



PUBLIC UTILITY DISTRICT NO. 1 of CHELAN COUNTY
P.O. Box 1231, Wenatchee, WA 98807-1231 • 327 N. Wenatchee Ave., Wenatchee, WA 98801
(509) 663-8121 • Toll free 1-888-663-8121 • www.chelanpud.org

December 3, 2015

Honorable Kimberly D. Bose, Secretary, and
Nathaniel J. Davis, Sr., Deputy Secretary
FEDERAL ENERGY REGULATORY COMMISSION
888 First Street, NE
Washington, DC 20426

VIA ELECTRONIC FILING

Mr. Charlie McKinney
WASHINGTON DEPARTMENT OF ECOLOGY
1250 West Alder Street
Union Gap, WA 98903-0009

Re: **Lake Chelan Hydroelectric Project No. 637**
License Article 401 and Water Quality Certification Condition V.B.
Request for Second Time Extension for the Chelan River Water Temperature Modeling
Study Quality Assurance Project Plan Report

Dear Secretary Bose, Deputy Secretary Davis, and Mr. McKinney:

On June 5, 2015, the Federal Energy Regulatory Commission (Commission) issued its order approving the Public Utility District No. 1 of Chelan County's (Chelan PUD) request for extending the deadline to February 15, 2016, for filing its final Chelan River Water Temperature Modeling Study Quality Assurance Project Plan (QAPP) Report for the Lake Chelan Hydroelectric Project (Project). The request was based on the need for more extensive consultation than anticipated with the Washington Department of Ecology (Ecology) regarding the development of the water temperature model, which affected its intended reporting deadline.

The water temperature model development and calibration is complete. Ecology reviewed a draft Chelan River Water Temperature Modeling Calibration Report, an interim work product, in June and provided comments on June 24, 2015, which Chelan PUD subsequently addressed on July 16, 2015 (see emails attached). Currently, work using the model is proceeding, in collaboration with Ecology, for evaluating the variables of Chelan River flow levels, future potential riparian vegetation shading, and other scenarios. Unfortunately, more work than anticipated was necessary to bring the model into calibration, and the development of realistic future shade conditions from developing riparian vegetation required extensive additional work by the contractor that conducted the Chelan River Riparian Revegetation Feasibility Investigation, as required by the 401 Water Quality Certification.

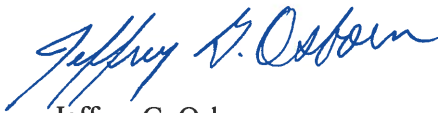
Model calibration took longer than expected for the following reasons:

- 1) Initial model runs predicted Chelan River wetted surface area much narrower than actual. The explanation was that LIDAR mapping measured the surface of very large substrate in the Chelan River, which did not depict accurately the water surface where the river flowed between and around the extremely large boulders in the river channel; and
- 2) Initial model runs predicted daily maximum and minimum temperatures that were as much as two degrees different than empirical measurements in the river. An additional model component was added to account for larger than expected hyporheic exchange between surface and subsurface flow, which required several model runs to bring the model into calibration. Additionally, potential riparian shade data were only recently provided from the Chelan River Riparian Revegetation Feasibility Investigation to the modeling team. These data are an extremely important component for the water temperature modeling effort to predict potential benefit of shade from developing riparian vegetation as the Chelan River matures.

Conducting accurate temperature modeling for the Chelan River is a vital component for Ecology's 10-year check-in scheduled for 2019. Chelan PUD is committed to providing the most accurate data possible with which Ecology can make decisions in 2019 for Chelan River water quality standards.

For the forgoing reasons, Chelan PUD requests, respectfully, that the Commission grant an extension to file its final Ecology-reviewed Chelan River Water Temperature Modeling Study QAPP Report, generated from model results, with the Commission by June 1, 2016.

Sincerely,



Jeffrey G. Osborn
License Compliance Supervisor
jeff.osborn@chelanpud.org
(509) 661-4176

Attachments: Ecology's and Chelan PUD's email consultation

cc: Paul Pickett, (Ecology)
Mark Peterschmidt, (Ecology)
Anna Harris, (Ecology)
Steve Hays, (Chelan PUD)

A summary of email communications documenting ongoing consultation between Chelan PUD, Washington Department of Ecology and Consultants working on the Chelan River Temperature Model Study

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From: Ray Walton [mailto:rwalton@westconsultants.com]
Sent: Monday, November 16, 2015 5:25 PM
To: Hays, Steve
Subject: RE: Chelan River Model - Status

Steve:

We just received the vegetative shade files from Herrera late this afternoon. I have asked Alec to open them, and try to run QUAL2Kw with both topographic and vegetative shade.

I will be in Boise the rest of this week teaching an HEC-RAS course. I will call in to see how Alec is getting along, and then update you later this week. When I get back next Monday, I'll update you on the state of the funding and then we can better discuss project extensions.

Ray

Raymond Walton, PhD, PE, D.WRE

WEST Consultants, Inc.

From: Hays, Steve [mailto:steve.hays@chelanpud.org]
Sent: Monday, November 16, 2015 3:08 PM
To: Ray Walton
Subject: Chelan River Model - Status

Hi Ray,

We have a meeting this Thursday with Ecology in Yakima – it is one of our more-or-less quarterly meetings to update and discuss the various activities under the Rocky Reach and Chelan project licenses. I was wondering how things are progressing with the riparian shade scenarios and other model gaming so that I could share the progress. We have two newly assigned people at Ecology that will be working with us on these projects since Pat Irle and Chris Coffin have retired. Also, I am thinking that I should put in a time extension on the WEST contract for this project since its term ends on December 31.

Steve

From: Ray Walton [mailto:rwalton@westconsultants.com]
Sent: Thursday, September 17, 2015 8:38 AM
To: Hays, Steve
Cc: Jeremy Bunn; Osborn, Jeff
Subject: Shade file and QUAL2Kw shape file

Colleagues:

I have placed on our FTP site (see below), (1) the latest input file for the SHADE model and (2) a “shape” file with the QUAL2Kw cells. It is important to note that the “cross sections” in the shape file represent the ends of the QUAL2Kw cells (and not their centers). Please let me know when you have downloaded the information so I can free up the space. And please let me know if you have any comments or questions. Thanks.....

Ray

Raymond Walton, PhD, PE, D.WRE

WEST Consultants, Inc.

From: Ray Walton [mailto:rwalton@westconsultants.com]

Sent: Monday, September 14, 2015 1:56 PM

To: Osborn, Jeff; Joy P. Michaud; Jeremy Bunn; Hays, Steve

Subject: RE: Conference call to develop shade scope for Chelan River Temperature Model

All these times work for me.

Ray

From: Osborn, Jeff [mailto:Jeff.Osborn@chelanpud.org]

Sent: Monday, September 14, 2015 11:33 AM

To: Joy P. Michaud; Jeremy Bunn; Ray Walton; Hays, Steve

Subject: Conference call to develop shade scope for Chelan River Temperature Model

Team: I talked with Steve Hays last Friday regarding data needed from the Herrera Team for input into the Chelan River Temperature Model. We came up with more questions than answers. We agreed that the best way to have questions answered is to hold a call between those “in the know,” primarily Ray Walton and Jeremy Bunn, to map out needs, and how to get them, for the temperature model. Below are some proposed dates and times for holding a one-hour conference call. Please let me know dates and times that fit with your schedules at your earliest convenience, and I will send out a formal meeting announcement to everyone.

Tuesday, September 15	1:00 – 2:00 pm;
Wednesday, September 16	afternoon; and
Friday, September 25	morning.

Apologies for the short notice. I am going to be out of the office almost all of next week.

Thank you very much.

Jeff

Jeff Osborn

***Compliance Program Supervisor
Public Utility District No. 1 of Chelan County***

From: Pickett, Paul (ECY) [mailto:Ppic461@ECY.WA.GOV]
Sent: Monday, August 17, 2015 1:51 PM
To: Osborn, Jeff; Hays, Steve
Cc: McKinney, Charlie (ECY); Mackie, Thomas L. (ECY); Coffin, Chris (ECY)
Subject: RE: Chelan River Fishery Forum conference call

Is the call on for tomorrow morning? Given the fiery mayhem in Chelan, I was wondering if folks were preoccupied and this was being postponed.

If the call is on, best add an agenda item to discuss how the fire may impact the river. Looks like it cut a swath across the canyon.

Paul

*Paul J. Pickett
WA Dept. of Ecology
P.O. Box 47710
Olympia, WA 98504-7710
desk (360) 407-6882
cell (509) 406-2459*

From: Osborn, Jeff [mailto:Jeff.Osborn@chelanpud.org]
Sent: Friday, July 31, 2015 3:55 PM
To: Coffin, Chris (ECY) <CCOF461@ECY.WA.GOV>; Pickett, Paul (ECY) <Ppic461@ECY.WA.GOV>
Cc: McKinney, Charlie (ECY) <cmck461@ECY.WA.GOV>; Mackie, Thomas L. (ECY) <tmac461@ECY.WA.GOV>
Subject: RE: Chelan River Fishery Forum conference call

Chris: I do appreciate your suggestion, as it is impossible to follow a PowerPoint presentation while on the phone. However, I do not plan on having any visual aids. I was hoping that CRFF folks would have ideas from reviewing the Chelan River Temperature Model Calibration and Riparian Feasibility/Limiting Factors reports that could be relayed to Ray Walton for modeling scenarios during the conference call.

Jeff

***Jeff Osborn
Compliance Program Supervisor
Public Utility District No. 1 of Chelan County***

From: Coffin, Chris (ECY) [mailto:CCOF461@ECY.WA.GOV]
Sent: Friday, July 31, 2015 2:57 PM
To: Pickett, Paul (ECY)
Cc: McKinney, Charlie (ECY); Mackie, Thomas L. (ECY); Osborn, Jeff
Subject: RE: Chelan River Fishery Forum conference call

It's scheduled as a conference call so that would work. You might want to remind Jeff O. to send out any visual aids that will be used. If we had them on our computers it would be easy to follow along with the discussion. In fact I'll do that right now by ccing Jeff on this email.

*Chris Coffin, Watershed Unit Supervisor
Water Quality Program
WA Dept. of Ecology*

From: Pickett, Paul (ECY)
Sent: Friday, July 31, 2015 2:49 PM
To: Coffin, Chris (ECY)
Cc: McKinney, Charlie (ECY); Mackie, Thomas L. (ECY)
Subject: FW: Chelan River Fishery Forum conference call

Chris,

I can participate in this meeting (on my calendar), and the main topic is modeling scenarios.

Would calling in suffice, or do you think it would be better if I attended in person?

Paul

*Paul J. Pickett
WA Dept. of Ecology*

From: Osborn, Jeff [<mailto:Jeff.Osborn@chelanpud.org>]
Sent: Friday, July 31, 2015 12:20 PM
To: Chelan River Fishery Forum Members
Cc: Ray Walton <rwalton@westconsultants.com>; Pickett, Paul (ECY) <Ppic461@ECY.WA.GOV>
Subject: Chelan River Fishery Forum conference call

Dear Chelan River Fishery Forum: The best date available for the next gathering of the Forum, in the form of a conference call, is August 18, 2015, from 9:00 am to 12:00 noon. Please see the meeting agenda attached. The call-in number is located in the banner at the top of the agenda. As you can see from the agenda, the task at hand is to provide Ray Walton with modeling scenarios involving flow, shade, channel configuration, or other actions that may have affect on the water temperature in the Chelan River. Please bring your ideas for discussion on the 18th.

Looking forward to your participation in furthering the Chelan River temperature modeling investigation!

Jeff

*Jeff Osborn
Compliance Program Supervisor
Public Utility District No. 1 of Chelan County*

From: Pickett, Paul (ECY) [<mailto:Ppic461@ECY.WA.GOV>]
Sent: Tuesday, July 07, 2015 10:58 AM
To: Ray Walton

Cc: Hays, Steve; Coffin, Chris (ECY); McKinney, Charlie (ECY)
Subject: RE: Chelan River Temperature Model Draft Calibration Report

Ray, your initial responses look pretty reasonable. I look forward to seeing your revisions in the next draft.

We can discuss more if you want, but it's not needed at my end.

Paul

Paul J. Pickett
WA Dept. of Ecology

From: Ray Walton [mailto:rwalton@westconsultants.com]
Sent: Thursday, July 02, 2015 1:01 PM
To: Pickett, Paul (ECY)
Cc: Hays, Steve (steve.hays@chelanpud.org)
Subject: RE: Chelan River Temperature Model Draft Calibration Report

Paul:

Thanks for providing the comments below. I quickly reviewed them, imported them into a review document, and provided some initial responses. Perhaps we might talk early next week to go over them and map the path forward? Thanks, and have a great July 4th....

Ray

Raymond Walton, PhD, PE, D.WRE

WEST Consultants, Inc.

TECHNICAL MEMO
Date: July 16, 2015
To: Steve Hays (Chelan PUD)
Copy: Paul Pickett (Ecology)
From: Raymond Walton (WEST Consultants, Inc)
RE: Responses to Comments on Draft Chelan River Temperature Model Calibration Report, Dated 6/24/2015

COMMENT 1: Section 2, "Model Data": provide a quantitative and qualitative analysis of the quality of the data used for input data. For example, what quality planning documents are used for flows and temperature monitoring, what are the results of any quality assessment, and are there confidence band estimates for the data?

RESPONSE 1: Steve Hays provided a brief section to discuss this. It was discussed in general in the QAPP.

BACKCHECK 1:

COMMENT 2: Section 2.8: what existing information is available on current riparian conditions? Can you verify the assumption of no shade from aerial photo analysis? For example, it appears that the Reach 4 Habitat Channel has some riparian vegetation, and I recall from the site visit there was some limited riparian vegetation emerging in Reach

RESPONSE 2: The “existing information” on current riparian conditions is covered in the Herrera report on shading. Herrera concluded that there is little current vegetative shading. We added a reference to the calibration report.

BACKCHECK 2:

COMMENT 3: Section 3.2: As we discussed, your analysis of modeled widths versus observed makes sense. However, that doesn’t leave us with confidence about the hydraulic model calibration. Do you have any information regarding modeled versus observed time of travel, velocities, or depths?

RESPONSE 3: A paragraph is added to the report that presents an analysis of travel times based on the observed response to sudden changes in flows through the low-flow outlet. We modeled this effect by lowering Mannings n roughness values to force critical depth conditions in the model. Under these conditions, the gravity wave speed e_1 equals the stream velocity. Depths and velocities are difficult to observe in the field because of the shallow depths and highly variable bed materials.

BACKCHECK 3:

COMMENT 4: Section 3.3, your power equations depend on the quality of calibration mentioned in the previous comment. Could the error in width you described also have implications for depth or velocity, and therefore for the accuracy of the power equations?

RESPONSE 4: We added a sensitivity to the power functions to the analysis to evaluate its effect (see Section 4.3.2).

BACKCHECK 4:

COMMENT 5: I would expect that the temperature model would be sensitive to stream width. How could this be tested? Discuss how the model results were translated to widths for the thermal exchange in the temperature model, and the implications of the hydraulic model’s under-predicted stream width on the temperature model.

RESPONSE 5: The power functions from HEC-RAS to QUAL2Kw describe cross sectional area and hydraulic mean depth as a function of flow. Top widths are then calculated within QUAL2Kw using these functions ($\text{width} = \text{area}/\text{depth}$). There is no way to explicitly define widths in QUAL2Kw. However, the sensitivity analysis to power functions (see Response 4) did shed light on this issue.

BACKCHECK 5:

COMMENT 6: Section 4.3.1 refers to “July 2014”. This is inconsistent with Table 6 and Figure 20. Please correct or explain.

RESPONSE 6: Corrected in report.

BACKCHECK 6:

COMMENT 7: Section 4.3.7: It is difficult to interpret the sensitivity analysis with only the input values shown. Generally, a sensitivity analysis varies inputs by a small set percentage. It would be helpful in Table 7 to show the initial calibrated values and the percentage that they were varied for the analysis. This would help to support the conclusions about the relative sensitivity of the different parameters.

RESPONSE 7: Disagree with general comment. Sensitivity analyses vary values over some range. While they can be +/- some percentage of the base value, they don’t have to be to illustrate the point. Having said this, we added percentages to Table 8 (formerly Table 7) to provide this information.

BACKCHECK 7:

COMMENT 8: Section 4.4: It surprises me that you calibrated to one data set and validated to 4 others. The model was calibrated was calibrated during a period of relatively warm water (20-24 degC).

Validation runs tended to perform equivalently for higher temperatures but somewhat less well for lower temperatures. It would be a more robust calibration process to calibrate to all the data sets, or at least to calibrate to 3 data sets in a wide range of temperatures and validate with two sets.

RESPONSE 8: The “ideal” process of validation is to use the calibrated values with no changes. One would only resort to changing these values if the validation results (plots and/or statistics) look poor. In our case, the validation plots and statistics compare well with the model calibration results. No changes made.

BACKCHECK 8:

COMMENT 9: Since the criterion from the standards is 17.5, it would be informative to develop calibration and validation statistics for temperature above 17.5. Also, since the WQ standards is based on the 7DADMax, it would be helpful to see the calibration and validation statistics for that metric.

RESPONSE 9: We believe that for a well calibrated model, the 7DADMax can be derived from the observations. A brief section is included in the report to present an overview of this information. This have been done by Chelan PUD. As the model simulation periods are each one week long, the 7DADMax would be only a single value and therefore serve no practical use. No changes made.

BACKCHECK 9:

COMMENT 10: Why were only five 7-day data sets used? It would seem that longer time periods would result in a stronger calibration and allow the 7DADMax to be calculated from multiple moving averaging periods.

RESPONSE 10: We believe that five simulation periods on different years and months from March to September, serve to cover well the variability in the Chelan River. (See Response 9 for 7DADMax discussion.) No changes made.

BACKCHECK 10:

COMMENT 11: Section 4.6: Your statement “the model validation statistics are similar to the calibration statistic” overlooks the tendency to perform better for higher temperature than for lower. As such, this seems like an over-simplistic statement that misses some key patterns. Some sensitivity analysis with one of the cooler calibration periods could help to understand the performance of the model in those conditions.

RESPONSE 11: We conducted a brief sensitivity analysis of for the March 2015 period. Model sensitivity was similar. We added a recommendation to measure groundwater temperatures near the base of the hyporheic zone.

BACKCHECK 11:

COMMENT 12: Section 5, “This is partially due to the dry conditions that support little tall vegetation elsewhere in the area, but also because the Chelan River is very wide for the depths it supports under low-flow conditions.” My understanding is that this is also due to the history of the river being dry, so that riparian vegetation has only recently had enough water to survive the summer.

RESPONSE 12: Text reworded.

BACKCHECK 12:

From: Pickett, Paul (ECY) [<mailto:Ppic461@ECY.WA.GOV>]

Sent: Wednesday, June 24, 2015 2:44 PM

To: Hays, Steve; Ray Walton; Osborn, Jeff

Cc: Mackie, Thomas L. (ECY); Coffin, Chris (ECY); McKinney, Charlie (ECY); Pelletier, Greg (ECY)
Subject: FW: Chelan River Temperature Model Draft Calibration Report

Steve, Ray, and Jeff,

Here are some preliminary comments on the calibration report that I'd like to get to you before tomorrow's meeting. I expect there will be further discussion over the next few weeks to address these comments and explore the report more deeply.

1. Section 2, "Model Data": provide a quantitative and qualitative analysis of the quality of the data used for input data. For example, what quality planning documents are used for flows and temperature monitoring, what are the results of any quality assessment, and are there confidence band estimates for the data?
2. Section 2.8: what existing information is available on current riparian conditions? Can you verify the assumption of no shade from aerial photo analysis? For example, it appears that the Reach 4 Habitat Channel has some riparian vegetation, and I recall from the site visit there was some limited riparian vegetation emerging in Reach 1.
3. Section 3.2: As we discussed, your analysis of modeled widths versus observed makes sense. However, that doesn't leave us with confidence about the hydraulic model calibration. Do you have any information regarding modeled versus observed time of travel, velocities, or depths?
4. Section 3.3, your power equations depend on the quality of calibration mentioned in the previous comment. Could the error in width you described also have implications for depth or velocity, and therefore for the accuracy of the power equations?
5. I would expect that the temperature model would be sensitive to stream width. How could this be tested? Discuss how the model results were translated to widths for the thermal exchange in the temperature model, and the implications of the hydraulic model's under-predicted stream width on the temperature model.
6. Section 4.3.1 refers to "July 2014". This is inconsistent with Table 6 and Figure 20. Please correct or explain.
7. Section 4.3.7: It is difficult to interpret the sensitivity analysis with only the input values shown. Generally, a sensitivity analysis varies inputs by a small set percentage. It would be helpful in Table 7 to show the initial calibrated values and the percentage that they were varied for the analysis. This would help to support the conclusions about the relative sensitivity of the different parameters.
8. Section 4.4: It surprises me that you calibrated to one data set and validated to 4 others. The model was calibrated during a period of relatively warm water (20-24 degC). Validation runs tended to perform equivalently for higher temperatures but somewhat less well for lower temperatures. It would be a more robust calibration process to calibrate to all the data sets, or at least to calibrate to 3 data sets in a wide range of temperatures and validate with two sets.
9. Since the criterion from the standards is 17.5, it would be informative to develop calibration and validation statistics for temperature above 17.5. Also, since the WQ standards is based on the 7DADMax, it would be helpful to see the calibration and validation statistics for that metric.
10. Why were only five 7-day data sets used? It would seem that longer time periods would result in a stronger calibration and allow the 7DADMax to be calculated from multiple moving averaging periods.
11. Section 4.6: Your statement "the model validation statistics are similar to the calibration statistic" overlooks the tendency to perform better for higher temperature than for lower. As

such, this seems like an over-simplistic statement that misses some key patterns. Some sensitivity analysis with one of the cooler calibration periods could help to understand the performance of the model in those conditions.

12. Section 5, "This is partially due to the dry conditions that support little tall vegetation elsewhere in the area, but also because the Chelan River is very wide for the depths it supports under low-flow conditions." My understanding is that this is also due to the history of the river being dry, so that riparian vegetation has only recently had enough water to survive the summer.

Paul

*Paul J. Pickett
WA Dept. of Ecology*

From: Hays, Steve [<mailto:steve.hays@chelanpud.org>]
Sent: Monday, June 15, 2015 3:38 PM
To: Pickett, Paul (ECY)
Cc: 'Ray Walton'; Osborn, Jeff
Subject: Chelan River Temperature Model Draft Calibration Report

Paul,

I realized today that you aren't on the regular Chelan River Fishery Forum (CRFF) email list and have not been notified of the schedule for the next meeting. The next meeting is scheduled for June 25, with a presentation on Herrera's Riparian Feasibility study in the morning and a presentation by Ray on the Chelan River Temperature Model Study progress in the afternoon. I am hoping for a discussion by CRFF members after Ray's presentation that will help define their expectations for the model gaming scenarios.

Also, on June 24, we will be doing some electroshock fishing in Reach 1 of the Chelan River to evaluate the presence and condition of cutthroat trout that were stocked into the river last fall and early this spring. You are welcome to join us if you can make it.

I have been reviewing West's first draft of the calibration report and would appreciate it if you can also review it. We will be sending it out to the CRFF later this week as preparation for the meeting next week. It looks pretty complete to me, but I don't have a modeler's eye so if you see anything that needs attention prior to the 6/25 meeting please let Ray know.

Thanks and sorry for the late notice. I will get you added to the CRFF mailing list.

Steve

From: Pickett, Paul (ECY) [<mailto:Ppic461@ECY.WA.GOV>]
Sent: Friday, May 29, 2015 10:53 AM
To: Hays, Steve; 'Ray Walton'
Cc: Osborn, Jeff; Steinmetz, Marcie; Coffin, Chris (ECY); Mackie, Thomas L. (ECY)
Subject: RE: Riparian Shade Analysis - Herrera Draft Report

Steve,

From the feedback I've gotten so far, the Chen method using Shade.xls is our standard approach. It should work well for the Chelan River.

One question: What vegetation assemblages are being evaluated for riparian planting? One comment I got was that willows were relatively short and would only create near-bank microclimate. This is a good thing for fish, but won't do much for the river as a whole. The model will be evaluating average temperature and not thermal refugia.

Which leads to two thoughts:

- Tall eastern Washington trees should be considered, such as Cottonwood or Ponderosa Pine.
- Some evaluations of thermal refugia might be useful, since it could provide more information about fish suitability than can be provided by only the model.

Paul

From: Pickett, Paul (ECY)

Sent: Thursday, May 21, 2015 11:35 AM

To: 'Hays, Steve'; 'Ray Walton'

Cc: Osborn, Jeff; Steinmetz, Marcie; Pelletier, Greg (ECY); Coffin, Chris (ECY); Mackie, Thomas L. (ECY)

Subject: RE: Riparian Shade Analysis - Herrera Draft Report

Steve,

Here's some thoughts about the shade analysis.

The work below is a good first step. However, it appears that they are only looking at the shade "footprint". An assumption that shade is 100% effective would be incorrect.

The Qual2kw model requires input of percent effective shade for each model segment for each time period of the day. This would require a calculation that takes into account the "footprint", the canopy density, and perhaps also the height and width of the riparian area. There are different approaches to developing that calculation:

- The more complex and physically complete method would be to use the method developed by Chen (see attachment). In my opinion, this approach would be more robust and defensible.
- A simple approach is to estimate canopy density and assume that would equal shade density. However, this ignores the factors of riparian vegetation height and width. But it would take less time to develop and might be good for a "first cut".

The Shade.xls model is a commonly used tool, and it allows options for both the Chen and simple methods. It has the advantage of directly linking the shade analysis to the model segmentation and time steps. However, it's possible to generate percent effective shade estimates directly from GIS using either method.

A couple other thoughts about this analysis:

- If local knowledge is needed to estimate the riparian zone width, height, and canopy density, the Chelan River Fish Forum might be a resource for finding that information.
- Since the expected future shade is uncertain, it might be useful to do a sensitivity analysis on the shade inputs to see the effect of assumptions. For example, you might model high, medium, and low estimates of canopy density, tree height, and buffer width. This would provide better

understanding of the effects of different implementation strategies or of their ultimate outcome.

A few more thoughts on this might come my way, so if I have more to add I'll send it along.

Also, of course, if you have questions about this, let me know.

Thanks,

Paul

*Paul J. Pickett
WA Dept. of Ecology*

From: Hays, Steve [<mailto:steve.hays@chelanpud.org>]
Sent: Tuesday, May 12, 2015 2:24 PM
To: 'Ray Walton'; Pickett, Paul (ECY)
Cc: Osborn, Jeff; Steinmetz, Marcie
Subject: Riparian Shade Analysis - Herrera Draft Report

Ray and Paul,

We are currently reviewing a draft Riparian Feasibility Report from Herrera and one of the deliverables in our contract was to provide an assessment of potential riparian shade that would be useful for the temperature model gaming. Below is the discussion regarding shade modeling that is in their draft report. My question to you is whether this method of analysis could be used by QUAL2Kw for gaming a future condition of mature (or partially mature) riparian shade. If this type of analysis is not useful, please let me know what other method could be used that would provide input needed for gaming with QUAL2Kw.

Thanks for your help on this,

Steve

Shadow modeling in GIS was used to assess the degree to which riparian revegetation could be used to increase shading of the Chelan River during the period when water temperatures are high. A date representative of the period of highest water temperatures was chosen by consulting a Chelan PUD annual temperature report for the upper Chelan River. The middle of the period of highest temperatures recorded in 2011 was approximately August 21.

Hourly solar elevation and azimuth were calculated for August 21, 2015, using the Washington Department of Ecology's SolRad solar radiation model. These were entered into the ArcGIS Hillshade tool, along with 2009 top surface lidar elevation data from Puget Sound Lidar Consortium, to calculate shadows at two hour increments between 6:00 am and 6:00 pm. Figure 4 depicts the resulting existing conditions shade map for 2:00 pm.

The shading effect of riparian revegetation at 20 years growth was estimated for both willow bands, and mixed riparian plantings. The height of expected growth was added to the lidar bare-earth elevation in the areas where each treatment is feasible, and those expected-growth top-surfaces were merged with the existing conditions top-surface to create proposed conditions top surfaces. These were entered into the ArcGIS Hillshade tool using the same solar azimuth and elevation data used for the existing conditions shade calculations. The difference between existing and proposed conditions shading was calculated, and the shaded water surface area at typical late August low-flow conditions

was estimated by intersecting the shaded area with the HEC-RAS modeled inundation surface at 80 cfs