APPENDIX J - QUAL2K TEMPERATURE ANALYSIS, DESCRIPTION, AND CONSTRAINING PARAMETERS

TABLE OF CONTENTS

J1.0 Approach ........................................................................................................................................... J-2
J2.0 Data Methods And Limitations ......................................................................................................... J-2
  J2.1 Shade ........................................................................................................................................... J-2
  J2.2 Stream Flow ................................................................................................................................. J-2
  J2.3 Hydraulic Characteristics ........................................................................................................... J-3
  J2.4 Climate ...................................................................................................................................... J-3
  J2.5 Water Temperature .................................................................................................................... J-3
  J2.6 Light and Heat Parameters ........................................................................................................ J-3
J3.0 Modeled Target Scenarios ................................................................................................................ J-3
J4.0 Results .............................................................................................................................................. J-4
  J4.1 Validation .................................................................................................................................. J-4
  J4.2 Scenario Outputs ......................................................................................................................... J-5
    J4.2.1 Cherry Creek ......................................................................................................................... J-5
    J4.2.2 Elk Creek ............................................................................................................................. J-6
    J4.2.3 Moore Creek ......................................................................................................................... J-8
J5.0 Parameters ....................................................................................................................................... J-10
  J5.1 Cherry Creek ............................................................................................................................ J-10
  J5.2 Elk Creek ................................................................................................................................ J-11
  J5.3 Moore Creek .............................................................................................................................. J-13
H6.0 Light and Heat Parameters, All Models .......................................................................................... J-15
H7.0 References ..................................................................................................................................... J-16
J1.0 APPROACH

The QUAL2K modeling approach was used to determine the effects of shade and streamflow conditions on temperatures within Cherry, Moore, and Elk Creeks. QUAL2K incorporates measured air temperature, riparian shading, stream flow, and channel characteristics to predict stream temperatures. Minimum, maximum temperatures were modeled along a longitudinal gradient of each creek for the hottest temperature day during summer 2013. After temperatures were predicted accurately using measured conditions, the effects of changes in temperature with streamflow and shade modifications were evaluated by increasing these to target conditions.

QUAL2K is a one-dimensional river and stream water quality model that assumes the channel is well-mixed vertically and laterally. The QUAL2K model uses steady state hydraulics that simulates non-uniform steady flow. Since hydraulic and flow data was not collected specifically for the modeling of temperature, data collected for each creek by Montana DEQ for other purposes was used in the QUAL2K model. Whenever possible, data was used from a similar timeframe as the day when the temperature was modeled. However, in several cases, the only available data was collected at a different timeframe than the day that was modeled. Differences in modeled and actual temperatures may be partly due to discrepancies in dates between available data.

Model performance was determined using the average absolute relative error, which was the average of the percent difference between temperatures measured in the field and those modeled at the same locations.

Detailed data and parameters used in these models are located at the end of this appendix.

J2.0 DATA METHODS AND LIMITATIONS

The following describe the methods used to determine bounding parameters and conditions for the QUAL2K modeling. The datasets are provided at the end of this appendix.

J2.1 SHADE

Aerial photography with ArcGIS was used to estimate existing effective shade along length of the creek using the Shade Tool (Washington State Department of Ecology 2007) (Appendix G) and validated using percent shade data collected in the field at the stream temperatures sites using a solar pathfinder.

J2.2 STREAM FLOW

Most of the streamflow data used in modeling was collected in the field by Montana DEQ. For Cherry Creek, temperature data was collected on 7/26/2013, while flow data used in modeling was collected on 8/5/2013. For Moore Creek, stream flow collected near the headwater site was not available from Montana DEQ near the date of the warmest temperature (7/3/2013). Therefore, stream flow data collected from Madison Stream Team on 7/3/2013 for their annual report was used in modeling (Madison Stream Team 2013). For Elk Creek, stream flow not available near the time of the highest temperature (7/3/2013) and stream flow collected on 6/12/13 was used in modeling.
Specific permitted irrigation withdrawals were not incorporated into the model. However, when possible, a water abstraction was used to represent the decrease in flow due to water use along the length of the River. For Cherry Creek, flow data from multiple sites on 8/5/2013 was used to estimate water withdrawals. Since Montana DEQ did not have adequate data available for Moore Creek near the date of highest temperature (July 3, 2013), the relative changes in water use for the date of 8/1/2003 was applied to the flow measured by Madison Stream Team. For Elk Creek, not enough data was available to determine relative changes in water consumption along the creek. Therefore, no abstractions were included in the model.

**J2.3 HYDRAULIC CHARACTERISTICS**

Wetted stream width and stream slope was estimated based on field measurements made by Montana DEQ during stream discharge estimates or habitat surveys. Manning’s n was derived from these measurements using the Manning’s Equation. When possible, flow and instream measurements taken near the time of the modelled temperature (i.e., the highest temperature day) were applied. Manning’s n values were greater than would be expected during high flow conditions but were in the range of those typically observed at lower and mid flows (Chapra et al. 2012). The specific dates of each measurement used in the QUAL2k model are detailed at the tables at the end of this appendix.

**J2.4 CLIMATE**

Climate data for the modeled days were obtained from the Western Climate Center (https://wrcc.dri.edu/), Ennis Montana Site, including hourly air temperature and dew point temperature. Cloud cover was set at 5% and wind speed was set at 4 mph, which are typical values present on warm temperature days in Montana.

**J2.5 WATER TEMPERATURE**

Hourly water temperature data was collected using HOBO temperature loggers deployed at temperature monitoring sites in summer 2013 as described in Appendix G. Hourly data from the uppermost temperature monitoring site was used as a bounding condition. Minimum, mean, and maximum data from each site on this date was used to evaluate performance of the baseline model.

**J2.6 LIGHT AND HEAT PARAMETERS**

QUAL2K Default light and heat parameters were used in the models. The exceptions were the Ryan-Stolzenbach solar parameter, which was increased from 0.80 to 0.85, and the thermal thickness parameter, which was increased from 10 cm to 15 cm. Increases in these values improved performance, and were similar to changes employed during other temperature modeling efforts previously done for creeks in western Montana by Montana DEQ.

**J3.0 MODELED TARGET SCENARIOS**

The potential management scenarios modeled as part of this exercise reflected targets recommended by DEQ, including a 15% increased flow scenario, an increased shade scenario to represent likely shade as a result of riparian restoration, and a scenario that included a combination of actions (15 % increased
flow and increased shade. In addition, for Elk Creek, a reduced width scenario was modeled given that a habitat sampling site (near temperature site 1C) was not meeting target width/depth conditions.

The resulting temperatures were predicted along the longitudinal gradient of each creek. Graphs were used to compare these temperatures with the 7-Day Lethal Temperature for 50% of the population of Cutthroat Trout, and the 24-hour Lethal Temperature for 10% of the Population of Cutthroat Trout. This comparison was made given the importance of this area for Westslope Cutthroat Trout, which is the most sensitive fish species present in the creeks of interest.

### J4.0 RESULTS

#### J4.1 VALIDATION

Modeled temperatures closely approximated actual temperatures for most temperature loggers (Tables J-1, J-2, and J-3) The absolute percent error was calculated for the maximum temperature value at each logger location using the formula:

\[
\text{Absolute Percent Error} = \left| \frac{\text{Modeled} - \text{Actual}}{\text{Actual}} \right| \times 100
\]

This was averaged across temperature loggers. The average absolute percent error between modeled and actual maximum temperatures for Cherry, Elk, and Moore Creeks were 1.9%, 2.4%, and 2.7%, respectively.

**Table J-1 Difference Between Actual and Modeled Temperatures for Cherry Creek, 7/26/2013**

<table>
<thead>
<tr>
<th>Logger ID</th>
<th>Distance (miles)</th>
<th>Temperature Measure</th>
<th>Actual ºC</th>
<th>Modeled ºC</th>
</tr>
</thead>
<tbody>
<tr>
<td>2A</td>
<td>13.5</td>
<td>minimum</td>
<td>11.28</td>
<td>12.89</td>
</tr>
<tr>
<td>2A</td>
<td>13.5</td>
<td>average</td>
<td>16.11</td>
<td>15.36</td>
</tr>
<tr>
<td>2A</td>
<td>13.5</td>
<td>maximum</td>
<td>18.01</td>
<td>17.76</td>
</tr>
<tr>
<td>2B</td>
<td>11.6</td>
<td>minimum</td>
<td>12.41</td>
<td>14.08</td>
</tr>
<tr>
<td>2B</td>
<td>11.6</td>
<td>average</td>
<td>15.78</td>
<td>16.41</td>
</tr>
<tr>
<td>2B</td>
<td>11.6</td>
<td>maximum</td>
<td>19.18</td>
<td>19.32</td>
</tr>
<tr>
<td>2C</td>
<td>1</td>
<td>minimum</td>
<td>15.17</td>
<td>16.88</td>
</tr>
<tr>
<td>2C</td>
<td>1</td>
<td>average</td>
<td>20.34</td>
<td>20.06</td>
</tr>
<tr>
<td>2C</td>
<td>1</td>
<td>maximum</td>
<td>25.47</td>
<td>24.76</td>
</tr>
</tbody>
</table>

**Table J-2 Difference Between Actual and Modeled Temperatures for Elk Creek, 7/3/2013**

<table>
<thead>
<tr>
<th>Logger ID</th>
<th>Distance (miles)</th>
<th>Temperature Measure</th>
<th>Actual ºC</th>
<th>Modeled ºC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1B</td>
<td>8.4</td>
<td>minimum</td>
<td>15.8</td>
<td>16.7</td>
</tr>
<tr>
<td>1B</td>
<td>8.4</td>
<td>average</td>
<td>20.3</td>
<td>20.6</td>
</tr>
<tr>
<td>1B</td>
<td>8.4</td>
<td>maximum</td>
<td>25.4</td>
<td>26.0</td>
</tr>
<tr>
<td>1C</td>
<td>7.2</td>
<td>minimum</td>
<td>16.1</td>
<td>17.0</td>
</tr>
<tr>
<td>1C</td>
<td>7.2</td>
<td>average</td>
<td>20.1</td>
<td>21.1</td>
</tr>
<tr>
<td>1C</td>
<td>7.2</td>
<td>maximum</td>
<td>25.3</td>
<td>25.9</td>
</tr>
<tr>
<td>1D</td>
<td>0.6</td>
<td>minimum</td>
<td>18.8</td>
<td>17.4</td>
</tr>
<tr>
<td>1D</td>
<td>0.6</td>
<td>average</td>
<td>25.0</td>
<td>23.0</td>
</tr>
<tr>
<td>1D</td>
<td>0.6</td>
<td>maximum</td>
<td>30.8</td>
<td>29.9</td>
</tr>
</tbody>
</table>
Table J-3. Difference Between Actual and Modeled Temperatures for Moore Creek, 7/3/2013

<table>
<thead>
<tr>
<th>Logger ID</th>
<th>Distance (miles)</th>
<th>Temperature Measure</th>
<th>Actual °C</th>
<th>Modeled °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>4A</td>
<td>10.5</td>
<td>minimum</td>
<td>16.7</td>
<td>16.63</td>
</tr>
<tr>
<td>4A</td>
<td>10.5</td>
<td>average</td>
<td>18.5</td>
<td>18.25</td>
</tr>
<tr>
<td>4A</td>
<td>10.5</td>
<td>maximum</td>
<td>20.3</td>
<td>20.11</td>
</tr>
<tr>
<td>4D</td>
<td>7.8</td>
<td>minimum</td>
<td>15.7</td>
<td>16.23</td>
</tr>
<tr>
<td>4D</td>
<td>7.8</td>
<td>average</td>
<td>18.9</td>
<td>18.43</td>
</tr>
<tr>
<td>4D</td>
<td>7.8</td>
<td>maximum</td>
<td>22.29</td>
<td>20.87</td>
</tr>
<tr>
<td>4F</td>
<td>1.8</td>
<td>minimum</td>
<td>14.78</td>
<td>15.75</td>
</tr>
<tr>
<td>4F</td>
<td>1.8</td>
<td>average</td>
<td>19.7</td>
<td>19.95</td>
</tr>
<tr>
<td>4F</td>
<td>1.8</td>
<td>maximum</td>
<td>25.5</td>
<td>25.24</td>
</tr>
</tbody>
</table>

J4.2 SCENARIO OUTPUTS

J4.2.1 Cherry Creek

Results indicated that the increased flow scenario decreased modeled maximum temperatures by an average of 1.1 °C at the most downstream site, while the increased shade scenario decreased modeled maximum temperatures by 1.5 °C. The combined scenario decreased modeled maximum temperatures by 1.9 °C (Figure J-1 to J-4).

None of the scenarios resulted in a substantial increase in potential stream miles inhabited by Westslope cutthroat trout (The combined scenario resulted in only a ~ 0.5 mile potential increase in usable habitat) although an increase in shade had the most impact. However, given that the modeling represented the warmest day of the year, increased shade could increase the habitable portion of Cherry Creek by a greater amount other parts of the summer with less warm temperatures.

![Figure J-1. Model Scenario for Cherry Creek-Current Conditions](image)
Figure J-2. Model Scenario for Cherry Creek-Increased Flow Conditions

Figure J-3. Model Scenario for Cherry Creek-Increased Shade Conditions

Figure J-4. Model Scenario for Cherry Creek-Increased Shade & Flow Conditions

J4.2.2 Elk Creek
Results indicate that the increased flow scenario decreased maximum temperatures at the most
downstream site by 1.1 °C, the increased shade scenario decreased temperatures by 4.7 °C, and the
combination scenario of increased shade and flow and decreased wetted width decreased temperatures
by 5.0 °C. (Figure J-5 to Figure J-8)

The increased shade scenario showed a decrease in the maximum temperature below the 7-Day Lethal
Temperature for 50% of the population at the most upstream section of the modeled portion (above
mile 13). The combination scenario (flow + shade+ width) did not greatly reduce temperatures below
values estimated for increased shade alone.
Figure J-7. Model Scenario for Elk Creek-Increased Shade Conditions

![Shade+Flow+Reduced Width Scenario-Elk Creek graph]

Figure J-8. Model Scenario for Elk Creek-Increased Shade and Flow Conditions

**J4.2.3 Moore Creek**

Results indicate that the increased flow scenario decreased modeled maximum temperatures at the most downstream site by 0.48 °C, the increased shade scenario decreased modeled maximum temperature by 2.1 °C, and the combination scenario decreased modeled maximum temperature by 2.4 °C.

While an increase in shade had a bigger impact on stream temperatures, the combined scenario could decrease the temperature near the mouth to be at or just slightly above the 24-hour Lethal temperature for 10% of the population for Westslope cutthroat trout, and would potentially increase the overall length of stream available to these species during the warmest times by up to 3 miles (Figure J-9 to Figure J-12)

**Figure J-9. Model Scenario for Moore Creek-Current Conditions**

![Modeled Current Conditions Scenario-Moore Creek graph]
Figure J-10. Model Scenario for Moore Creek-Increased Flow Conditions

<table>
<thead>
<tr>
<th>Distance Downstream (miles)</th>
<th>Temperature (°C)</th>
<th>Flow Scenario-Moore's Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>10.00</td>
<td>20.00</td>
<td></td>
</tr>
<tr>
<td>20.00</td>
<td>25.00</td>
<td></td>
</tr>
<tr>
<td>30.00</td>
<td>30.00</td>
<td></td>
</tr>
</tbody>
</table>

Figure J-11. Model Scenario for Moore Creek-Increased Shade Conditions

<table>
<thead>
<tr>
<th>Distance Downstream (miles)</th>
<th>Temperature (°C)</th>
<th>Shade Scenario-Moore's Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>10.00</td>
<td>15.00</td>
<td></td>
</tr>
<tr>
<td>20.00</td>
<td>20.00</td>
<td></td>
</tr>
<tr>
<td>30.00</td>
<td>25.00</td>
<td></td>
</tr>
</tbody>
</table>

Figure J-12. Model Scenario for Moore Creek-Increased Shade Conditions

<table>
<thead>
<tr>
<th>Distance Downstream (miles)</th>
<th>Temperature (°C)</th>
<th>Shade and Flow Scenario-Moore's Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>10.00</td>
<td>15.00</td>
<td></td>
</tr>
<tr>
<td>20.00</td>
<td>20.00</td>
<td></td>
</tr>
<tr>
<td>30.00</td>
<td>25.00</td>
<td></td>
</tr>
</tbody>
</table>
J5.0 PARAMETERS

J5.1 CHERRY CREEK

The following tables describe parameters used in the Cherry Creek model, including headwater bounding conditions (Table J-4) reach characteristics (Table J-5), and hourly climate and shade Conditions (Table J-6).

Table J-4 Headwater characteristics for Cherry Creek

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Original Scenario</th>
<th>Flow Scenario</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow (m³/s)</td>
<td>0.5</td>
<td>0.58</td>
<td>DEQ: 8/5/2013, site 2C</td>
</tr>
<tr>
<td>Flow Abstraction (m³/s) (3 km-0 km)</td>
<td>0.07</td>
<td>0.07</td>
<td>DEQ 8/5/2013 sites 2A,2B,2C</td>
</tr>
<tr>
<td>Elevation (m)</td>
<td>1383</td>
<td>1383</td>
<td>ArgGIS Site 2A</td>
</tr>
<tr>
<td>Slope</td>
<td>0.015</td>
<td>0.015</td>
<td>estimated from photos 8/5/2013, site 2C</td>
</tr>
<tr>
<td>Manning’s n</td>
<td>0.18</td>
<td>0.18</td>
<td>Derived from Mannings Equation</td>
</tr>
<tr>
<td>Bottom Width (m)</td>
<td>9</td>
<td>9</td>
<td>DEQ: 8/5/2013, site 2C</td>
</tr>
</tbody>
</table>

Table J-5. Reach Characteristics for Cherry Creek

<table>
<thead>
<tr>
<th>Upstream Distance (km)</th>
<th>Downstream Distance (km)</th>
<th>Longitude</th>
<th>Latitude</th>
<th>Slope</th>
<th>Bottom Width (m)</th>
<th>Manning’s n</th>
<th>Data Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>14</td>
<td>45.5870</td>
<td>111.4702</td>
<td>0.015</td>
<td>8.9</td>
<td>0.18</td>
<td>Bot Width=DEQ: 8/5/2013, Site2C; slope=DEQ: stream photos, Site 2C</td>
</tr>
<tr>
<td>14</td>
<td>9.5</td>
<td>45.5968</td>
<td>111.4953</td>
<td>0.015</td>
<td>8.9</td>
<td>0.18</td>
<td>Bot Width=DEQ: 8/5/2013, Site2C; slope=DEQ: stream photos, Site 2C</td>
</tr>
<tr>
<td>9.5</td>
<td>8.1</td>
<td>45.5950</td>
<td>111.4893</td>
<td>0.005</td>
<td>5.6</td>
<td>0.18</td>
<td>Bot Width=DEQ: 8/5/2013, Site2B; slope=DEQ: 8/5/2014, SITE CHRR18-02</td>
</tr>
<tr>
<td>8.1</td>
<td>6.6</td>
<td>45.5916</td>
<td>111.4863</td>
<td>0.005</td>
<td>5.6</td>
<td>0.18</td>
<td>Bot Width=DEQ: 8/5/2013, Site2B; slope=DEQ: 8/5/2014, SITE CHRR18-02</td>
</tr>
<tr>
<td>6.6</td>
<td>0</td>
<td>45.6184</td>
<td>111.5497</td>
<td>0.006</td>
<td>9</td>
<td>0.09</td>
<td>Bot Width=DEQ: 8/5/2013, Site2A; slope=DEQ: 8/5/2014, SITE CHRR20-01</td>
</tr>
</tbody>
</table>

Table J-6 Cherry Creek Hourly Climate and Shade Data 7/26/2013

<table>
<thead>
<tr>
<th>Parameter</th>
<th>12:00 AM</th>
<th>1:00 AM</th>
<th>2:00 AM</th>
<th>3:00 AM</th>
<th>4:00 AM</th>
<th>5:00 AM</th>
<th>6:00 AM</th>
<th>7:00 AM</th>
<th>8:00 AM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud Cover (%)</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Wind Speed (m/s)</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Dew Point (°C)</td>
<td>17.8</td>
<td>22.2</td>
<td>21.1</td>
<td>15.6</td>
<td>25.0</td>
<td>26.1</td>
<td>13.3</td>
<td>10.0</td>
<td>5.6</td>
</tr>
<tr>
<td>Headwater Temperature (°C), 7/26/2013</td>
<td>14.6</td>
<td>13.8</td>
<td>13.1</td>
<td>12.4</td>
<td>11.7</td>
<td>11.0</td>
<td>10.8</td>
<td>10.5</td>
<td>10.4</td>
</tr>
<tr>
<td>Air Temperature (°C)</td>
<td>13.3</td>
<td>12.2</td>
<td>11.7</td>
<td>9.4</td>
<td>12.2</td>
<td>15.6</td>
<td>18.9</td>
<td>22.8</td>
<td>25.6</td>
</tr>
<tr>
<td>Shade (15.0-14.0):Original</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>65%</td>
<td>65%</td>
<td>65%</td>
</tr>
<tr>
<td>Shade (14.0-9.5):Original</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>16%</td>
<td>16%</td>
<td>16%</td>
</tr>
<tr>
<td>Shade (9.5-5.0):Original</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>22%</td>
<td>22%</td>
<td>22%</td>
</tr>
<tr>
<td>Shade (15.0-14.0):Shade Model</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>65%</td>
<td>65%</td>
<td>65%</td>
</tr>
<tr>
<td>Shade (14.0-9.5):Shade Model</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>22%</td>
<td>22%</td>
<td>22%</td>
</tr>
<tr>
<td>Shade (9.5-5.0):Shade Model</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>22%</td>
<td>22%</td>
<td>22%</td>
</tr>
</tbody>
</table>
Table J-6 Cherry Creek Hourly Climate and Shade Data 7/26/2013

<table>
<thead>
<tr>
<th>Parameter</th>
<th>9:00 AM</th>
<th>10:00 AM</th>
<th>11:00 AM</th>
<th>12:00 PM</th>
<th>1:00 PM</th>
<th>2:00 PM</th>
<th>3:00 PM</th>
<th>4:00 PM</th>
<th>5:00 PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud Cover (%)</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Wind Speed (m/s)</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Dew Point (°C)</td>
<td>2.8</td>
<td>-0.6</td>
<td>-6.1</td>
<td>-11.1</td>
<td>-12.2</td>
<td>-12.2</td>
<td>-12.8</td>
<td>-10.6</td>
<td></td>
</tr>
<tr>
<td>Headwater Temperature (°C)</td>
<td>10.4</td>
<td>10.6</td>
<td>11.1</td>
<td>11.9</td>
<td>12.4</td>
<td>14.1</td>
<td>15.7</td>
<td>16.9</td>
<td>17.7</td>
</tr>
<tr>
<td>Air Temperature (°C)</td>
<td>28.9</td>
<td>31.1</td>
<td>33.3</td>
<td>32.8</td>
<td>33.9</td>
<td>33.9</td>
<td>30.6</td>
<td>28.3</td>
<td></td>
</tr>
<tr>
<td>Shade (15.0-14.0):Original</td>
<td>65%</td>
<td>65%</td>
<td>65%</td>
<td>65%</td>
<td>65%</td>
<td>65%</td>
<td>65%</td>
<td>65%</td>
<td></td>
</tr>
<tr>
<td>Shade (14.0-9.5):Original</td>
<td>16%</td>
<td>16%</td>
<td>16%</td>
<td>16%</td>
<td>16%</td>
<td>16%</td>
<td>16%</td>
<td>16%</td>
<td></td>
</tr>
<tr>
<td>Shade (9.5-0.0):Original</td>
<td>16%</td>
<td>16%</td>
<td>16%</td>
<td>16%</td>
<td>16%</td>
<td>16%</td>
<td>16%</td>
<td>16%</td>
<td></td>
</tr>
<tr>
<td>Shade (15.0-14.0):Shade Model</td>
<td>65%</td>
<td>65%</td>
<td>65%</td>
<td>65%</td>
<td>65%</td>
<td>65%</td>
<td>65%</td>
<td>65%</td>
<td></td>
</tr>
<tr>
<td>Shade (14.0-9.5):Shade Model</td>
<td>22%</td>
<td>22%</td>
<td>22%</td>
<td>22%</td>
<td>22%</td>
<td>22%</td>
<td>22%</td>
<td>22%</td>
<td></td>
</tr>
<tr>
<td>Shade (9.5-0.0):Shade Model</td>
<td>22%</td>
<td>22%</td>
<td>22%</td>
<td>22%</td>
<td>22%</td>
<td>22%</td>
<td>22%</td>
<td>22%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>6:00 PM</th>
<th>7:00 PM</th>
<th>8:00 PM</th>
<th>9:00 PM</th>
<th>10:00 PM</th>
<th>11:00 PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud Cover (%)</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Wind Speed (m/s)</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Dew Point (°C)</td>
<td>-9.4</td>
<td>-8.3</td>
<td>-7.8</td>
<td>-7.8</td>
<td>-4.4</td>
<td>-1.1</td>
</tr>
<tr>
<td>Headwater Temperature (°C)</td>
<td>18.0</td>
<td>18.0</td>
<td>17.8</td>
<td>17.4</td>
<td>16.8</td>
<td>16.2</td>
</tr>
<tr>
<td>Air Temperature (°C)</td>
<td>27.8</td>
<td>26.7</td>
<td>26.7</td>
<td>23.3</td>
<td>21.1</td>
<td>20.0</td>
</tr>
<tr>
<td>Shade (15.0-14.0):Original</td>
<td>65%</td>
<td>65%</td>
<td>65%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Shade (14.0-9.5):Original</td>
<td>16%</td>
<td>16%</td>
<td>16%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Shade (9.5-0.0):Original</td>
<td>16%</td>
<td>16%</td>
<td>16%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Shade (15.0-14.0):Shade Model</td>
<td>65%</td>
<td>65%</td>
<td>65%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Shade (14.0-9.5):Shade Model</td>
<td>22%</td>
<td>22%</td>
<td>22%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Shade (9.5-0.0):Shade Model</td>
<td>22%</td>
<td>22%</td>
<td>22%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

J5.2 ELK CREEK

The following tables describe parameters used in the Elk Creek model, including headwater bounding conditions (Table J-7) reach characteristics (Table J-8), and hourly climate and shade Conditions (Table J-9)

Table J-7. Headwater characteristics for Elk Creek

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Original Scenario</th>
<th>Flow Scenario</th>
<th>Flow and Width Scenario</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow (m³/s)</td>
<td>0.076</td>
<td>0.087</td>
<td>0.087</td>
<td>DEQ: 6/12/2013, Site1B</td>
</tr>
<tr>
<td>Elevation (m)</td>
<td>1577</td>
<td>1577</td>
<td>1577</td>
<td>ArcGIS, site 1B</td>
</tr>
<tr>
<td>Slope</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>DEQ: 08/19/2013, site M06ELK07</td>
</tr>
<tr>
<td>Manning’s n</td>
<td>0.12</td>
<td>0.12</td>
<td>0.12</td>
<td>Derived from Mannings Equation</td>
</tr>
<tr>
<td>Bottom Width (m)</td>
<td>2.22</td>
<td>2.22</td>
<td>2.22</td>
<td>DEQ 6/12/2013, site 1B</td>
</tr>
</tbody>
</table>
Table J-8. Reach characteristics for Elk Creek

<table>
<thead>
<tr>
<th>Upstream Distance (km)</th>
<th>Downstream Distance (km)</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Slope</th>
<th>Bottom Width (m)</th>
<th>Manning’s n</th>
<th>Data Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>23</td>
<td>45.6056</td>
<td>111.3968</td>
<td>0.020</td>
<td>2.2</td>
<td>0.14</td>
<td>Bot Width=DEQ: 6/12/2013, Site1B; slope=DEQ: 08/23/2013, Site ELK 11-01</td>
</tr>
<tr>
<td>23</td>
<td>18</td>
<td>45.6279</td>
<td>111.4137</td>
<td>0.017</td>
<td>1.9/1.6</td>
<td>0.13</td>
<td>Bot Width=DEQ: 8/15/2013, site1C; slope=DEQ: 08/19/2013, site ELKC 06-02</td>
</tr>
<tr>
<td>18</td>
<td>0</td>
<td>45.6539</td>
<td>111.5208</td>
<td>0.017</td>
<td>1.5</td>
<td>0.13</td>
<td>Wet Width=DEQ: 8/15/2013, site1D; slope=DEQ: 2013, site MO6ELKC07</td>
</tr>
</tbody>
</table>

1 The second value after the / was used in the reduced width scenario.

Table J-9 Elk Creek Hourly Climate and Shade Data 7/3/2013

<table>
<thead>
<tr>
<th>12:00 AM</th>
<th>1:00 AM</th>
<th>2:00 AM</th>
<th>3:00 AM</th>
<th>4:00 AM</th>
<th>5:00 AM</th>
<th>6:00 AM</th>
<th>7:00 AM</th>
<th>8:00 AM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud Cover (%)</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Wind Speed (m/s)</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Dew Point (˚C)</td>
<td>10.6</td>
<td>10.0</td>
<td>9.4</td>
<td>8.3</td>
<td>10.0</td>
<td>12.2</td>
<td>10.6</td>
<td>11.7</td>
</tr>
<tr>
<td>Headwater Temperature (˚C)</td>
<td>19.4</td>
<td>18.8</td>
<td>18.4</td>
<td>17.9</td>
<td>17.5</td>
<td>17.0</td>
<td>16.6</td>
<td>16.2</td>
</tr>
<tr>
<td>Air Temperature (˚C)</td>
<td>20.0</td>
<td>20.0</td>
<td>18.3</td>
<td>18.3</td>
<td>17.8</td>
<td>17.8</td>
<td>21.7</td>
<td>24.4</td>
</tr>
<tr>
<td>Shade (30-23):Original</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>28%</td>
<td>28%</td>
</tr>
<tr>
<td>Shade(23-18):Original</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>43%</td>
<td>43%</td>
</tr>
<tr>
<td>Shade (18-0): Original</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>63%</td>
<td>63%</td>
</tr>
<tr>
<td>Shade (30-23):Shade Model</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>Shade(23-18):Shade Model</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>42%</td>
<td>42%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>9:00 AM</th>
<th>10:00 AM</th>
<th>11:00 AM</th>
<th>12:00 PM</th>
<th>1:00 PM</th>
<th>2:00 PM</th>
<th>3:00 PM</th>
<th>4:00 PM</th>
<th>5:00 PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud Cover (%)</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Wind Speed (m/s)</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Dew Point (˚C)</td>
<td>13.3</td>
<td>9.4</td>
<td>7.2</td>
<td>6.7</td>
<td>7.8</td>
<td>6.1</td>
<td>7.8</td>
<td>8.9</td>
</tr>
<tr>
<td>Headwater Temperature (˚C)</td>
<td>16.4</td>
<td>16.9</td>
<td>17.8</td>
<td>19.6</td>
<td>21.7</td>
<td>23.7</td>
<td>24.9</td>
<td>25.4</td>
</tr>
<tr>
<td>Air Temperature (˚C)</td>
<td>28.9</td>
<td>31.7</td>
<td>32.2</td>
<td>32.8</td>
<td>33.9</td>
<td>32.8</td>
<td>32.2</td>
<td>31.7</td>
</tr>
<tr>
<td>Shade (30-23):Original</td>
<td>28%</td>
<td>28%</td>
<td>28%</td>
<td>28%</td>
<td>28%</td>
<td>28%</td>
<td>28%</td>
<td>28%</td>
</tr>
<tr>
<td>Shade(23-18):Original</td>
<td>43%</td>
<td>43%</td>
<td>43%</td>
<td>43%</td>
<td>43%</td>
<td>43%</td>
<td>43%</td>
<td>43%</td>
</tr>
<tr>
<td>Shade (18-0): Original</td>
<td>17%</td>
<td>17%</td>
<td>17%</td>
<td>17%</td>
<td>17%</td>
<td>17%</td>
<td>17%</td>
<td>17%</td>
</tr>
<tr>
<td>Shade (30-23):Shade Model</td>
<td>63%</td>
<td>63%</td>
<td>63%</td>
<td>63%</td>
<td>63%</td>
<td>63%</td>
<td>63%</td>
<td>63%</td>
</tr>
<tr>
<td>Shade(23-18):Shade Model</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>Shade (18-0): Shade Model</td>
<td>42%</td>
<td>42%</td>
<td>42%</td>
<td>42%</td>
<td>42%</td>
<td>42%</td>
<td>42%</td>
<td>42%</td>
</tr>
</tbody>
</table>
Table J-9 Elk Creek Hourly Climate and Shade Data 7/3/2013

<table>
<thead>
<tr>
<th>Time</th>
<th>Cloud Cover (%)</th>
<th>Wind Speed (m/s)</th>
<th>Dew Point (°C)</th>
<th>Headwater Temperature (°C)</th>
<th>Air Temperature (°C)</th>
<th>Shade (30-23):Original</th>
<th>Shade (23-18):Original</th>
<th>Shade (18-0): Original</th>
<th>Shade (30-23):Shade Model</th>
<th>Shade (23-18):Shade Model</th>
<th>Shade (18-0): Shade Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>6:00 PM</td>
<td>5</td>
<td>4.0</td>
<td>13.3</td>
<td>23.8</td>
<td>28.3</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>7:00 PM</td>
<td>5</td>
<td>4.0</td>
<td>11.1</td>
<td>23.2</td>
<td>25.6</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>8:00 PM</td>
<td>5</td>
<td>4.0</td>
<td>11.1</td>
<td>22.5</td>
<td>22.2</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>9:00 PM</td>
<td>5</td>
<td>4.0</td>
<td>11.7</td>
<td>21.6</td>
<td>22.2</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>10:00 PM</td>
<td>5</td>
<td>4.0</td>
<td>10.6</td>
<td>20.6</td>
<td>19.4</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>11:00 PM</td>
<td>5</td>
<td>4.0</td>
<td>11.1</td>
<td>19.8</td>
<td>18.3</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

J5.3 MOORE CREEK

The following tables describe parameters used in the Moore Creek model, including headwater bounding conditions (Table J-10) reach characteristics (Table J-11), and hourly climate and shade Conditions (Table J-12).

Table H-10. Headwater characteristics for Moore Creek

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Original Scenario</th>
<th>Flow Scenario</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow (m³/s)</td>
<td>0.16</td>
<td>0.18</td>
<td>Stream Team, 2013 Report</td>
</tr>
<tr>
<td>Elevation (m)</td>
<td>1500</td>
<td>1500</td>
<td>ArcGIS site 4A</td>
</tr>
<tr>
<td>Slope</td>
<td>0.01</td>
<td>0.01</td>
<td>DEQ: 09/04/2014, site MOOR 09-01</td>
</tr>
<tr>
<td>Manning’s n</td>
<td>0.03</td>
<td>0.03</td>
<td>Derived from Mannings Equation</td>
</tr>
<tr>
<td>Bottom Width (m)</td>
<td>1.6</td>
<td>1.6</td>
<td>DEQ 08/1/2003, site 4F</td>
</tr>
</tbody>
</table>

Table H-11. Reach Characteristics for Moore Creek

<table>
<thead>
<tr>
<th>Upstream Distance (km)</th>
<th>Downstream Distance (km)</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Slope</th>
<th>Bottom Width (m)</th>
<th>Manning’s n</th>
<th>Data Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.2</td>
<td>10.2</td>
<td>45.3369</td>
<td>111.7411</td>
<td>0.010</td>
<td>1.8</td>
<td>0.06</td>
<td>Bot Width=DEQ; 08/01/2013, site 4F; slope:=DEQ: 09/04/2014, site MOOR 09-01</td>
</tr>
<tr>
<td>10.2</td>
<td>7.8</td>
<td>45.3369</td>
<td>111.7411</td>
<td>0.010</td>
<td>1.8</td>
<td>0.06</td>
<td>Bot Width=DEQ:08/01/2013, Site 4F; slope:=DEQ: 09/04/2014, site MOOR 09-01</td>
</tr>
<tr>
<td>7.8</td>
<td>5.6</td>
<td>45.3519</td>
<td>111.7295</td>
<td>0.010</td>
<td>1.6</td>
<td>0.05</td>
<td>Bot Width=DEQ; 08/01/2013, site 4D; slope:=DEQ: 09/04/2014, site MOOR 09-01</td>
</tr>
<tr>
<td>5.6</td>
<td>2.1</td>
<td>45.4084</td>
<td>111.7092</td>
<td>0.005</td>
<td>2.1</td>
<td>0.05</td>
<td>Bot Width=DEQ; 08/01/2013, site 4A; slope:=DEQ: 09/02/2014, site MOOR 09-02</td>
</tr>
</tbody>
</table>
### Table H-11. Reach Characteristics for Moore Creek

<table>
<thead>
<tr>
<th>Upstream Distance (km)</th>
<th>Downstream Distance (km)</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Slope</th>
<th>Bottom Width (m)</th>
<th>Manning’s n</th>
<th>Data Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>9</td>
<td>45.4084</td>
<td>111.7092</td>
<td>0.005</td>
<td>2.1</td>
<td>0.05</td>
<td></td>
</tr>
</tbody>
</table>

### Table J-12. Moore Creek Hourly Climate and Shade Data 7/3/2013

<table>
<thead>
<tr>
<th>Cloud Cover (%)</th>
<th>Wind Speed (m/s)</th>
<th>Dew Point (˚C), 7/3/2013</th>
<th>Headwater Temperature (˚C), 7/3/2013</th>
<th>Air Temperature (˚C)</th>
<th>Shade (12.2-10.2): Original</th>
<th>Shade (10.2-7.8): Original</th>
<th>Shade (7.8-5.6): Original</th>
<th>Shade (5.6-2.1): Original</th>
<th>Shade (2.1-0.0): Original</th>
<th>Shade (12.2-10.2): Shade Model</th>
<th>Shade (10.2-7.8): Shade Model</th>
<th>Shade (7.8-5.6): Shade Model</th>
<th>Shade (5.6-2.1): Shade Model</th>
<th>Shade (2.1-0.0): Shade Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>4.0</td>
<td>10.6</td>
<td>19.0</td>
<td>20.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>5</td>
<td>4.0</td>
<td>10.6</td>
<td>19.0</td>
<td>20.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>5</td>
<td>4.0</td>
<td>10.6</td>
<td>19.0</td>
<td>20.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>5</td>
<td>4.0</td>
<td>10.6</td>
<td>19.0</td>
<td>20.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>5</td>
<td>4.0</td>
<td>10.6</td>
<td>19.0</td>
<td>20.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

### Madison Sediment and Temperature TMDLs – Appendix J

Reach Characteristics for Moore Creek

<table>
<thead>
<tr>
<th>Upstream Distance (km)</th>
<th>Downstream Distance (km)</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Slope</th>
<th>Bottom Width (m)</th>
<th>Manning’s n</th>
<th>Bot Width=DEQ: 08/01/2013, site 4A; slope=DEQ: 09/02/2014, site MOOR 09-02</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>9</td>
<td>45.4084</td>
<td>111.7092</td>
<td>0.005</td>
<td>2.1</td>
<td>0.05</td>
<td></td>
</tr>
</tbody>
</table>

### Data Sources

- Bot Width=DEQ: 08/01/2013, site 4A; slope=DEQ: 09/02/2014, site MOOR 09-02
Table J-12. Moore Creek Hourly Climate and Shade Data 7/3/2013

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>12:00 AM</th>
<th>1:00 AM</th>
<th>2:00 AM</th>
<th>3:00 AM</th>
<th>4:00 AM</th>
<th>5:00 AM</th>
<th>6:00 PM</th>
<th>7:00 PM</th>
<th>8:00 PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shade (7.8-5.6): Shade Model</td>
<td>70%</td>
<td>70%</td>
<td>70%</td>
<td>70%</td>
<td>70%</td>
<td>70%</td>
<td>70%</td>
<td>70%</td>
<td>70%</td>
</tr>
<tr>
<td>Shade (5.6-2.1): Shade Model</td>
<td>47%</td>
<td>47%</td>
<td>47%</td>
<td>47%</td>
<td>47%</td>
<td>47%</td>
<td>47%</td>
<td>47%</td>
<td>47%</td>
</tr>
<tr>
<td>Shade (2.1-0.0): Shade Model</td>
<td>47%</td>
<td>47%</td>
<td>47%</td>
<td>47%</td>
<td>47%</td>
<td>47%</td>
<td>47%</td>
<td>47%</td>
<td>47%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>6:00 PM</th>
<th>7:00 PM</th>
<th>8:00 PM</th>
<th>9:00 PM</th>
<th>10:00 PM</th>
<th>11:00 PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud Cover (%)</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Wind Speed (m/s)</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Dew Point (°C)</td>
<td>11.7</td>
<td>13.3</td>
<td>11.1</td>
<td>11.1</td>
<td>11.7</td>
<td>10.6</td>
</tr>
<tr>
<td>Headwater Temperature (°C), 7/3/2013</td>
<td>20.0</td>
<td>20.0</td>
<td>19.8</td>
<td>15.3</td>
<td>19.7</td>
<td>19.4</td>
</tr>
<tr>
<td>Air Temperature (°C)</td>
<td>30.0</td>
<td>28.3</td>
<td>25.6</td>
<td>22.2</td>
<td>22.2</td>
<td>19.4</td>
</tr>
<tr>
<td>Shade (12.2-10.2): Original</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Shade (10.2-7.8): Original</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Shade (7.8-5.6): Original</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Shade (5.6-2.1): Original</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Shade (2.1-0.0): Original</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Shade (12.2-10.2): Shade Model</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Shade (10.2-7.8): Shade Model</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Shade (7.8-5.6): Shade Model</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Shade (5.6-2.1): Shade Model</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Shade (2.1-0.0): Shade Model</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

H6.0 LIGHT AND HEAT PARAMETERS, ALL MODELS

Default light and heater parameters were used in all models, except that the Ryan Stolzenbach solar parameter was increased from 0.80 to 0.85 and the sediment thermal thickness was increased from 10 cm to 15 cm (Table J-13)

Table J-13 Heat and Light Parameters Used in Models (Copied from Qual2k)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photosynthetically Available Radiation</td>
<td>0.47</td>
<td>/m</td>
</tr>
<tr>
<td>Background light extinction</td>
<td>0.2</td>
<td>1/m-(ugA/L)</td>
</tr>
<tr>
<td>Linear chlorophyll light extinction</td>
<td>0.0088</td>
<td>1/m-(ugA/L)^2/3</td>
</tr>
<tr>
<td>Nonlinear chlorophyll light extinction</td>
<td>0.054</td>
<td>1/m-(mgD/L)</td>
</tr>
<tr>
<td>ISS light extinction</td>
<td>0.052</td>
<td>1/m-(mgD/L)</td>
</tr>
<tr>
<td>Detritus light extinction</td>
<td>0.174</td>
<td>1/m-(mgD/L)</td>
</tr>
</tbody>
</table>
Table J-13 Heat and Light Parameters Used in Models (Copied from Qual2k)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar shortwave radiation model</td>
<td></td>
<td></td>
</tr>
<tr>
<td>atmospheric turbidity coefficient (2=clear, 5=smoggy, default=2)</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Ryan-Stolzenbach solar parameter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>atmospheric transmission coefficient (0.70-0.91, default 0.8)</td>
<td>0.85</td>
<td></td>
</tr>
<tr>
<td>Downwelling atmospheric longwave IR radiation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>atmospheric longwave emissivity model</td>
<td></td>
<td>Brutsaert</td>
</tr>
<tr>
<td>Evaporation and air convection/conduction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>wind speed function for evaporation and air convection/conduction</td>
<td>Adams 2</td>
<td></td>
</tr>
<tr>
<td>Sediment heat parameters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
<td>Units</td>
</tr>
<tr>
<td>Sediment thermal thickness</td>
<td>15</td>
<td>cm</td>
</tr>
<tr>
<td>Sediment thermal diffusivity</td>
<td>0.0118</td>
<td>cm²/s</td>
</tr>
<tr>
<td>Sediment density</td>
<td>2.2</td>
<td>g/cm³</td>
</tr>
<tr>
<td>Water density</td>
<td>1</td>
<td>g/cm³</td>
</tr>
<tr>
<td>Sediment heat capacity</td>
<td>0.4</td>
<td>cal/(g °C)</td>
</tr>
<tr>
<td>Water heat capacity</td>
<td>1</td>
<td>cal/(g °C)</td>
</tr>
<tr>
<td>Sediment diagenesis model</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compute SOD and nutrient fluxes</td>
<td></td>
<td>Yes</td>
</tr>
</tbody>
</table>

H7.0 REFERENCES
