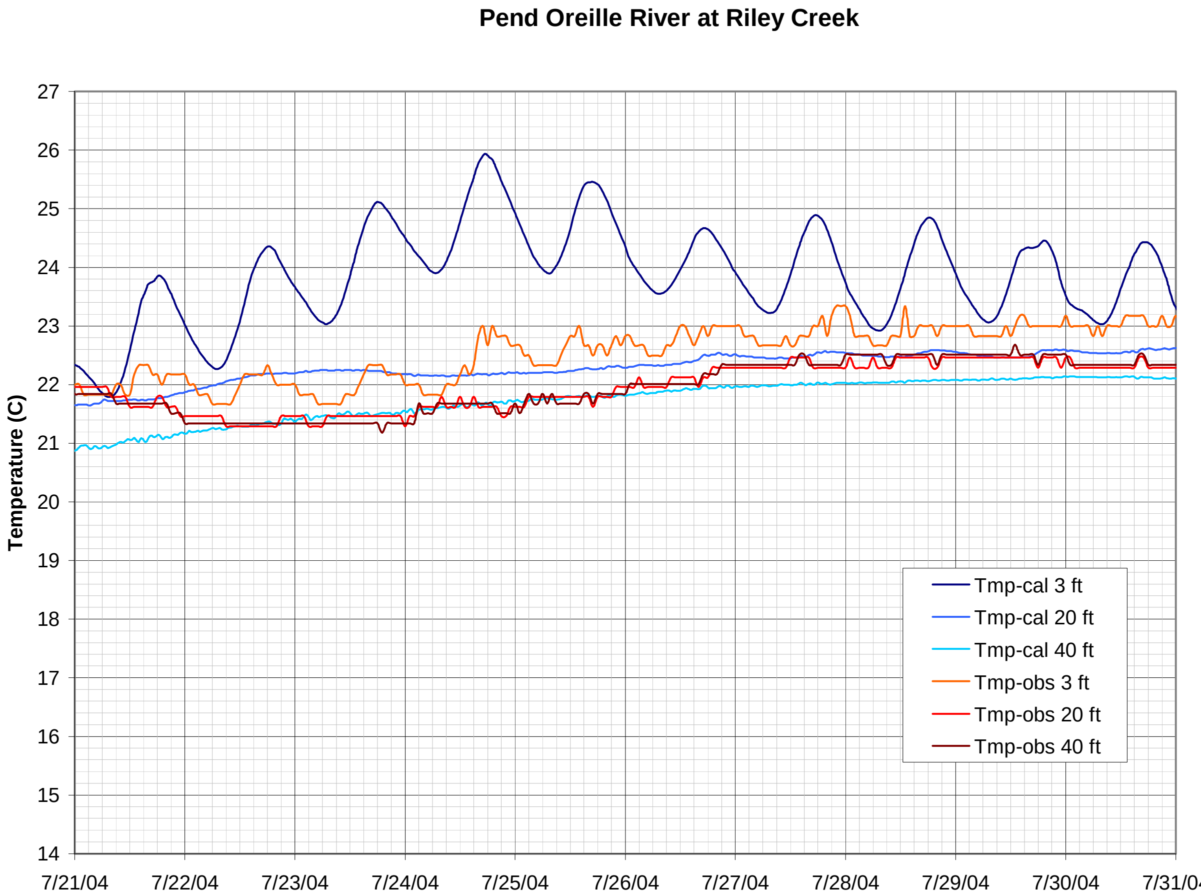

Figure 2. Time history of hourly observed and calculated temperatures in Pend Oreille River near Riley Creek. (Tmp-cal 3 ft = calculated temperature at a depth 3 ft, Tmp-obs 3 ft=observed temperature at a depth 3 ft)

The temperature detection tolerance for a comparable level of performance was considerably smaller when predicting the daily average vertically integrated temperatures at Riley Creek as compared to the daily maximum surface temperatures. The percentage of observations within the temperature detection tolerance of the model estimates for three temperature metrics were determined for the study period as shown in Figure 3. For example, 22 percent of the observed daily maximum temperatures at Riley Creek were within 0.3 °C of the estimated temperatures from June 21-September 21, 2007. About 50 percent of the maximum surface temperatures were contained by the model estimates for a detection tolerance of 1.0 °C. A detection tolerance greater than 2.0 °C was required for over 90 percent of the observations of maximum daily surface temperatures to be bounded by model estimates.

The model was successful in estimating temperatures within 0.3 ^{o}C of the observed daily average depth-integrated and daily maximum depth-integrated temperatures about 57 percent of the time. A detection tolerance of 0.7 ^{o}C was required for reaching a 90 percent confidence interval for observed daily average depth-integrated and daily maximum depth-integrated temperatures. The confidence limits required to predict daily average surface temperatures fell between the curves for daily average depth-integrated temperatures and daily maximum surface temperatures (**Figure 3**). The 90 percent confidence limit associated with predicting the daily maximum surface temperature near Riley Creek was nearly three times as large as the confidence limit for the daily average depth-integrated and daily maximum depth-integrated temperatures. The 90 percent confidence interval for calculating the daily average depth-integrated temperatures was over twice as large as the compliance tolerance of 0.3 ^{o}C used in the Pend Oreille TMDL. The 90 percent confidence interval for estimating the daily maximum surface temperatures was about seven times larger than the compliance tolerance of 0.3 ^{o}C. The model provides much more reliable estimates of daily average depth-integrated temperatures and daily maximum depth-integrated temperatures than daily maximum surface temperatures.

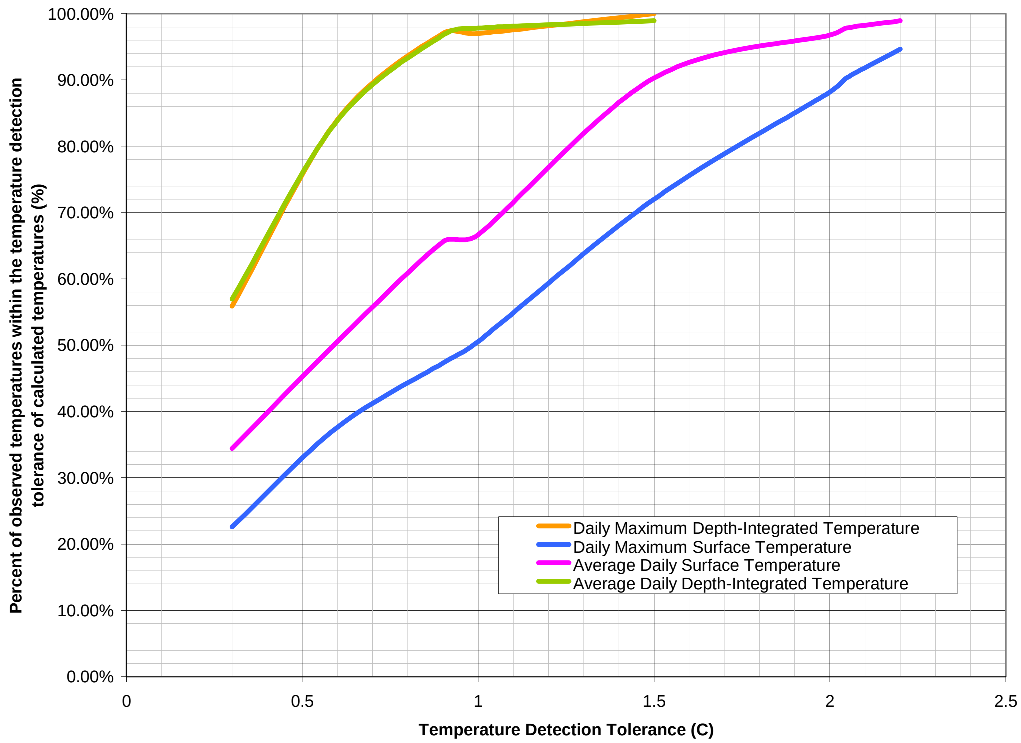

Figure 3. Percent of observed temperatures within the temperature detection tolerance of calculated temperatures for daily maximum surface temperatures (blue), daily average surface temperatures (pink), daily average depth-integrated temperatures (green), and daily maximum depth-integrated temperatures (orange) in the Pend Oreille River near Riley Creek, June 21-September 21, 2004.

Conclusions

This analysis quantified the prediction errors of daily maximum surface temperatures, daily maximum depth-integrated temperatures, and daily average depth-integrated temperatures in the Pend Oreille River at Riley Creek during June 21-September 21, 2004. The prediction errors of model estimates of surface temperatures were found to be much larger than errors of simulated daily average depth-integrated temperatures and daily maximum depth-integrated temperatures. The 90 percent confidence interval of 2.1 ^{o}C corresponding with model estimates of daily maximum surface temperature was three times larger than the estimated confidence limit (0.7 ^{o}C) for model estimates of the daily maximum depth-integrated temperatures and daily average depth-integrated temperatures. The estimated daily maximum surface temperatures consistently over-estimated the observed surface temperatures in the Pend Oreille River at Riley Creek as evidenced by a mean prediction error of -1.0 ^{o}C. The determination of non-compliance using narrowly defined water quality metrics that are based on a singular response at a specific place like daily maximum surface temperatures, need to consider the much larger uncertainty associated with numerical model simulations of these temperature properties. The application of a vertically-integrated maximum and average daily temperature would be more reflective of available habitat in the Pend Oreille River and result in more reliable model estimates of these temperature metrics. It is hard to justify claims of non-compliance and thermal impairment when the differences between simulated natural and existing conditions are significantly smaller than the detection tolerance of the model at meaningful confidence levels and when the occurrence of these events is infrequent. In addition, the determination of thermal impairment caused by the existence and operation of Albeni Falls Dam must be based on clearly identifying both the source and significance of these thermal events.

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CEERD-HF-HE (1110-2-1403b) November 15, 2007

MEMORANDUM FOR Commander, US Army Engineer District, Seattle, ATTN: CENWS-EC-TB-WM (Mr. Kent Easthouse),

Subject Technical assessment of prediction errors of model estimates of temperatures in the Pend Oreille River, Idaho

Background

Numerical simulations of water temperature for existing and natural conditions in the Pend Oreille River, Idaho were used to identify occurrences of non-compliance with Idaho State water quality regulations. A set of water quality compliance metrics and locations were outlined in the TMDL and provide the basis for identifying Albeni Falls Dam as the prominent source for thermal pollution in the Pend Oreille River. A temperature compliance tolerance of $0.3\ ^{o}C$ was used to determine if an excursion above the applicable temperature criteria was evident. The specific compliance metrics included the daily average volume-weighted temperature by river segment, daily average temperatures in surface and bottom cells, daily maximum temperatures in surface cells, and instantaneous temperatures on August 8 and 16 in any cell. The following analyses will quantify the prediction error properties of the two-dimensional model of the Pend Oreille River, Idaho at the Riley Creek sampling station during the summer of 2004.

Problem Statement

The current TMDL for temperature in the Pend Oreille River is based upon simulated differences in temperature metrics for natural and existing conditions at a tolerance of $0.3\ ^{o}C$ without clearly identifying the source or significance of these events. The ability of the model to reproduce certain thermal attributes of existing conditions in the Pend Oreille River is highly variable. The prediction errors of model estimates of temperature at a specific point in time and space can be much larger than prediction errors of simulated temperatures averaged over time and space. There is a need to recognize the variation in the predictive capability of the model to support decisions regarding compliance with water quality standards at meaningful confidence levels. The basis for making a determination of non-compliance based on simulated temperature differences of $0.3\ ^{o}C$ is not strongly supported when the detection tolerance of the model to observed conditions is several times greater than $0.3\ ^{o}C$.

Approach

The natural conditions simulation of the Pend Oreille River, Idaho was conducted with the corrected hydrology for 2004. The calculated water temperatures at a depth of 3 ft, 20 ft, and 40 ft were output on a frequency of 0.02 days at segment 107. Segment 107 corresponds with the location of a COE sampling station at Riley Creek containing hourly observations of temperatures at these three depths from June 15 through November 3, 2004. The Riley Creek station provided the most comprehensive temperature data set quantifying the observed surface and subsurface temperature characteristics in the Pend Oreille River during the summer of 2004. The calculated and observed temperatures were compared each hour from June 21-September 21, 2004. This time period corresponds with the "critical time" period during the warm summer months defined by the State of Idaho for determination of 303D listing as outlined in WBAG II Appendix D. This time period is inclusive of all temperature excursions in the Pend Oreille River above the Idaho numerical criteria for maximum temperature of 22 ^{o}C, and daily average temperature of 19 ^{o}C.

Results

The model estimates of surface temperature consistently over-estimated the observed temperatures at a depth of 3 ft through much of the study period at the Riley Creek station as shown in **Figure 1**. The prediction error of surface temperatures are larger during periods of increasing river temperatures in June and July and smaller during extended periods of cooling in August and September where the vertical gradients in temperature were small (surface temperature = depth integrated average temperature). A statistical summary of the prediction errors are listed in **Table 1**. The mean prediction error of hourly temperatures at a 3 ft depth was -0.7 ^{o}C and ranged from -3.3 to 0.5 ^{o}C. The absolute mean error for hourly surface temperatures at Riley Creek for the summer of 2004 was 0.7 ^{o}C. The detailed hourly responses of calculated and observed temperatures at Riley Creek are shown in **Figure 2**. The variability of subsurface temperatures were much smaller than the surface response for both observed and calculated conditions. The observed temperatures at 20 and 40 ft of depth were nearly identical throughout the time period whereas the calculated temperatures at these two depths remained different by as much as 0.8 ^{o}C.

If should be noted that the model error statistics listed in Table 1 are much larger than those listed in the Idaho Pend Oreille River Model, Model Scenario Simulations report (PSU, 2007). The statistics listed in Table 19 of the Model Scenario Simulations report for the mean, absolute mean, and root mean square errors were 0.436, 0.522, and 0.736 ^{o}C, respectively for all the temperature observations at the Riley Creek station at a depth of 3 ft. The error statistics listed in Table 1 correspond only to the critical period from June 21-September 21, 2004 and therefore are a more appropriate measure of model error when determining water temperature compliance with Idaho standards.

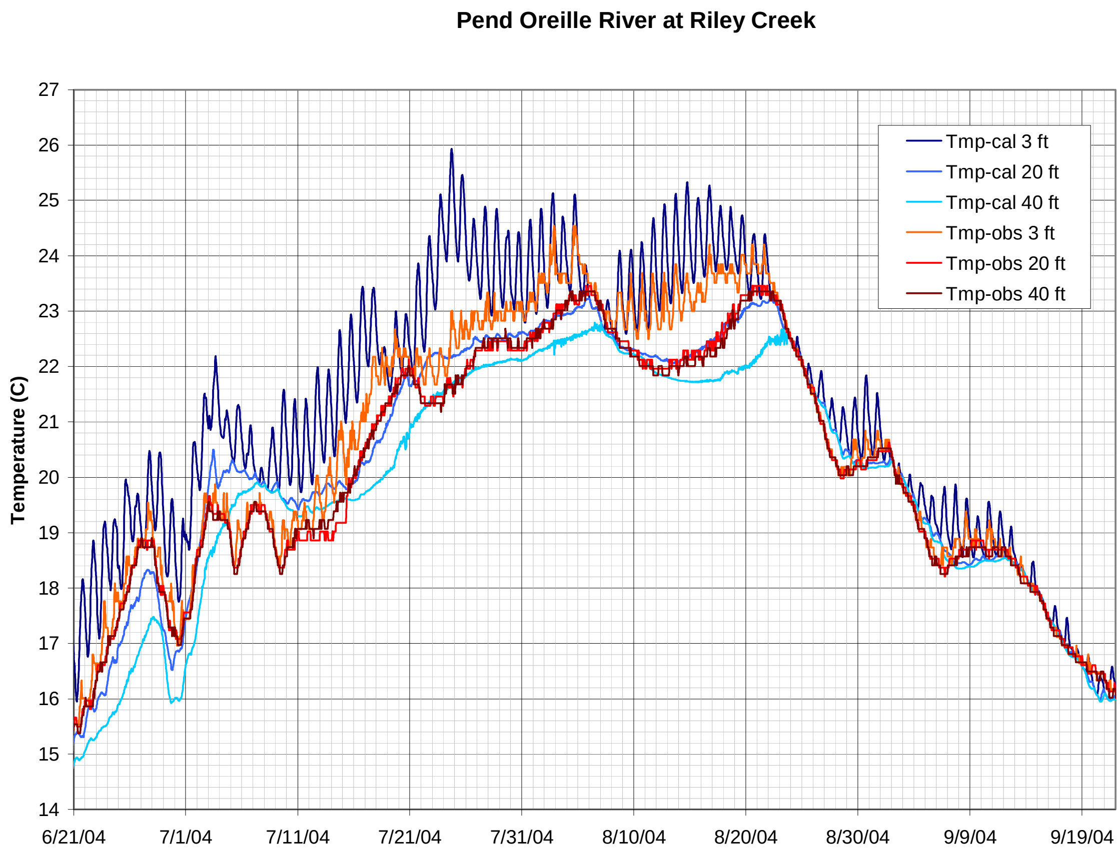
The calculated and observed maximum daily surface temperatures at Riley Creek at a depth of 3 ft were determined and the prediction error statistics computed as listed in **Table 1**. The mean error of the maximum daily surface temperature was -1.0 ^{o}C and the corresponding standard deviation was 0.8 ^{o}C, both of which were larger than the prediction error of the hourly data. The prediction error statistics for the mean daily surface temperatures listed in **Table 1** were similar to the hourly surface error statistics. The vertically integrated daily maximum temperature error statistics were similar to the vertically integrated daily average error statistics with a small mean error (0.00 ^{o}C) and a standard deviation of 0.43 ^{o}C.

Table 1. Summary Statistics of Prediction Errors of Observed Temperatures in the Pend Oreille River at Riley Creek for Existing Conditions, June 21-September 21, 2004

Temperature Prediction Error Parameters (Temp-observed minus Temp-calculated) (^{o}C)		Hourly Surface Temperature	Daily Maximum Surface Temperature	Daily Average Surface Temperature	Daily Average Vertically Integrated Temperature	Daily Maximum Vertically Integrated Temperature
N*		2234	93	93	93	93
Mean		-0.69	-0.99	-0.69	-0.04	0.00
Absolute Mean		0.75	1.00	0.72	0.32	0.32
Maximum		0.52	0.23	0.30	0.93	1.06
Minimum		-3.26	-2.93	-2.54	-1.51	-1.18
Standard Deviation		0.71	0.75	0.63	0.44	0.43
Percentile	.01	-2.58	-2.79	-2.14	-1.32	-1.16
	.05	-2.03	-2.19	-1.83	-0.74	-0.74
	.10	-1.74	-2.03	-1.49	-0.61	-0.60
	.25	-1.17	-1.52	-1.16	-0.23	-0.16
	.50	-0.56	-0.97	-0.56	-0.01	0.01
	.75	-0.11	-0.34	-0.17	0.21	0.29
	.90	0.12	-0.04	0.01	0.50	0.50
	.95	0.22	0.01	0.10	0.58	0.63
	.99	0.37	0.22	0.23	0.82	0.75

* N = number of observations.

The vertical temperatures at Riley Creek were integrated to estimate a daily average vertically-integrated temperature for the observed and calculated data in the Pend Oreille River from June 21-September 21, 2007. The mean prediction error of the vertically integrated daily average temperature was -0.04 ^{o}C, and the corresponding standard deviation was 0.4 ^{o}C (**Table 1**), both of which were considerably smaller than the prediction errors for the daily maximum surface temperature metric. The ability of the model to predict the daily maximum surface temperature was considerably poorer than the corresponding vertically-integrated daily average temperature. The predicted surface temperatures were consistently over-estimated (error bias of -1.0 ^{o}C) and could contribute to erroneous conclusions of non-compliance when compared with surface temperatures simulated for natural conditions. The likelihood of a comparable prediction error bias in surface temperatures during the natural conditions simulations is highly unlikely due to the differences in vertical mixing and transport between natural and existing river environments. Even in the case of daily average vertically-integrated temperatures, the standard deviation of the predictive error (0.44 ^{o}C) was considerably greater than the compliance temperature tolerance of 0.3 ^{o}C.



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The ability of model estimates to effectively reproduce different observed thermal conditions in the Pend Oreille River was quantified as a function of a parameter called the temperature detection tolerance. The temperature detection tolerance is another means of quantifying the confidence limits about model estimates. A model estimate was determined to successfully capture the observed thermal conditions if the estimated temperature plus or minus the temperature detection tolerance bounded the observed temperature. The percent of observations falling within the temperature detection tolerance of the calculated temperature was determined for four temperature metrics. The four temperature metrics used in this analysis were: the daily maximum surface temperatures, the daily average surface temperatures, the daily average depth-integrated temperatures and the daily maximum depth-integrated temperatures. The calculated and

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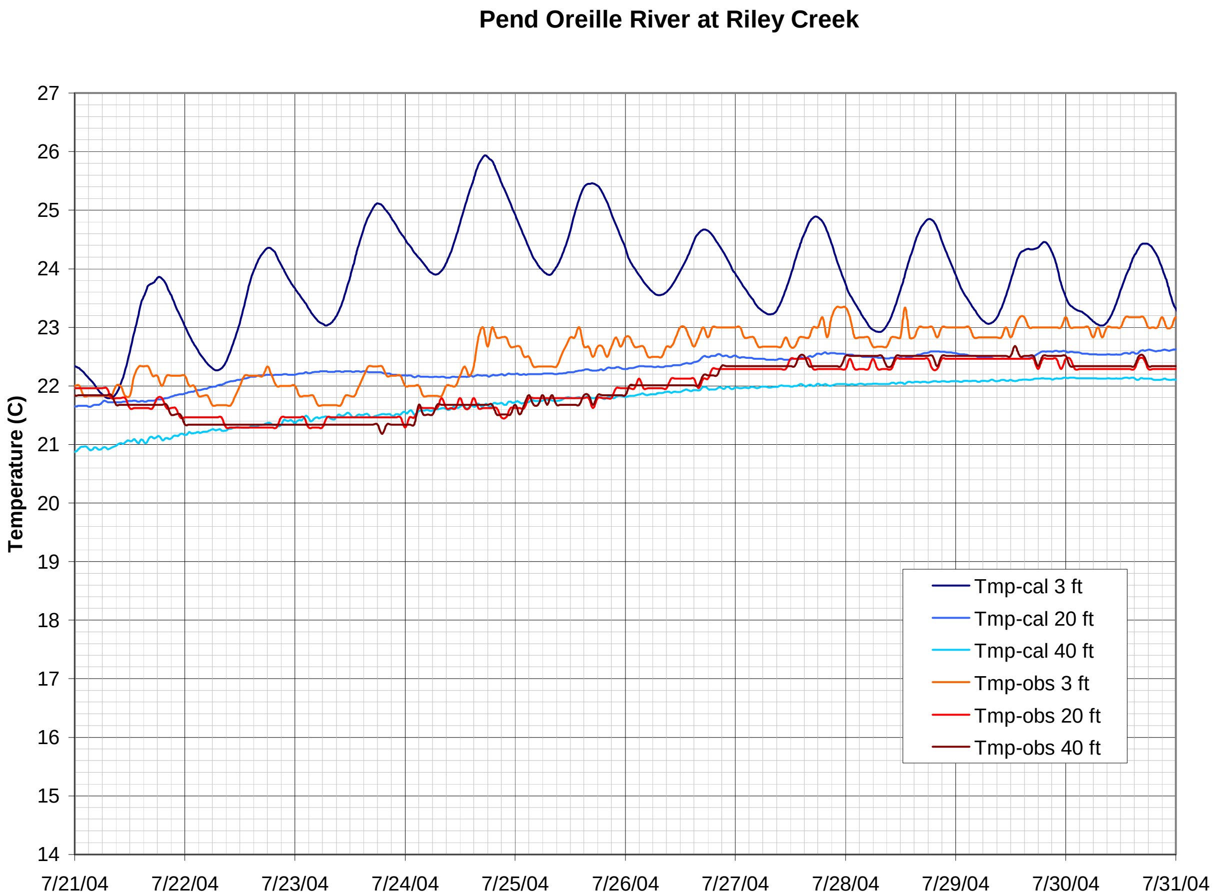

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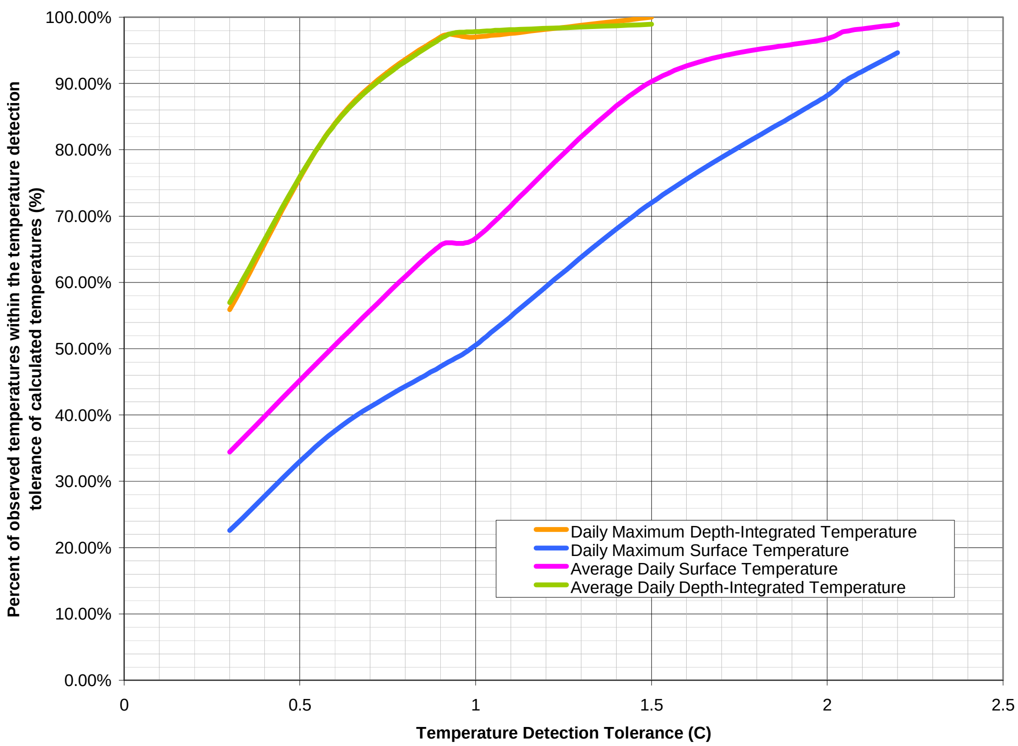

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