JOHN DAY RIVER BASIN TMDL

APPENDIX B:
TEMPERATURE MODEL SCENARIO REPORT

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THIS DOCUMENT IS SUPPLEMENTAL TO THE JOHN DAY RIVER BASIN TEMPERATURE TMDL

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1. INTRODUCTION

This appendix reports the simulation and thermal assessment of rivers in the John Day Basin, for the purpose of Total Maximum Daily Load (TMDL) development. The model method and development, and identification of river reaches, time frames and data inputs are described in **Appendix A**. In summary, much of the length of the John Day River mainstem, North Fork John Day River and Middle Fork John Day River were simulated for temperature using Heat Source 8.0.

Once stream temperature models were developed and calibrated, scenarios that represent different sets of conditions were developed by changing one or more input values. The scenarios were developed to represent potential "natural" attributes in terms of potential vegetation, flow and channel morphology. First, these attributes were simulated individually. Next, they were run simultaneously. The ultimate goal was to combine the various natural condition attributes into one Natural Thermal Potential (NTP) scenario, which estimates instream temperatures free from anthropogenic influences, by considering the influence of changes in vegetation, flow and channel morphology. The term *NTP*, as used here, is defined in association with the natural condition criteria of the Oregon temperature standard (Oregon Administrative Rules (OAR) 340-041-0028) – refer to **Chapter 2** for further discussion. The methodologies for developing the natural condition inputs are described generally below and more specifically **Section 6**. In general, the NTP model temperatures are cooler than the current calibrated condition (CCC) temperatures. The largest temperature differences between CCC and NTP temperatures and their locations are presented in **Table B-1**, expressed in terms of the 'maximum of the 7-day rolling average of daily maximum' (maximum 7DADM) stream temperature during the model period.

Throughout this appendix and the entire TMDL document, the *river kilometer* is measured from zero at the most downstream point of the model (typically the river mouth), increasing upstream.

Table B-1. Longitudinal maximum difference between current and estimated natural conditions with the location of the maximum difference (point of maximum impact).

Waterbody	Greatest excursion from NTP (maximum 7DADM, Δ °C)	Current point of Maximum Impact (river km)
John Day River	10.8	327.00
North Fork John Day River	3.6	168.7
Middle Fork John Day River	7.6	2.55

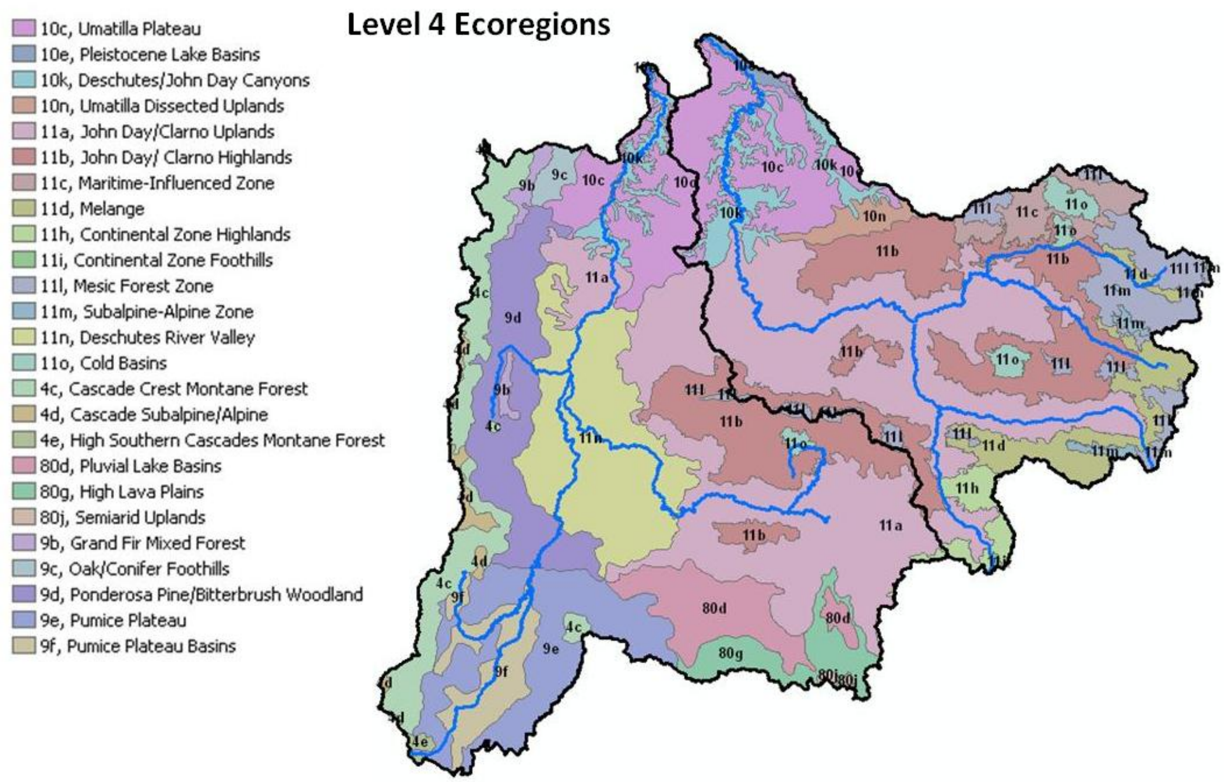
2. SYSTEM POTENTIAL VEGETATION

System potential vegetation is an estimate of the mature species composition, height and density of vegetation that would occur in the absence of human disturbances. System potential vegetation conditions were used in stream temperature modeling scenarios to quantify the impacts of nonpoint source solar radiation loads, and ultimately to develop nonpoint source load allocations for the TMDL.

Appendix C, *Estimate of the Type and Form of Natural Potential Vegetation in the John Day and Deschutes Basins*, describes the method used to determine potential vegetation in the John Day River Basin. In brief, the potential vegetation estimates are spatially delineated first on level IV Ecoregion polygons (**Figure B-1**) and, second, on valley form *sensu* McAllister (2008). In some instances, other differentiating features are applied to increase spatial resolution. The output of this delineation is a list of Ecoregion-physiographic types (hereafter *EP Types*) that covers all possible EP Types within the landscape. Each EP Type is assigned a vegetation height and shade density attribute, based on basin-specific historic assessments, plant association studies and observations during TMDL monitoring, technical committee review and, for additional vegetation height information, general botanical literature.

Every reach within the landscape can be assigned an explicit EP Type after identifying valley form and ecoregion. For each EP Type, a single height and shade density was assigned to each vegetation community. Where stands of shade-producing vegetation are intermittent, each vegetation community within that EP Type was assigned a frequency based on the proportion of the stream length it occupies. For example, reaches within EP Type 8 are potentially 80% conifer forest and 20% willow-shrub-grasses. While preserving the proportion of stream length, the placement of each vegetation community was randomly assigned. The natural potential vegetation estimates and the associated thermal influence are shown subsequently in this appendix.

Figure B-1. Level III & IV Ecoregions in the John Day River and Deschutes River Basins (for vegetation types, height and density, refer to Appendix C)



3. POTENTIAL FLOW

Potential flow is the volume of water estimated to be in the modeled reach if there were no human-related influences. In parts of the Basin, flow of water in the John Day Basin has been altered significantly from historic and natural conditions. **Table B-2** shows the mean August flow during the model year at four gages in the Basin. The percent exceedance shown in the Table is the percent of other years' mean August flows that exceeded the model year's. In other words, the John Day River August flows at John Day were relatively high during 2002 (only 34% of years on record had higher August flows), while the North Fork John Day River August flows at Monument were relatively low (only 27% of years on record had lower August flows). It is important to note that there is relatively little consumptive use in the upper North Fork drainage – progressively less above Monument and much less above the Middle Fork. The difference between 2002 and NTP temperature and flow profile, above the Middle Fork, should not be interpreted as human-caused flow deficit. Rather, the estimate reflects annual variability and generalized estimation methods.

Oregon Water Resources Department (OWRD) provided estimates of natural potential flow using the methodology outlined in *Determining Surface Water Availability in Oregon* (OWRD 2002). OWRD estimates were available monthly along the modeled rivers and for some tributary inflows to the model streams. At these points, OWRD provides estimates of the 50% and 80% exceedances level natural flows meaning that during any natural flow year, there is a 50% and 80% chance, respectively, that the actual flow will exceed the estimated values. The estimated 50th percentile natural flows were used herein to target a median natural flow year.

To simulate natural potential flow to the modeled reaches, we started by modifying tributaries (to model corridors) where OWRD estimated natural inflows. These tributary inputs were modified to reflect the natural flow estimate. After comparing the resulting modeled river (model corridors – North Fork, Middle Fork and John Day River) flow with the natural flow estimate of OWRD, further flow modifications in the tributaries were necessary. Inflows from the tributaries were modified to create the closest match between the model flows and OWRD estimates during the lowest flow period of the year, generally August. The resulting natural potential flow estimates in the model, and the associated thermal influence, are shown subsequently in this appendix.

Table B-2. Mean August flow during model year and percent exceedance at gages in the John Day River Basin.

USGS Gage	Mean August flow during model year	Percent Exceedance Flow of August in Model Year
John Day River at Blue Mountain Hot Springs (14036860)	28.2 cfs (2004)	58% (11 year record)
John Day River at John Day (14038530)	42.1 cfs (2004)	34% (40 year record)
North Fork John Day River at Monument (14046000)	81.5 cfs (2002)	73% (81 year record)
Middle Fork John Day River at Ritter (14044000)	30.4 cfs (2002)	48% (80 year record)

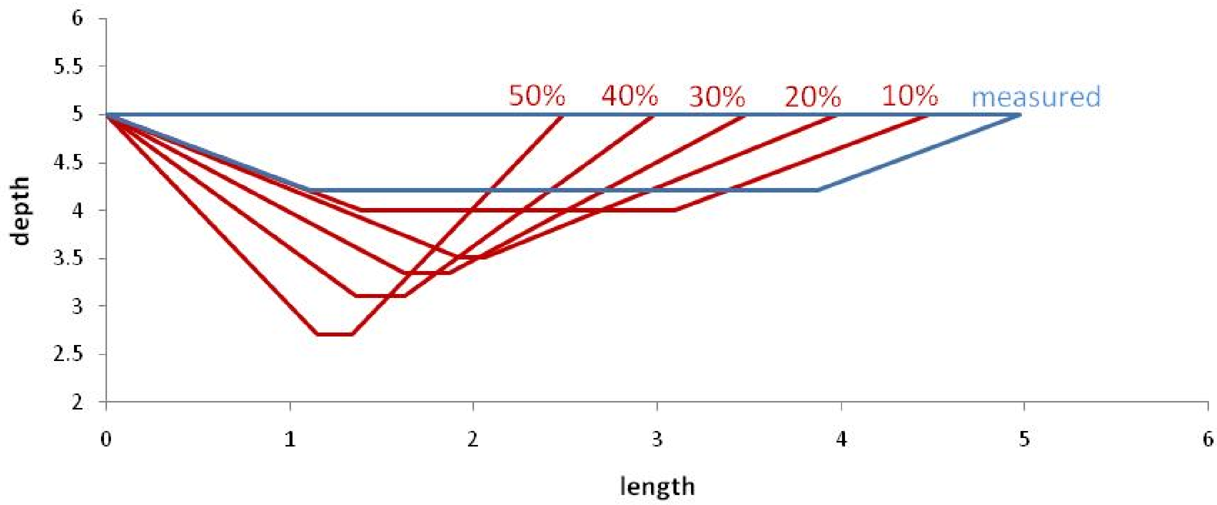
4. POTENTIAL MORPHOLOGY

The morphology of the streams and rivers in the John Day Basin has been altered significantly from historic and natural conditions. As channels and uplands are modified through land use, instream and bedload sediment loads generally increase, which generally results in widening the downstream channel. Through restoration, though channel widths will not always decrease, we generally expect potential decreases of 25-50% (Anderson et al. 2004, Beechie et al. 2007, Castro & Jackson 2001, Grande Ronde Model Watershed 2002, Hey, R. 2006, Li et al. 1994, McDowell, P. 2000, ODSL 2005, River Design Group 2007, Rosgen 1996, Smith & Smith 1984, USBLM 1998, USFS 1995, USFS 2007). Alternatively, one example of channel widening via restoration is found in the USFS restoration of nine miles of upper-middle part of the North Fork of the John Day, where channel and vegetation restoration through and area of dredge mine tailings resulted in a slight widening of the channel. There are other areas in the John Day Basin, including the Granite Creek watershed, where in-channel dredging occurred and similar results might be expected, where tailing piles have artificially narrowed channels. This underscores the difficulty in pre-determining channel potential. As described in Chapter 2.1, the Department temperature TMDL surrogate for channel morphology is narrative rather than quantitative.

In the course of this assessment, several attempts were made to estimate the potential morphological conditions. First, several morphological parameters were measured in undisturbed reference reaches. Of the possible parameter pairings, the strongest correlations were identified, such as drainage area and channel width. When the regression equations were extrapolated to model corridors, the results were unrealistic in lower regions, which are associated with fewer representative reference reaches. Then, the potential morphology parameters were estimated from the literature. The literature values were estimated for small watersheds up to 900 sq. km, which may or may not well represent the lower John Day mainstem (10,000 – 22,000 sq. km). There is still no clear source of information from which to estimate potential morphology in the Basin, particularly as drainage area increases.

Due to the uncertainty in estimating historic or natural channel morphological traits, a series of channel width reduction scenarios were simulated for each model. The bankfull widths were reduced by 10-50% every 50 m, while cross sectional areas were preserved (**Figure B-2**). Assuming a trapezoidal shape, the resulting bottom widths and angle of the bank ("z" as defined in **Appendix A**) were calculated and input to the scenario. As the bankfull widths were reduced, some wetted areas were converted to land. Those areas were assigned a vegetation type from the nearest downstream neighbor. The range of natural morphological scenarios produced a range of potential instream temperatures, which showed the impact morphology can have on rivers in the Basin.

Figure B-2. Example of bankfull width reductions and resulting channel shapes.



These scenarios represent a range of potential morphological conditions that bound the probable natural condition. The model results were therefore one representation of the natural morphological condition, but it should be realized that further understanding of Basin morphologic potential is needed for robust quantitative estimations. In the interim, the Department considers that a 30% reduction is a reasonable estimate, being within that which would be derived from comparison to existing natural conditions, restoration targets and general literature values. However, as described in **Chapter 2** of the main document, this is not a prescriptive target for this TMDL. The 30% bankfull width reduction scenario was used as an average example when only one representation was needed, such as inputting values to another model. The range of morphological changes and the associated thermal influence are shown subsequently in this appendix.

5. NATURAL THERMAL POTENTIAL

The *NTP scenario* results from combining the system potential vegetation, potential flow and potential morphology input values into one scenario. The range of potential morphological conditions was simulated, although only the NTP scenario results from the 30% bankfull width reduction are shown where only one result is needed. In a more natural state, other parameters are expected to change in a river, such as increased hyporheic exchange and reduced incoming temperatures from tributaries. The large number of tributaries, the variability in the derivation of their current temperature profiles, the lack of information about their potential temperature profiles, and the sensitivity of the model to inflows culminated in a large uncertainty around estimating natural tributary temperatures. Therefore, no estimates of potential tributary temperatures were made, except for the NTP model outputs from the Middle Fork and North Fork John Day Rivers. More details about the individual NTP scenario development are described in **Section 6**.

According to the temperature standard, where the NTP value is greater than the biologically based standard, the NTP value supersedes the numeric standard. The NTP values are estimates based on the modeled representation of the system and are subject to revision as more information about the basin becomes available.

6. TEMPERATURE SIMULATION SCENARIOS

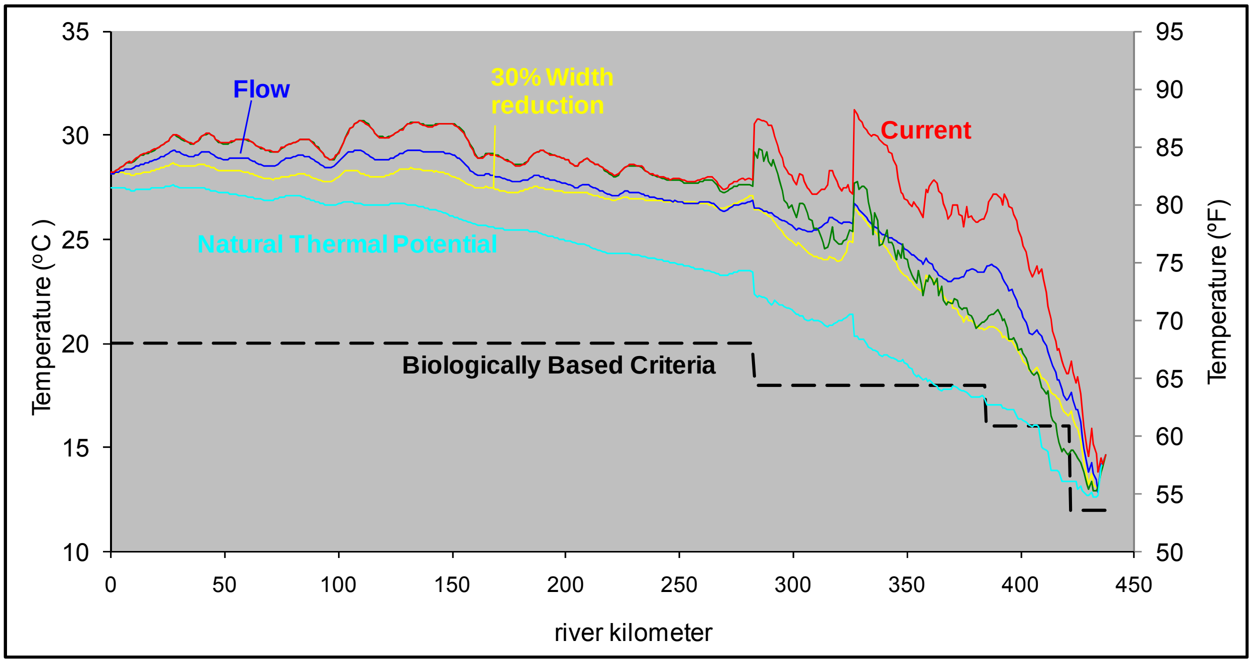
6.1 John Day River

The Heat Source model was used to predict the influence of various factors on stream temperature in the John Day River. The model setup is the same as described in the current calibrated conditions in **Appendix A,** except for the different simulation scenarios described in **Table B-3**. Further discussion of the scenarios is provided below. The maximum 7DADM temperatures resulting from various John Day River scenarios are shown in **Figure B-3**. The model predicts that NTP temperatures are warmer than the biologically-based criteria along most of the river and therefore the natural condition criteria applicability is established for the warm season. For a small portion nearer the headwaters, the applicable criteria are the biologically-based criteria. Other criteria still apply, for instance in seasons where modeling was not conducted – this is primarily relevant to point sources, as discussed in **Chapter 2** of the main document.

Table B-3. Simulated Scenario Definitions

"Current"	Current Calibrated Condition (see **Appendix A** for details). Model results produced every 200 m and 1 min. Model extent was 437.0 km)
"Restored Vegetation"	System Potential Vegetation (see **Section 2** and below for details).
"Restored Flow"	No points of diversion or ditch inputs and tributary flows adjusted to OWRD's estimates of natural flow (see **Section 3** for details)
"Restored Morphology"	Bankfull widths reduced by 10-50% while cross sectional area preserved (see **Section 4** for details).
"NTP"	Natural Thermal Potential: combining the inputs of system potential vegetation, natural stream flow, and reduced bankfull width estimates (see **Section 5** for details). North Fork JDR NTP at 30% bankfull width reduction outputs were fed into this model from 6/15-9/1. No temperature adjustments were made to tributary inputs.

Figure B-3. Predicted maximum 7DADM temperature profiles of the John Day River resulting from described scenarios during the model period, 2004.



"Restored Vegetation" Scenario

The potential natural vegetation within the riparian corridor was assigned according to the method described in **Section 2**. As described in **Section 2**, natural potential vegetation was assigned based on EP Types, based on valley form and ecoregion. EP Type reach breaks were established for the modeled rivers. Breaks were located at each ecoregion boundary, and further delineated by valley form determination based on 10-m DEM assessment, and other criteria, as described in **Appendix C**. The resultant reaches are listed in **Table B-4** and mapped in **Figure B-4.** The John Day River had an additional consideration below river km 282 (North Fork confluence), which contains upslope areas that are naturally incapable of supporting trees or other shade producing vegetation, due to soil type, water table depth, instability, etc.. Outside of a 50 m buffer around the main channel, these areas are not predicted to support near-stream vegetation. Model inputs outside of the 50 m buffer retained their existing vegetation coverage (i.e., barren steep rocky slopes, bedrock outcrops, etc.) in the potential vegetation scenario (**Appendix A, Table 3**), unless they were clearly anthropogenically influenced (i.e., roads, buildings, rail, dams, etc.), in which case, they were assigned the nearest neighbor's land cover. Inside the 50 m riparian buffer, the potential vegetation communities were assigned potential land cover as described in **Section 2**. **Figure B-5** shows the potential percent shade and corresponding daily average solar flux simulated by this vegetation scenario. The solar flux is the solar radiation that reaches the stream and is inversely proportional to percent effective shade. **Figure B-6** shows the potential percent shade simulation at a higher resolution of every 100 m.

Table B-4. John Day River Potential vegetation by reach (reach identification numbers correspond with those in Figure B-4)

	Mainstem John Day River, classified into reaches based on ecoregion, valley gradient and subtype breaks								
Reach ID #	Upper node	Lower node	Model node range (meters from mouth)		Level 4 Ecoregion	Valley sub-type	Ecoregion-Physiographic Type	Land Cover Height in meters (stream length in %)	Land Cover Density (%)
1	model boundary	bottom of Ecoregion 11l	437000	433750	11l	C	57	29.3 (100)	80
2	top of Ecoregion 11d	conifer forest lower edge	433700	430050	11d	C	49	28.8 (100)	85
3	conifer forest lower edge	Deardorff Creek	430000	424800	11a	D	8	27.4 (80) 2.5 (20)	85 85
4	Deardorff Creek	Prairie City	424750	409600	11a	A	43.5	27.4 (80) 2.5 (20)	85 85
5	Prairie City	top of Picture Gorge	409550	316550	11a	A	43.5	27.4 (80) 2.5 (20)	85 85
6 *	top of Picture Gorge	North Fork	316500	282250	11a	D	8	21 (40) 2.5 (60)	85 85
7 *	North Fork	Service Creek	282200	238200	11a	D	8	21 (40) 2.5 (60)	85 85
8 *	Service Creek	bottom of Ecoregion 11a	238150	135350	11a	D	8	16.3 (25) 2.5 (75)	85 85
9 *	top of Ecoregion 10k	bottom of Ecoregion 10k	135300	17000	10k	D	2	10.8 (50) 2.5 (50)	90 90
10 *	top of Ecoregion 10e	Tumwater Falls	16950	0	10e	D	41	8.4 (50) 1.5 (50)	90 90

* Outside the 50 m riparian buffer was left at "existing" vegetation values.

Figure B-4. John Day River potential vegetation numbered reaches

Figure B-5. John Day River comparison of current and potential shade and corresponding daily average solar flux on August 1. Model results produced every 1000 m.

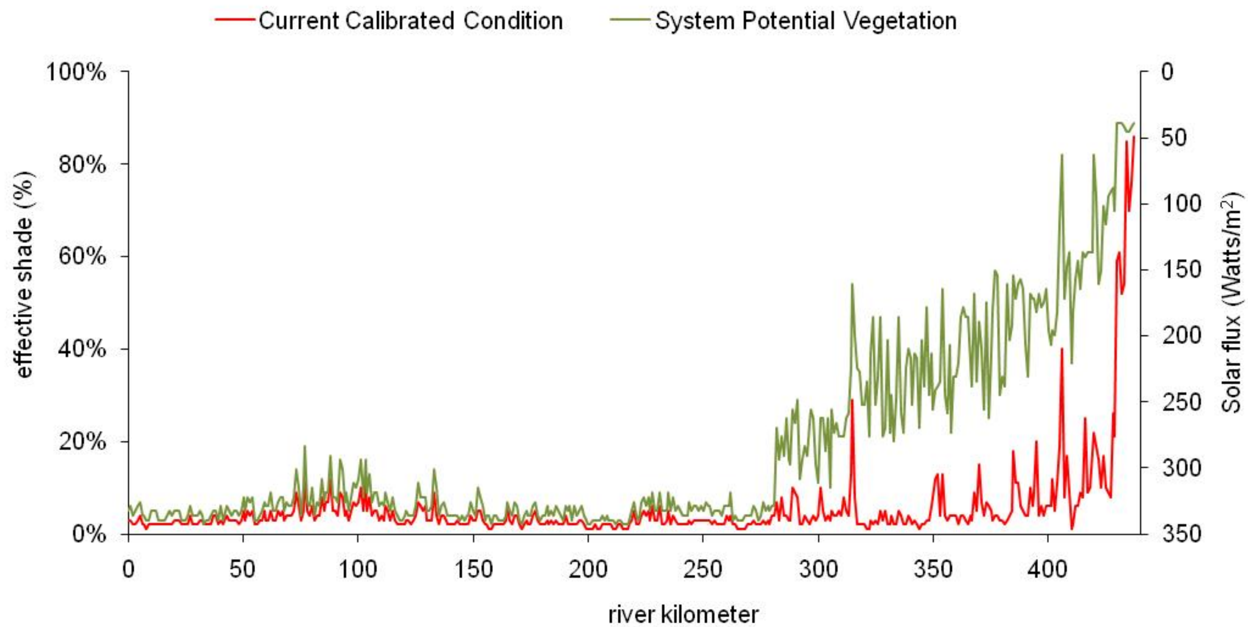
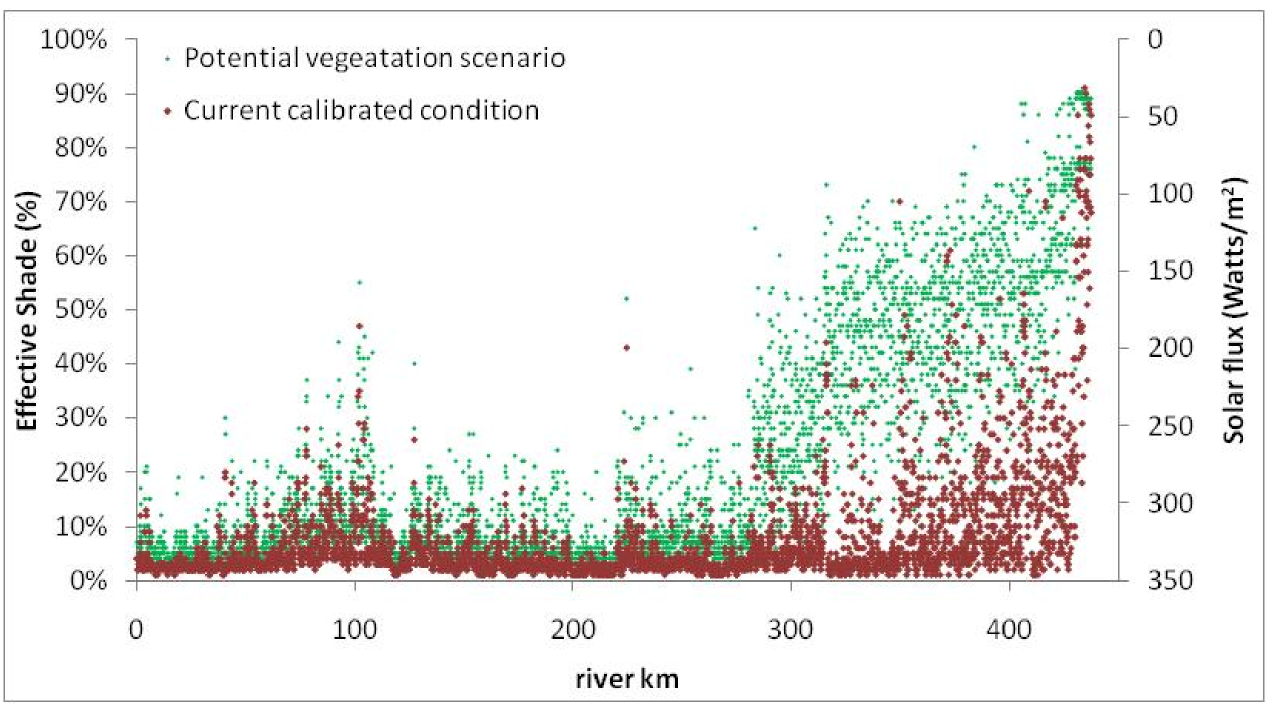


Figure B-6. John Day River comparison of current and potential shade and corresponding daily average solar flux on August 1 at a higher model resolution of every 100 m.



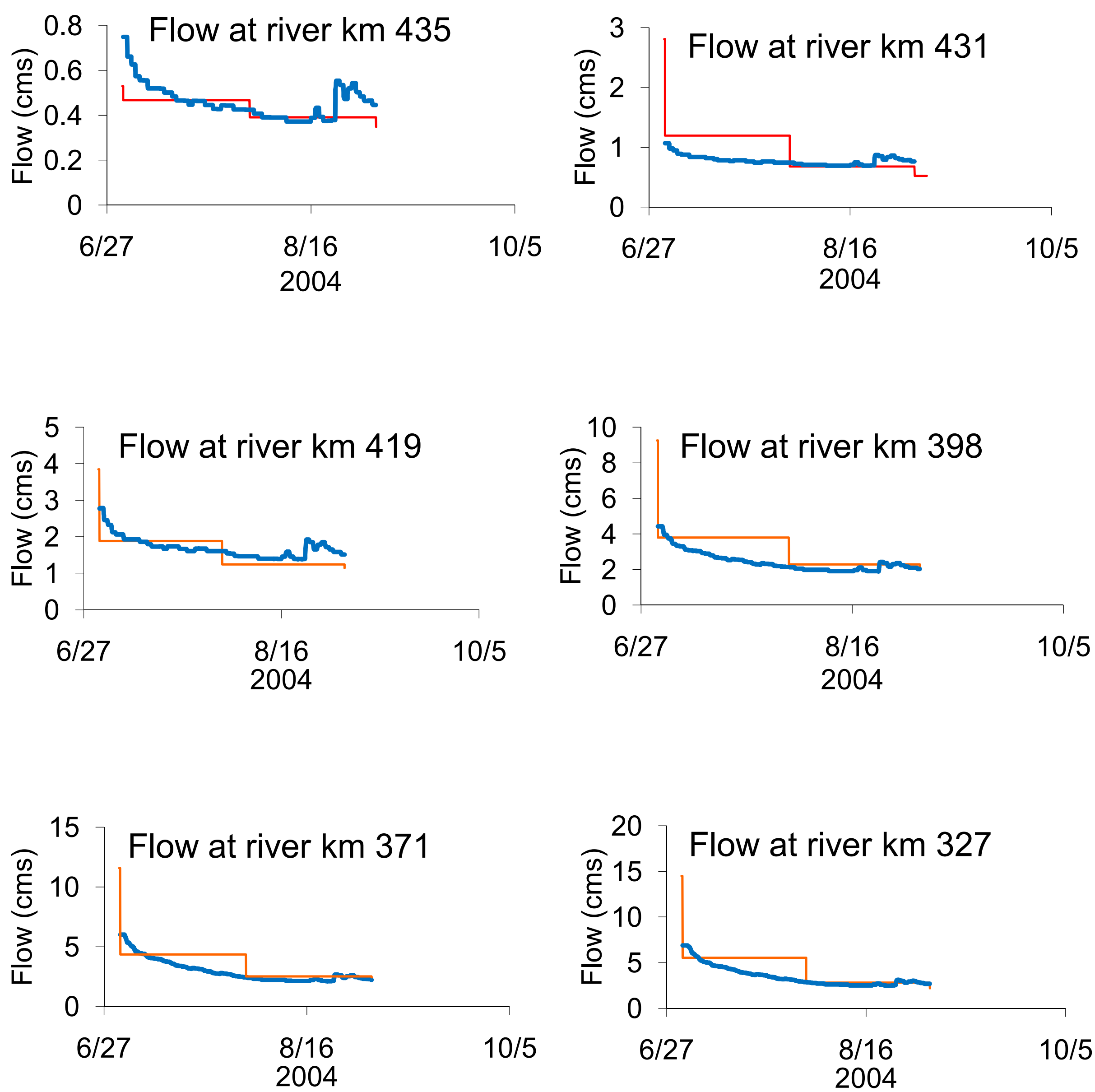
"Restored Flow" Scenario

In order to provide a better estimate of natural thermal potential, estimates of natural flow inputs to the John Day River from its tributaries were derived as discussed in **Section 3**. All irrigation return flows derived for calibration (described in **Appendix A**) and points of diversion were eliminated. To supply the flow of water from the tributaries, commensurate with the OWRD estimates of natural flow in the mainstem, appropriate tributaries' current flows were increased according to **Table B-5**. These model inputs resulted in the instream flows shown at nine points on the John Day River in **Figure B-7**. Direct comparison is difficult because OWRD provides monthly natural flow estimates for two different flow year types. The longitudinal profiles of predicted flows are presented graphically in **Figure B-8**.

Table B-5. John Day River inflows from tributaries to simulate natural flows

Inflow	Calibration factor
Boundary	Current flow times 1.7
Call Creek	OWRD estimates
Deardorff Creek	Current flow times 1.25
Return of side channel (Isham Creek?), Strawberry, Slyfe/Strawberry, Dixie, Indian, Pine, Seep (near Dean and Dissel), Canyon Creek Laycock, Enterprise drain return flow, Beech, Spring (near Birch Cr), Spring, Belshaw & Fields Creeks & Spring	Current flow doubled
South Fork John Day River	Current flow times 1.50

Figure B-7. Comparison of TMDL-input natural flow for the John Day River flow (blue lines) at several points with estimated natural flows (OWRD 2002). The OWRD estimated natural flows (red lines) represent the 50% exceedance stream flow.



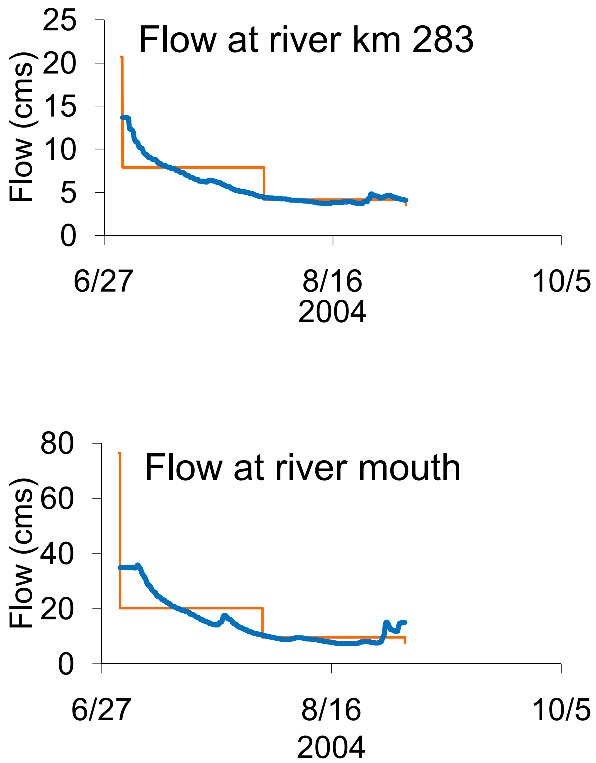
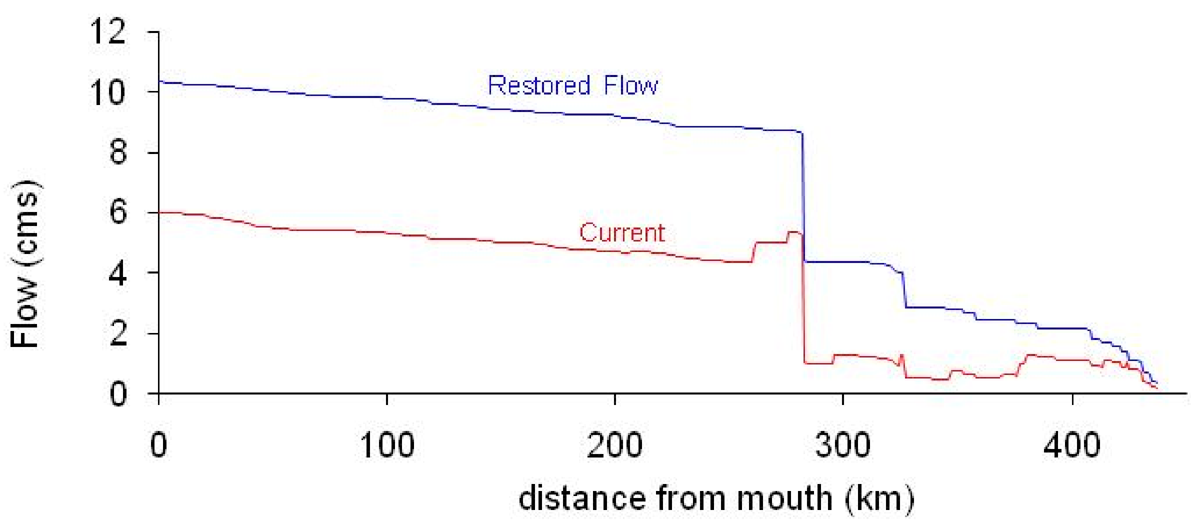


Figure B-8. Longitudinal profiles of predicted flows on August 1, 2004 for scenarios that considered flow alterations. Model results produced every 1000 m.



"Restored Morphology" Scenario

To test the sensitivity of river temperature to morphological changes, five scenarios were run with bankfull widths incrementally decreased from 10% to 50%, as described and illustrated in **Section 4**. When changing the bankfull widths, the shade provided by the vegetation in the morphology scenarios do not vary widely from the current effective shade (**Figure B-9**). The changes in channel morphology created differences in the timing, but not the volume, of flow in the river (**Figure B-10**). The maximum 7DADM temperatures during the model period resulting from the changes in morphology are shown in **Figure B-11**. A 10% - 50% channel width reduction results in a range of average decreases in temperature from 1.3 °C – 3.3 °C, respectively.

Figure B-9. Range of percent effective shade on August 1 resulting from various channel width reductions. Model results produced every 1000 m.

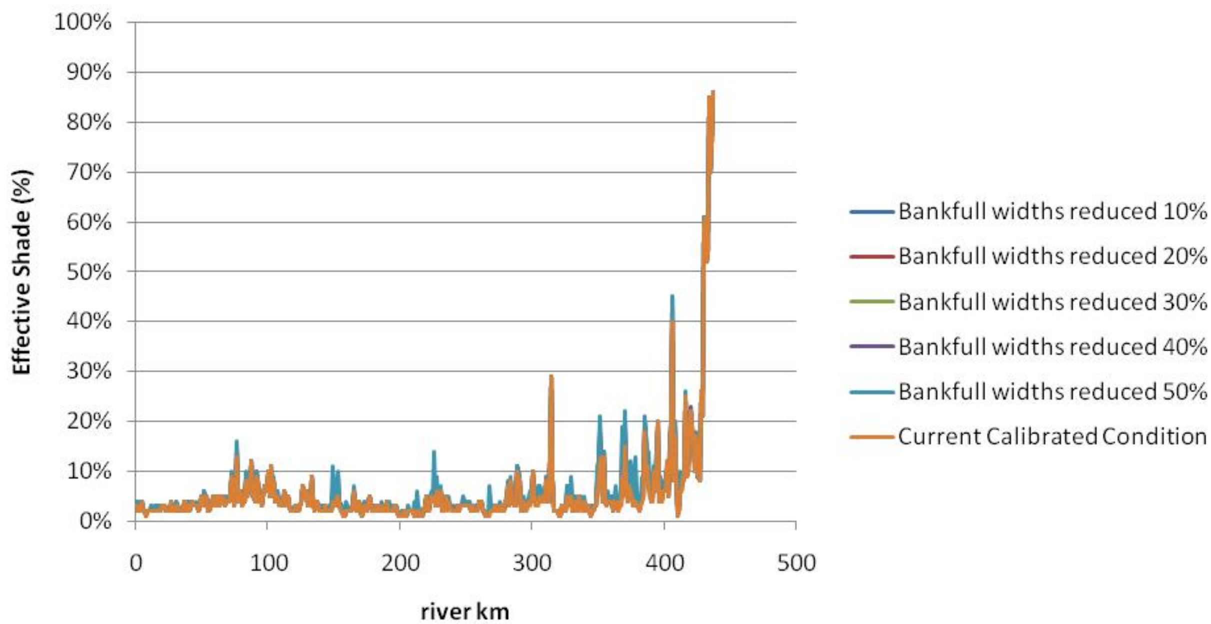


Figure B-10. Range of flows on August 1 resulting from various channel width reductions. Model results produced every 1000 m.

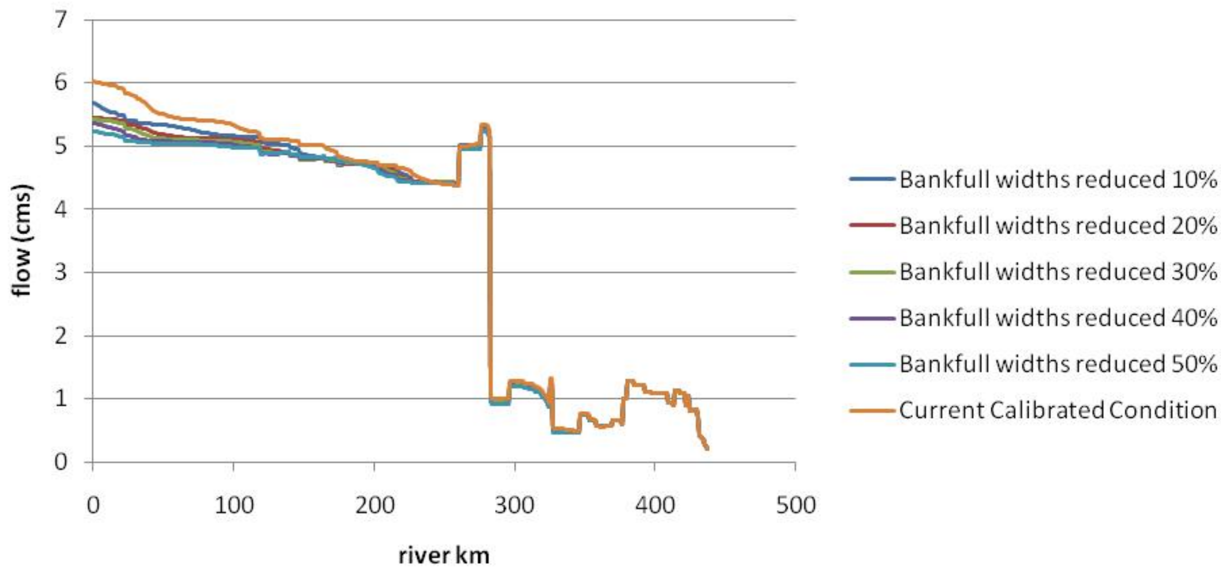
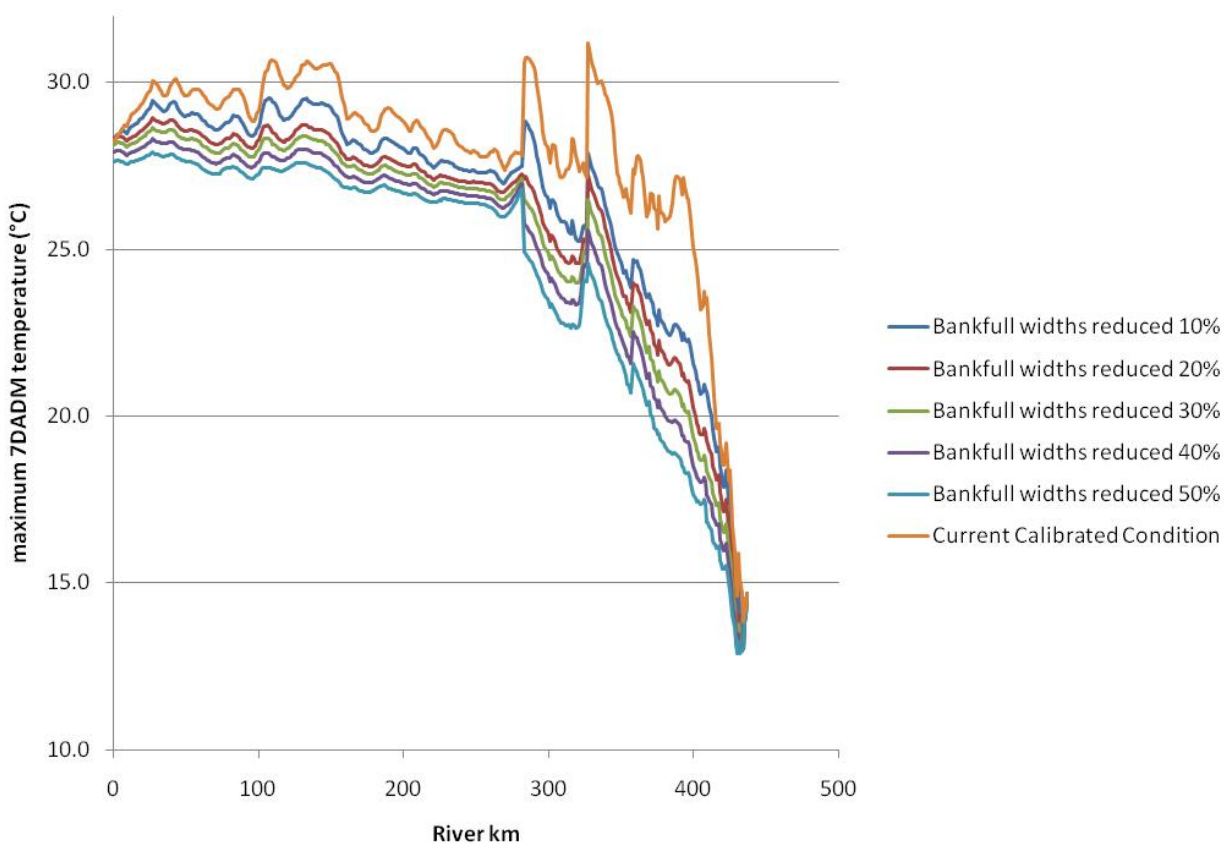


Figure B-11. Range of maximum 7DADM during model period resulting from various channel width reductions. Model results produced every 1000 m.



Natural Condition Criteria

As described previously, the NTP model inputs include the restored flow and vegetation parameter values, and each of the potential morphological scenarios was represented. As explained in **Section 2**, the placement of each potential vegetation community was randomly assigned for each scenario involving potential vegetation. Since there were five NTP scenarios (one for each morphological bankfull width reduction), the potential vegetation communities shifted, but their proportions remain the same. This produces variability in the amount of effective shade around an average line. In some places, the variability in vegetation type placement causes the effective shade profiles on August 1 to overlap (**Figure B-12)**. The flow results on August 1 from the range of morphological scenarios are shown in **Figure B-13**. The range of NTP maximum 7DADM temperatures is shown in **Figure B-14**. The 30% width reduction scenario was used to represent the average NTP values when only one NTP scenario was required. In order to compare 7DADM temperatures corresponding to the individual potential vegetation, flow and morphological scenarios with the full NTP scenario at 30% width reduction, refer to **Figure B-3**.

Figure B-12. Range of percent effective shade on August 1 resulting from various channel width reductions under NTP conditions. Model results produced every 1000 m.

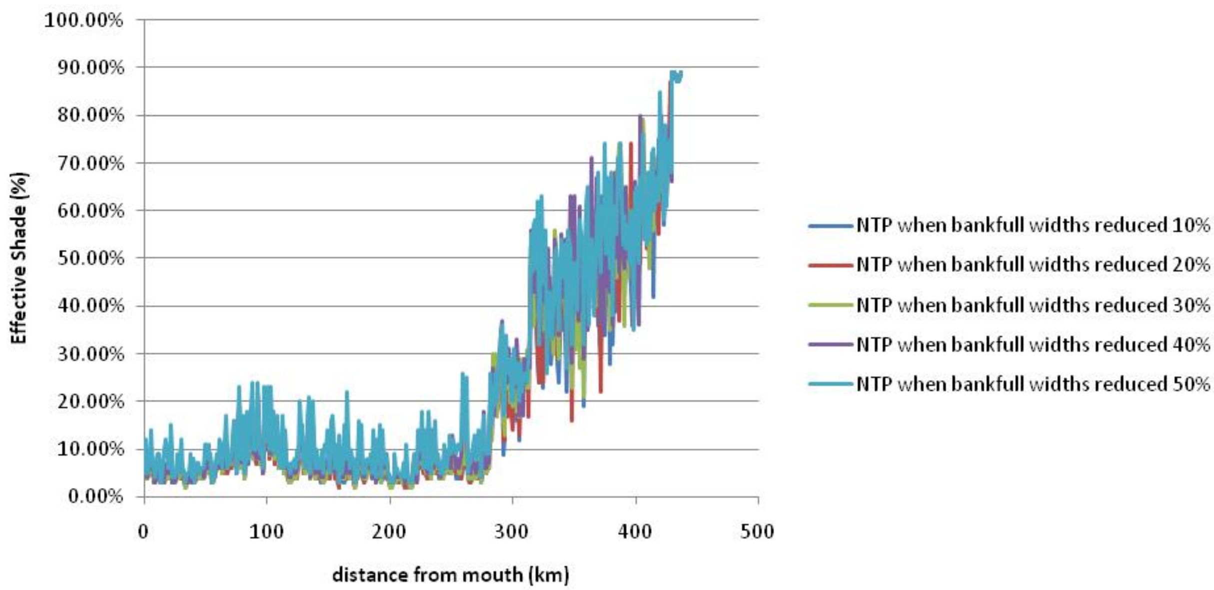


Figure B-13. Range of flows on August 1 resulting from various channel width reductions under NTP conditions. Model results produced every 1000 m.

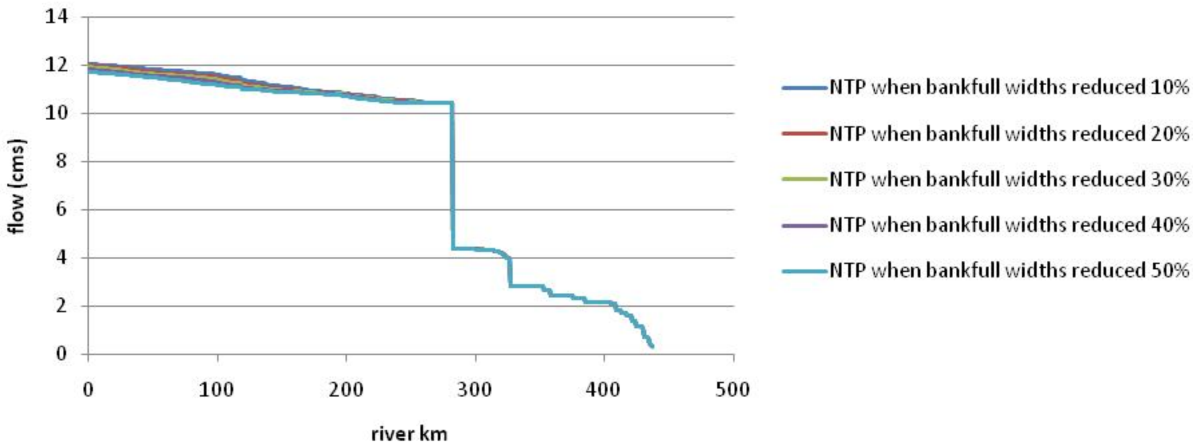
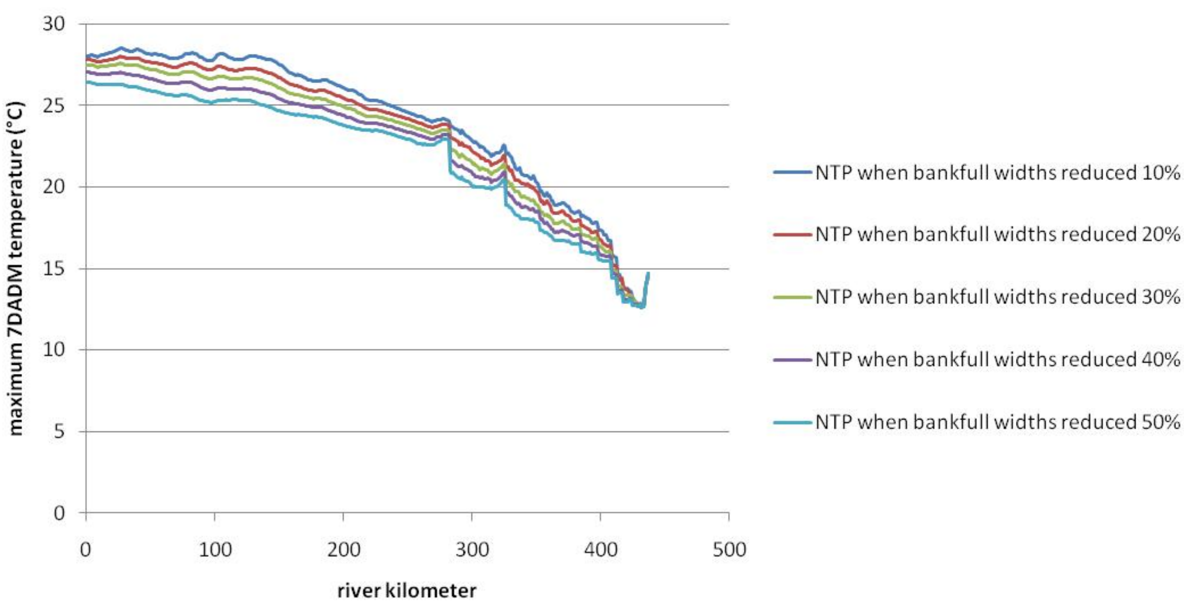


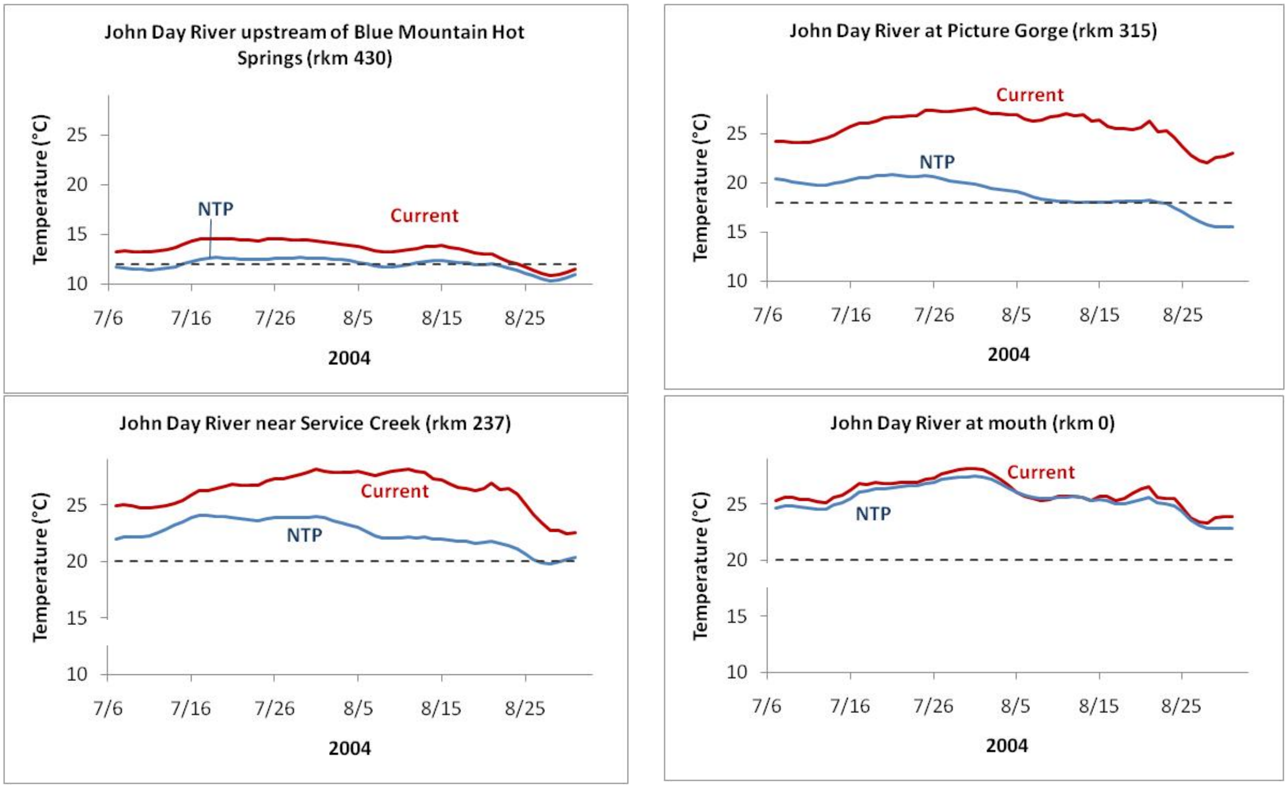
Figure B-14. Range from morphological changes of maximum 7DADM temperatures during the model period under NTP conditions. Model results produced every 1000 m.



Temporal Variability

The water quality temperature standard has several criteria that vary in time and space. The suite of biologically based criteria and the natural condition criterion, as well as the ‘protecting cold water’ criterion, all have relevance in this TMDL. Determining which criteria are applicable sometimes depends on whether NTP exceeds biologically based criteria. As described in **Chapter 2**, for this TMDL, the natural condition criteria is invoked at the Basin scale. This provides for load allocations that address nonpoint source heating throughout the basin as well as enabling natural temperatures on the modeled corridors where the natural condition criteria clearly applies through much of the river length. However, for point sources located where NTP is less than biologically based criteria, the biologically based criteria may be applied if it does not impede criteria attainment where NTP is applicable, or at times when NTP has not been determined. Comparisons of time series at several points are below (**Figure B-15**). No scenarios were run during the spawning time period. For further discussion, refer to **Chapter 2**.

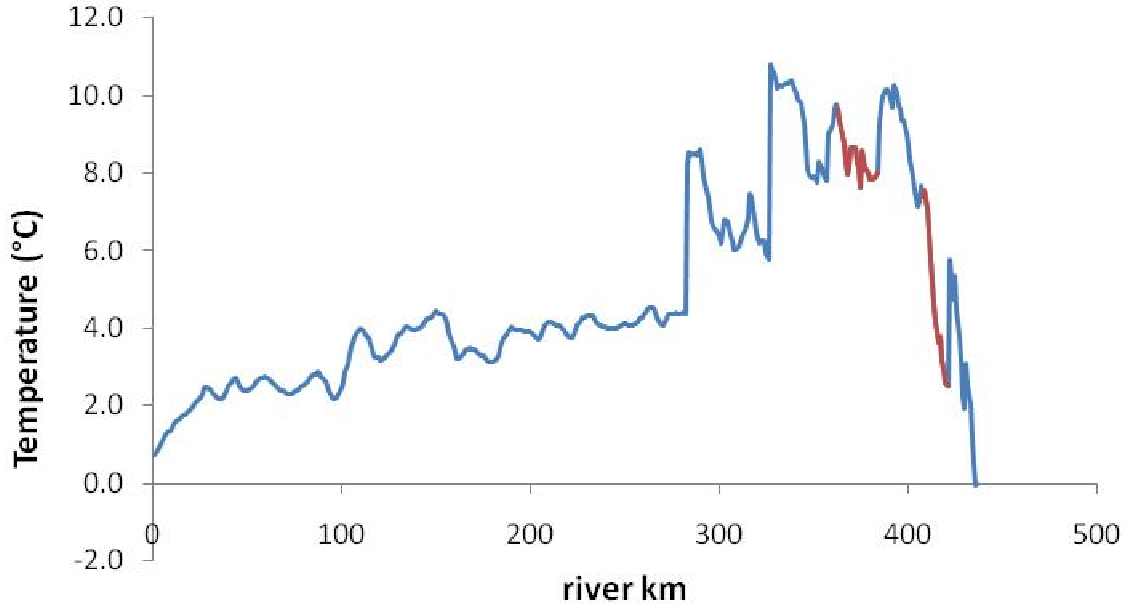
Figure B-15. Comparison of 'current', natural thermal potential (NTP) and the biologically based criteria (dashed line) at four locations on the John Day River using the rolling 7DADM during the model period.



Divergence from standard

The differences between the maximum 7DADM current temperatures and the applicable criteria in the water quality temperature standard are shown in (**Figure B-16**). The areas with the largest difference in temperature could merit prioritized restoration opportunities.

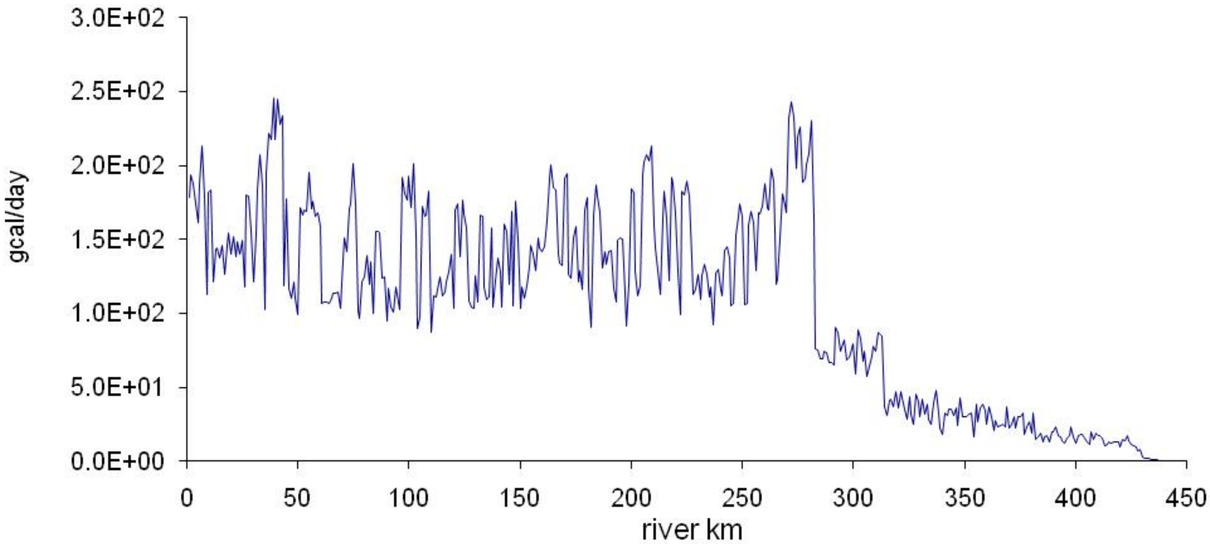
Figure B-16. Differences between the current maximum 7DADM temperature during the model period and applicable criterion. Red line indicates biologically based criteria are the applicable criteria.



Background solar load

The natural background solar load is the amount of solar radiation received immediately above the stream surface area under NTP conditions. To calculate this figure, at each modeled interval, the average daily solar radiation flux immediately above the stream surface was multiplied by the wetted width under NTP conditions and converted to a daily solar load. On July 1, 2004, the modeled John Day River received an average daily solar load according to **Figure B-17**. In total, the modeled John Day River received a total solar load of 47,462 gcals/day. The natural background solar load is one of the components to determine Loading Capacity of the river.

Figure B-17. John Day River solar load under NTP conditions on July 1, 2004. Model results produced every 1000 m.



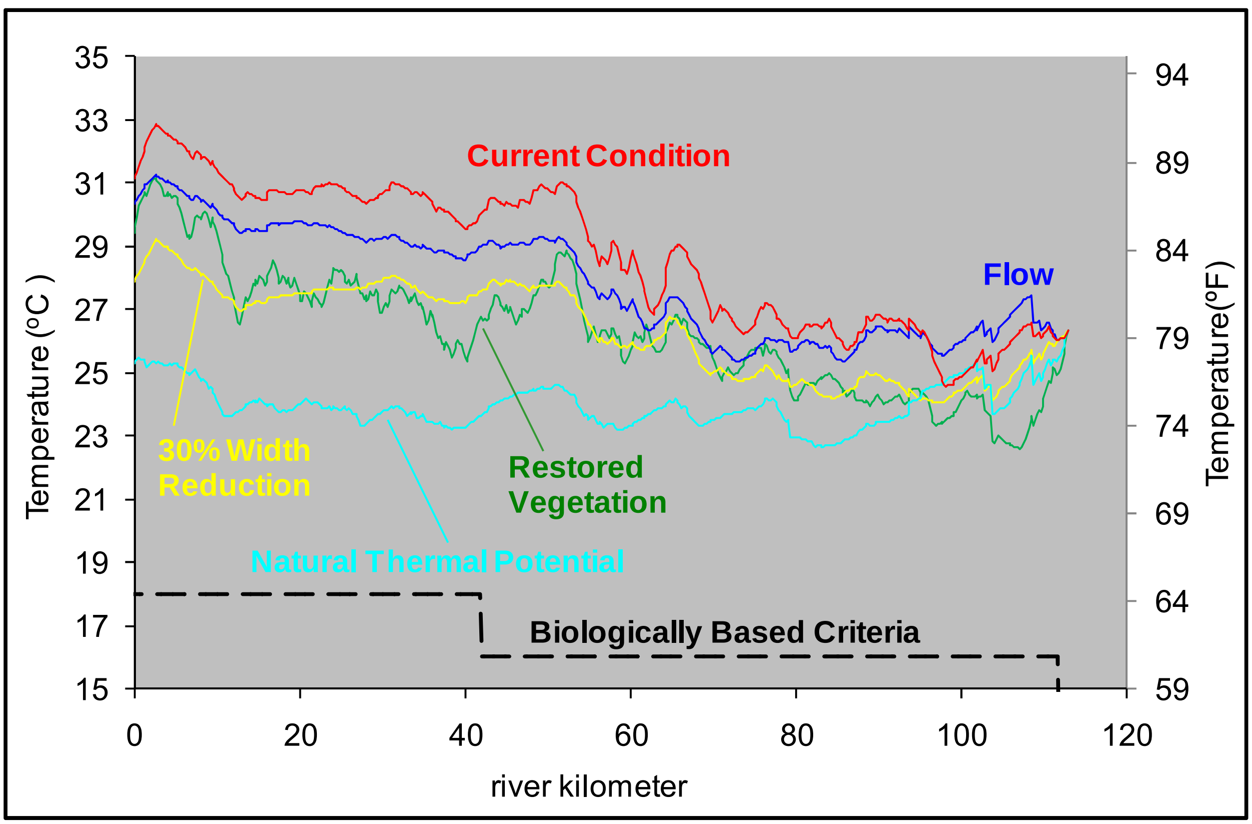
6.2 North Fork John Day River

The Heat Source model was used to predict the influence of various factors on stream temperature in the North Fork John Day River. The model setup is as described in **Appendix A**, except for changes to the current calibrated conditions model as described in **Table B-6**. During the NTP scenarios, the distance step was increased from 100 m to 200 m for model stability. The current calibrated condition model results were averaged every 200 m for comparison to the scenarios. The maximum 7DADM temperatures during the model period resulting from various scenarios are shown in **Figure B-18.** The model indicates that maximum 7DADM temperatures during the model period under the NTP scenario were greater than the biologically based criteria throughout the entire reach and therefore the natural conditions criteria applicability is established, superseding the warm season biologically based criterion.

Table B-6. Simulated Scenario Definitions

"Current"	Current Calibrated Condition (see **Appendix A** for details). Model results produced every 0.5 min and 100 m averaged to every 200 m when compared with NTP. Model extent was 172.9
"Restored Vegetation"	System Potential Vegetation throughout, Wilderness reach left at existing vegetation (see **Section 2** and below for details). Model results produced every 0.5 min and 100 m.
"Restored Flow"	No points of diversion or ditch inputs and tributary flows adjusted to OWRD's estimates of natural flow (see **Section 3** for details). Model results produced every 0.5 min and 100 m.
"Restored Morphology"	Bankfull widths reduced by 10-50% while cross sectional area preserved (see **Section 4** for details) from mouth to rkm 93.85. Model results produced every 0.5 min and 100 m.
"NTP"	Natural Thermal Potential: combining the inputs of system potential vegetation, natural stream flow, and reduced bankfull width estimates (see **Section 5** for details). Wilderness reach left at existing vegetation. Morphological changes were made according to **Table B-9**. Middle Fork JDR NTP at 30% bankfull width (without hyporheic adjustments in meadow reaches) reduction outputs were fed into this model. No temperature adjustments were made to tributary inputs. Model results produced every 0.5 min and 200 m.

Figure B-18. Predicted maximum 7DADM temperatures on North Fork John Day River during the model period of 2002. Model results produced every 100 m, except Natural Thermal Potential was modeled 200 m.



"Restored Vegetation" Scenario

The potential natural vegetation within the riparian corridor was assigned according to the method described in **Section 2**. As described in **Section 2**, natural potential vegetation was assigned based on EP Types, based on valley form and ecoregion. EP Type reach breaks were established for the modeled rivers. Breaks were located at each ecoregion boundary, and further delineated by valley form determination based on 10-m DEM assessment. The resultant reaches are listed in **Table B-7** and mapped in **Figure B-19**. Reaches 3-7 lie within as the North Fork John Day Wilderness Area, which is assumed to represent the best estimate of an un-impacted landscape. In the Wilderness reaches, the current vegetation conditions were assumed to be at potential and were not changed in the potential vegetation scenario. The effective shade provided under the potential vegetation and current scenarios, as well as the corresponding solar flux, are shown in **Figure B-20**.

Table B-7. North Fork John Day River Potential vegetation by reach (reach identification numbers correspond to those in Figure B-19)

	North Fork John Day River, classified into reaches based on ecoregion, valley gradient and subtype breaks								
Reach ID #	Upper node	Lower node	Model node range (meters from mouth)		Level 4 Ecoregion	Valley sub-type	Ecoregion-Physiographic Type	Land Cover Height in meters (stream length in %)	Foliage Density (%)
1	model boundary	bottom of wide valley	172900	166950	11l	A	55	29.9 (100)	53
2	top of narrow valley	immediately above Wilderness	166900	164300	11l	D	57.5	22 (100)	53
3	top of Wilderness	ecoregion transition	164250	151500	11l	C	57	existing	
4	ecoregion transition	ecoregion transition	151450	148750	11d	D	49.5	existing	
5	ecoregion transition	ecoregion transition	148700	143950	11d/11l	D	49.5-57.5	existing	
6	ecoregion transition	ecoregion transition	143900	140500	11d/11l	D	49.5-57.5	existing	
7	ecoregion transition	bottom of Wilderness	140450	120500	11l	D	57.5	existing	
8	immediately below Wilderness	above flat valley bottom, ecoregion transition	120450	112350	11l	D	57.5	existing	
9	top of flat valley bottom	bottom of flat valley bottom	112300	108650	11b	D	11	existing	
10	bottom of flat valley bottom	narrow flat valley bottom	108600	104950	11b	D	11	existing	
11	top of v-shaped valley	bottom of v-shaped valley, bottom of 9 km USFS restoration	104900	91450	11b	D	11	existing	
12	top of flat valley bottom	bottom of flat valley bottom	91400	64450	11b	D	11	21.9 (100)	53
13	top of sinuous valley	bottom of sinuous valley, ecoregion transition	64400	54100	11b	D	11	21.9 (100)	53
14 u/s	ecoregion transition	bottom of narrow valley	54050	32200	11a	D	8	27.4 (80)	57
								2.5 (20)	57
14 d/s	ecoregion transition	bottom of narrow valley	32200	28800	11a	D	8	27.4 (80)	85
								2.5 (20)	85
15	top of wide valley	bottom of wide valley	28750	24400	11a	A	43.5	21 (40)	85
								2.5 (60)	85
16	top of bare rock (Mon. gage)	bottom of bare rock	24350	23500	11a	D	8	21 (40)	85
								2.5 (60)	85
17	top of wide lower valley	mouth	23450	0	11a	A	43.5	21 (40)	85
						A		2.5 (60)	85

green shading indicates areas undergoing broad scale restoration or preservation

Figure B-19. North Fork John Day River potential vegetation numbered reaches

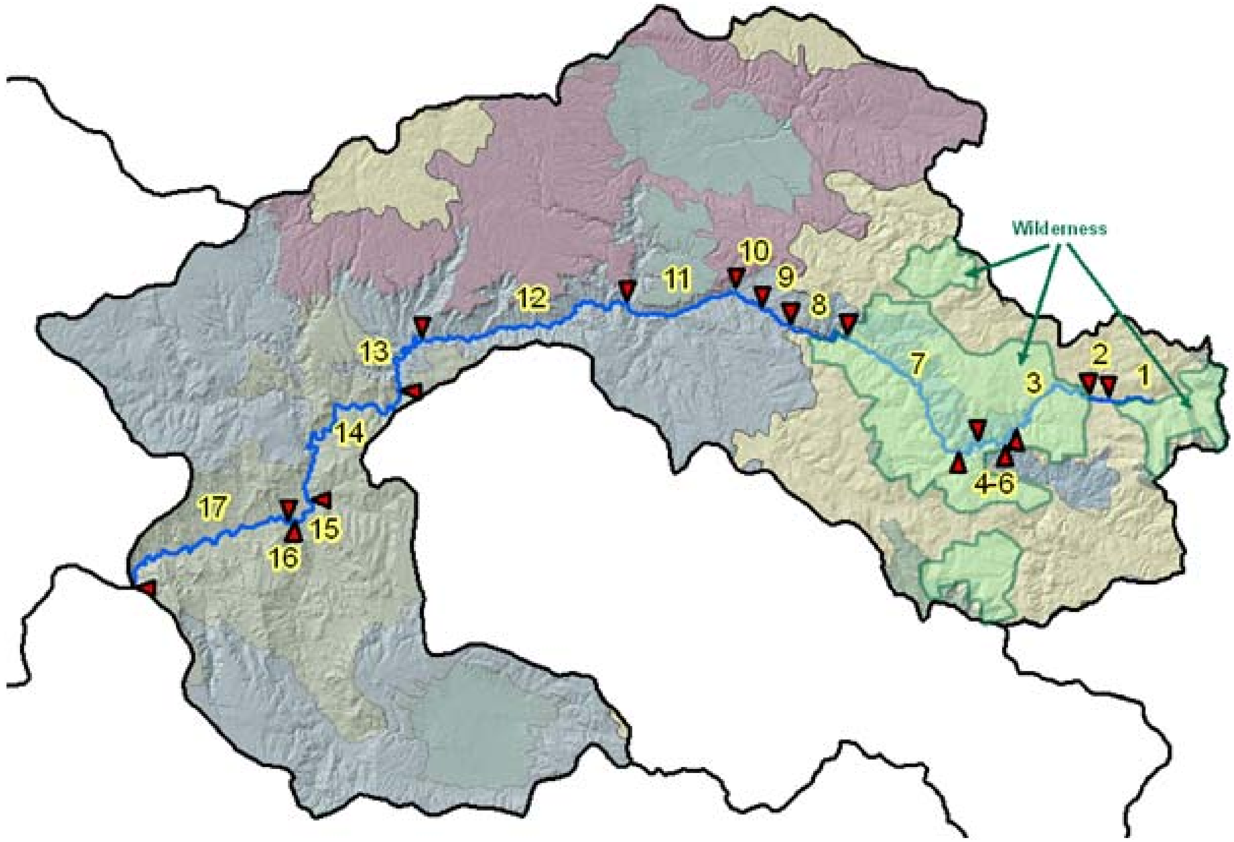
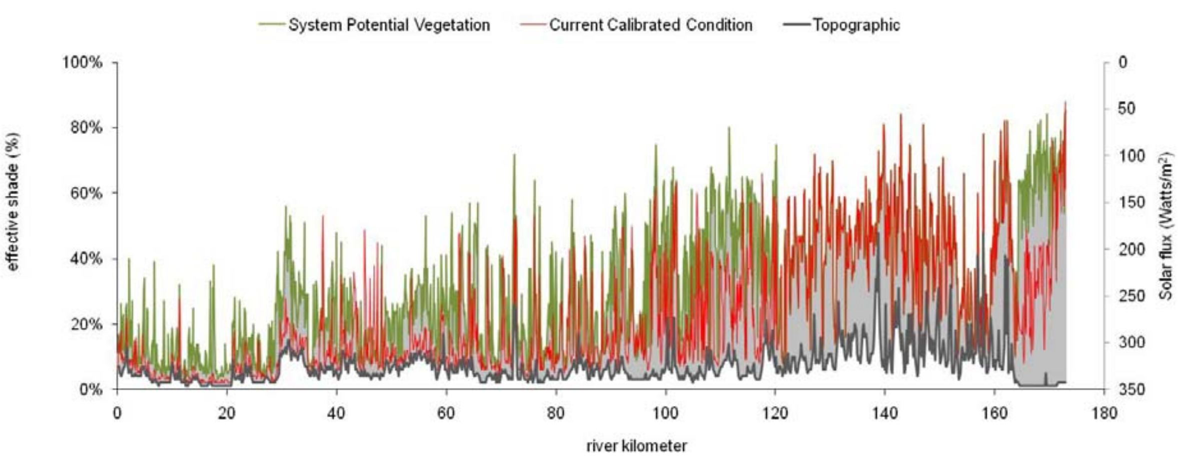


Figure B-20. North Fork John Day River comparison on August 1 of current and potential shade and corresponding daily average solar flux. Model results produced every 100 m.



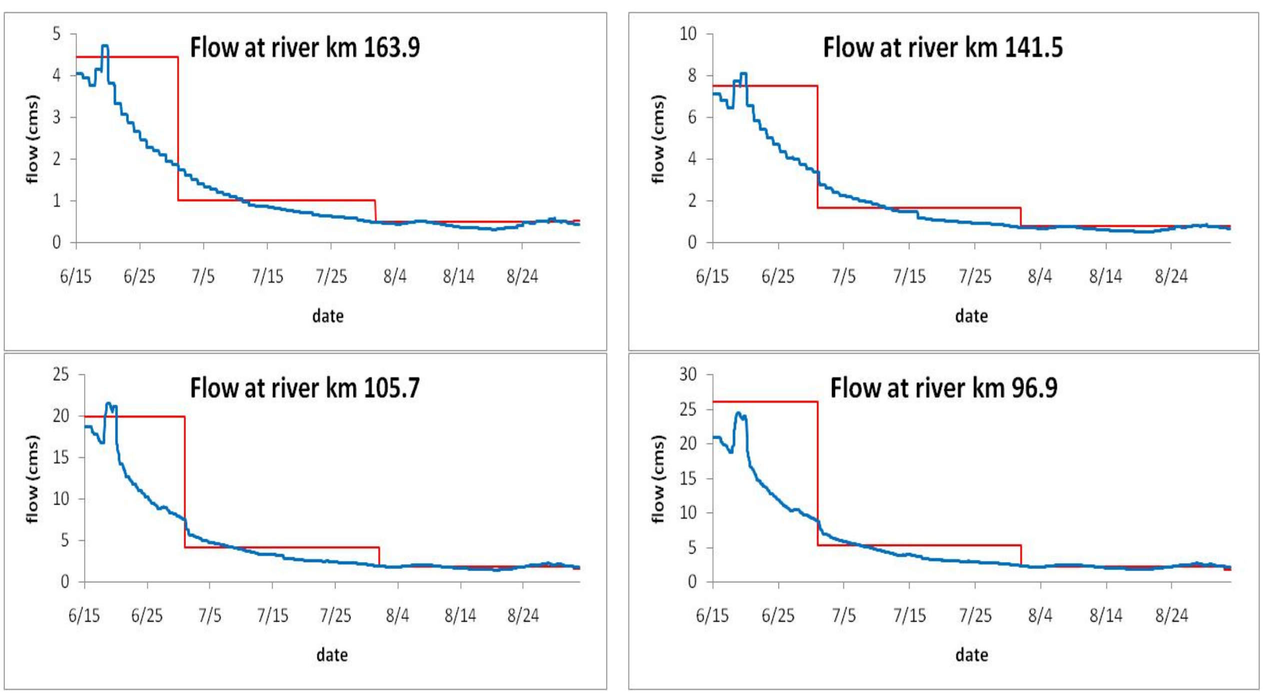
"Restored Flow" Scenario

In order to provide a better estimate of natural thermal potential, estimates of natural flow inputs to the North Fork John Day River from its tributaries were derived as discussed in **Section 3**. All irrigation return flows derived for calibration (described in **Appendix A**) and points of diversion were eliminated. In the North Fork John Day, OWRD provided estimates of the 50th percentile natural flow at several points along the mainstem as well as the tributaries. In order to match the OWRD instream flow estimates, the tributary flows were increased by calculating the ratio between the OWRD estimates of natural flow to the current flow rate on August 1, then applying that ratio to each daily flow during the model period. OWRD did not estimate natural flow for several tributaries. For these tributaries, the current flow was doubled as an estimate of natural flow. Additional flow was needed during June and early July, so three tributary flow profiles were multiplied by a factor of 2 to 6. Granite and Big Creeks received 2.5 cms of additional flow at all times in June. The changes to the tributaries' flow are summarized in **Table B-8.** The model prediction and OWRD estimates are presented at seven points on the North Fork John Day River in **Figure B-21.** Direct comparison is difficult because OWRD provides monthly natural flow estimates for two different flow year types. The flows predicted longitudinally in this scenario are presented graphically in **Figure B-22.**

Table B-8. North Fork John Day River inflows from tributaries to simulate natural flows

Inflow	Calibration factor
Trail, Middle Fork John Day, Desolation, Camas, Cottonwood, Granite, Big, Potamus, Crane, Ditch, Stony, Mallory, Texas Bar Creeks	Ratio between OWRD estimate and current flow on August 1
Big Wall Creek	Current flow multiplied by 0.8
Meadow Brook	Current flow doubled
Trail, Granite, Big	Current or estimate of flow was multiplied by 2 to 6 or flow was added directly during June and parts of July.

Figure B-21. Comparison of TMDL-input natural flow for the North Fork John Day River flow (blue lines) at several points with estimated natural flows (OWRD 2002). The OWRD estimated natural flows (red lines) represent the 50% exceedance stream flow.



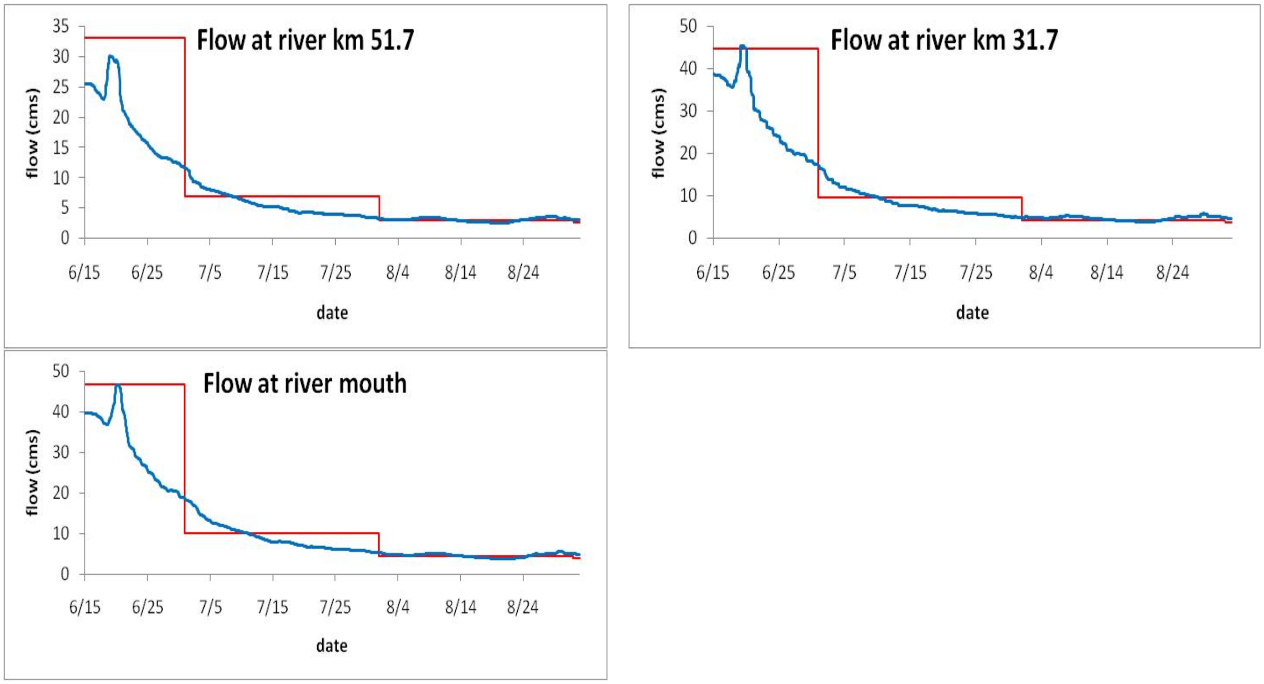
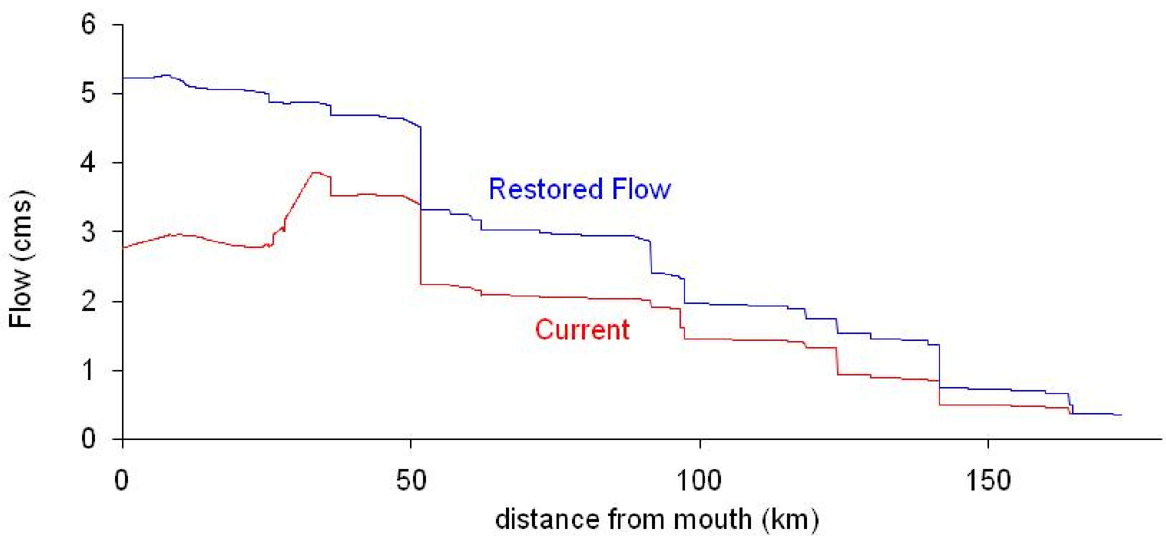


Figure B-22. Longitudinal profiles of predicted flows for scenarios which considered flow alterations on North Fork John Day River for 8/1/2002. Model results produced every 100 m.



"Restored Morphology" Scenario

To test the sensitivity of river temperature to morphological changes, five scenarios were run with the bankfull widths incrementally decreased from 10% to 50% downstream of Reichman Canyon (rkm 39.00). **Section 2** includes schematic illustrations of the channel scenarios. On other model corridors in the Basin, we simulated the 10-50% reduction range along the entire model reach. The North Fork is treated differently. This is because we believe that the upper river, from somewhere between Desolation Creek and Reichman Canyon upstream to the headwaters, may not have potential to narrow. Part of the area is Wilderness Area, and below the Wilderness, wide-scale restoration (USFS) and associated monitoring indicates that recovery did not lead to a net reduction in channel width. Downstream of Hwy 395 (rkm

93.85) and upstream of Reichman Canyon (rkm 39.00), the bankfull widths were decreased by the percent shown in **Table B-9**. When changing bankfull widths, the shade provided by the vegetation and flow in the morphology scenarios do not vary widely from current conditions (**Figure B-23** and **Figure B-24**). A 10% - 50% channel width reduction results in a range of average decreases in temperature from 0.2 °C – 0.5 °C (**Figure B-25**).

Table B-9. NFJDR morphology scenario bankfull width reductions by river km.

	Percent by which bankfull widths were reduced		
Name of scenario	Headwaters to rkm 93.85	rkm 93.85 to rkm 39.00	rkm 39.00 to mouth
Morph10	0	10	10
Morph20	0	10	20
Morph30	0	20	30
Morph40	0	20	40
Morph50	0	30	50

Figure B-23. Range of percent effective shade on August 1 resulting from various channel width reductions. Model results produced every 100 m.

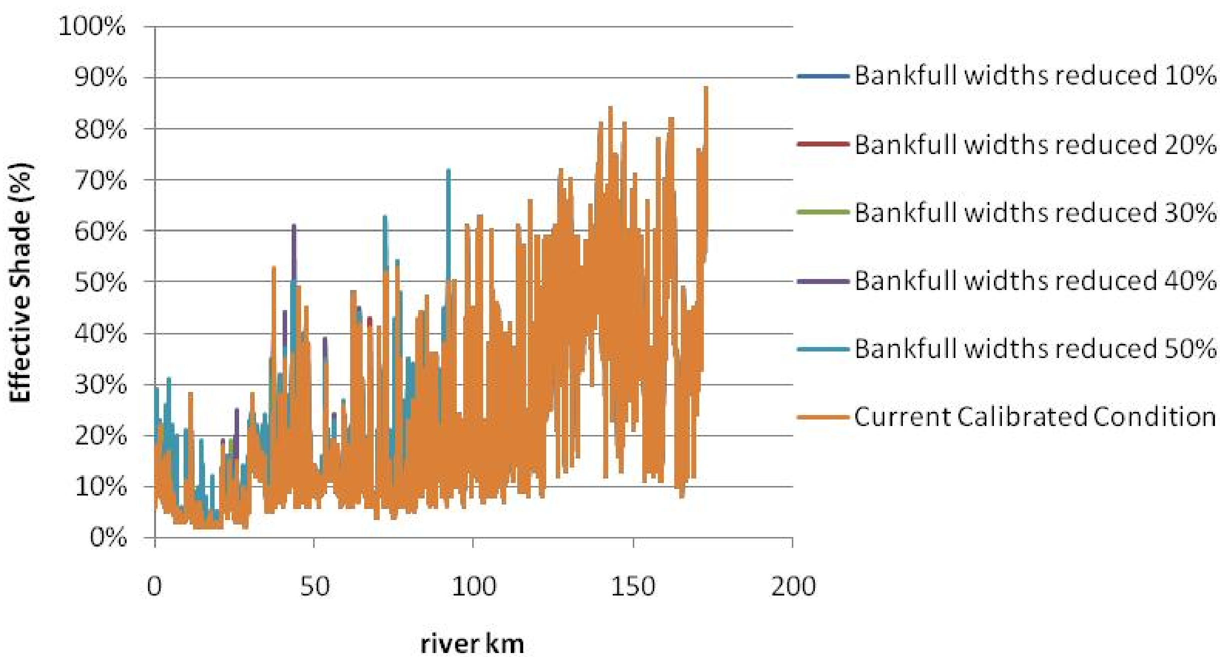


Figure B-24. Range of flows on August 1 resulting from various channel width reductions. Model results produced every 100 m.

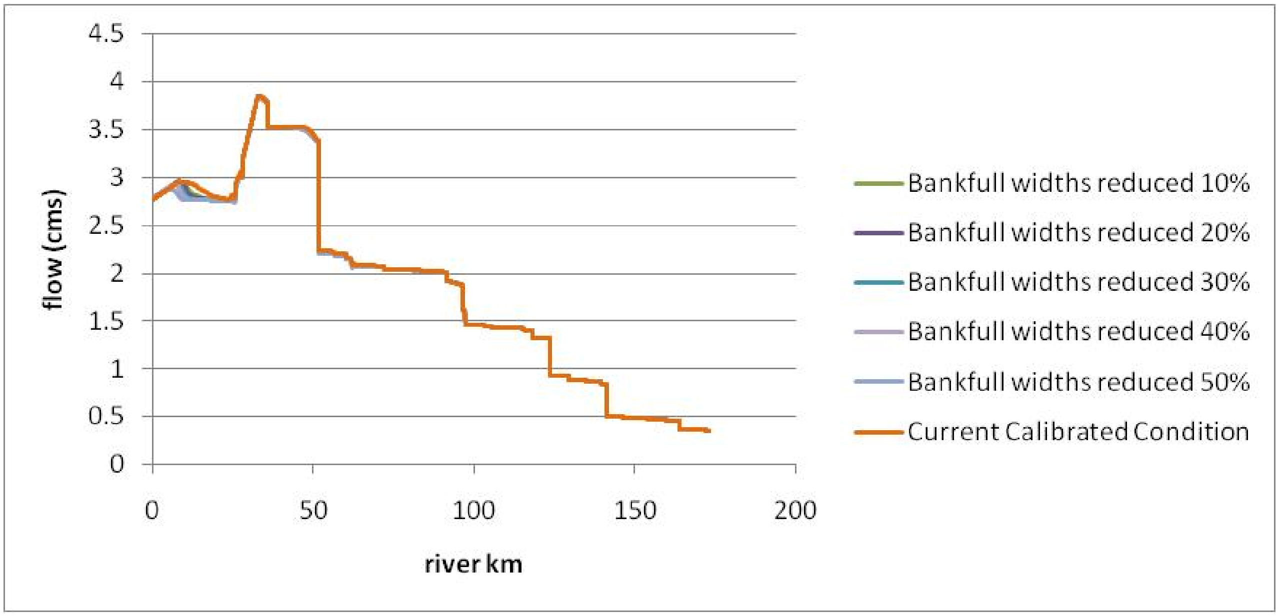
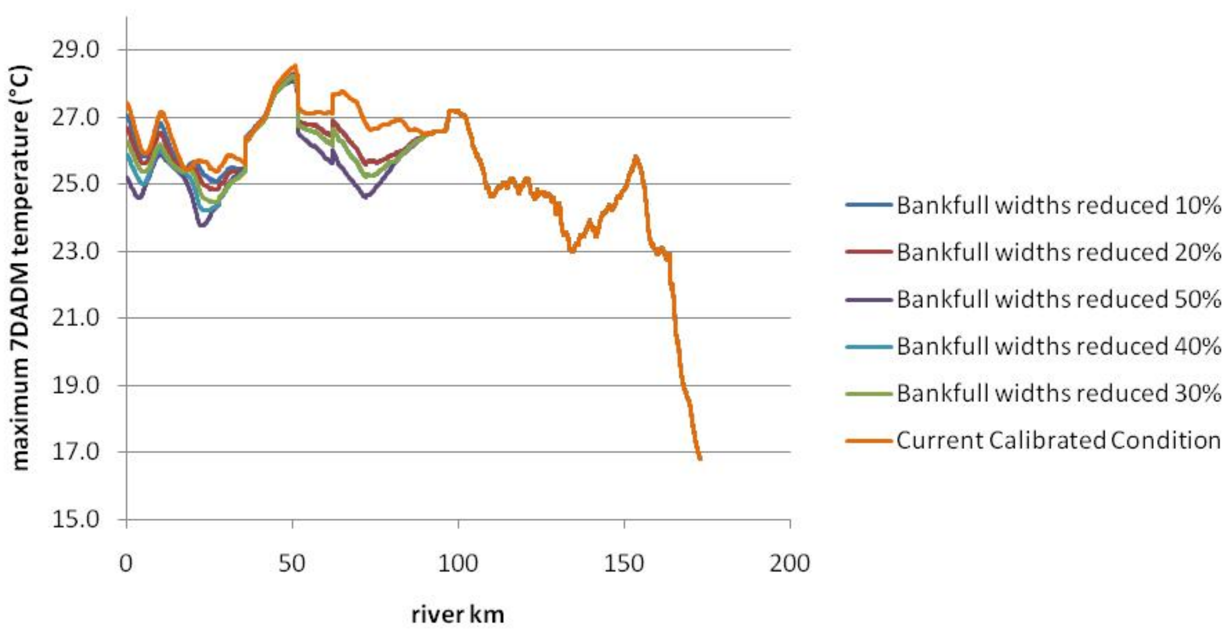


Figure B-25. Range of maximum 7DADM temperatures during the model period resulting from various channel width reductions. Model results produced every 100 m.



Natural Condition Criteria

As described previously, the NTP model inputs included the restored flow and vegetation parameter values, and each of the potential morphological scenarios was represented. Within the Wilderness reach, the vegetation was left at existing conditions. The Middle Fork John Day River outputs (temperature and flow) from its NTP scenario were used to estimate temperature and flow of the tributary to the North Fork model. The Middle Fork NTP scenario used was the bankfull widths reduced by 30% and no hyporheic flow added. No other temperature adjustments were made to tributary inputs. The effective shade and flow results on August 1 from the range of morphological scenarios are shown in **Figure B-26** and **Figure B-27** . The range of NTP maximum 7DADM temperatures during the model period is shown in **Figure B-28**. The 30% width reduction scenario was used to represent the average NTP values when only one NTP scenario was required. In order to compare 7DADM temperatures corresponding to the individual potential vegetation, flow and morphological scenarios with the full NTP scenario at 30% width reduction, refer to **Figure B-18**.

Figure B-26. Range of percent effective shade on August 1 resulting from various channel width reductions under NTP conditions. Model results produced every 200 m.

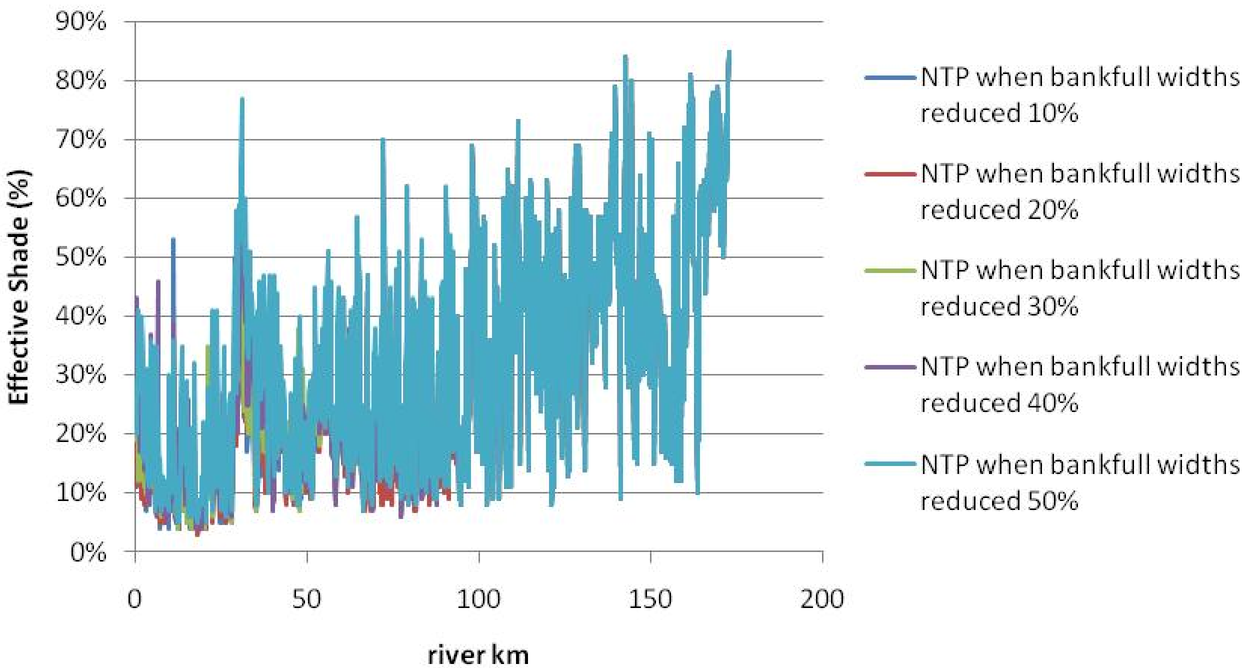


Figure B-27. Range of flows on August 1 resulting from various channel width reductions under NTP conditions. Model results produced every 200 m.

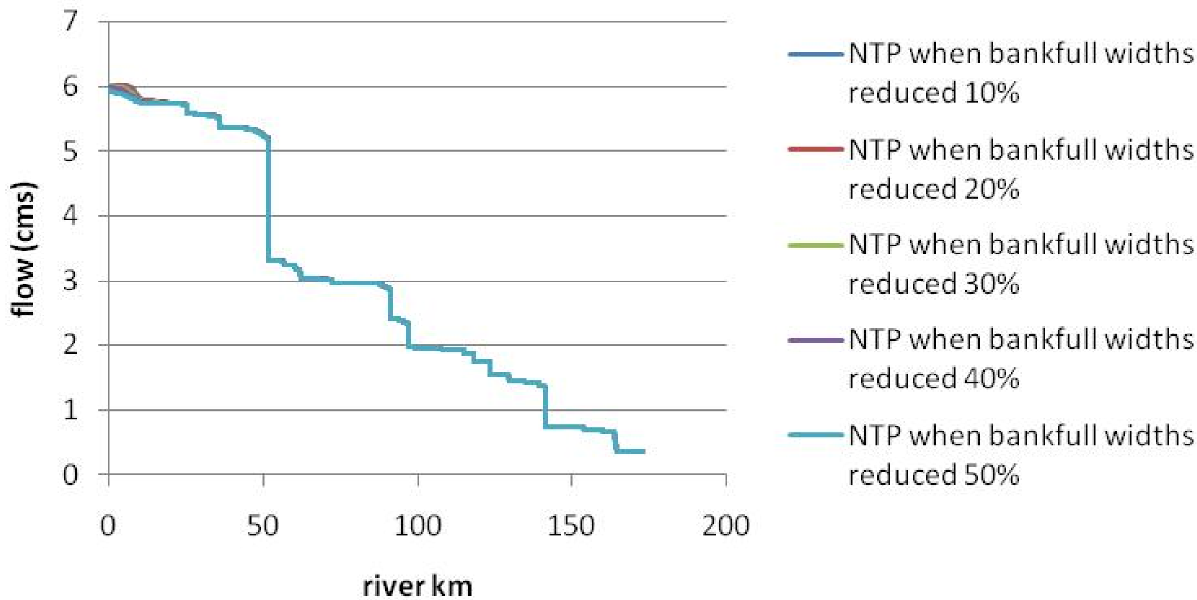
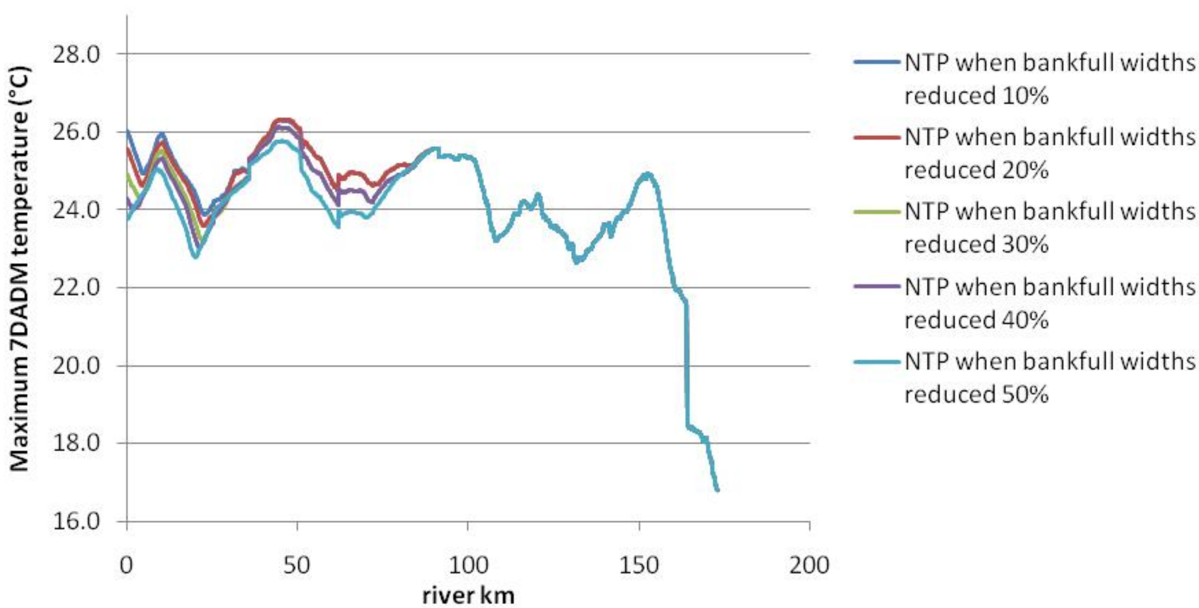


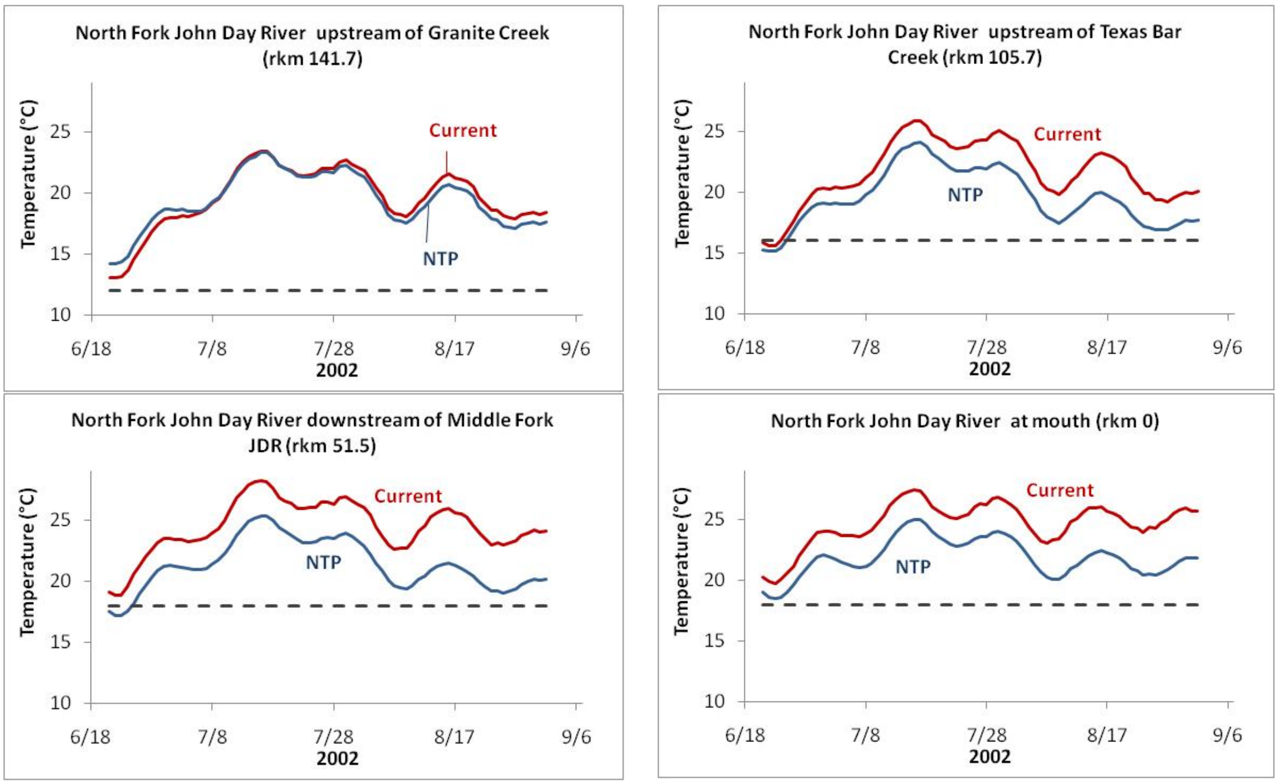
Figure B-28. Range of maximum 7DADM temperatures during the model period under NTP conditions. Model results produced every 200 m.



Temporal Variability

The water quality temperature standard has several criteria which vary in time and space. The suite of biologically based criteria and the natural condition criterion, as well as the 'protecting cold water' criterion, all have relevance in this TMDL. Determining which criteria are applicable sometimes depends on whether NTP exceeds biologically based criteria. As described in **Chapter 2**, for this TMDL, the natural condition criteria is invoked at the Basin scale. This provides for load allocations that address nonpoint source heating throughout the basin as well as enabling natural temperatures on the modeled corridors where the natural condition criteria clearly applies through much of the river length. However, for point sources located where NTP is less than biologically based criteria, the biologically based criteria may be applied if it does not impede criteria attainment where NTP is applicable, or at times when NTP has not been determined. Comparisons of time series at several points are below (**Figure B-29**). No scenarios were run during the spawning time period. For further discussion, refer to **Chapter 2**.

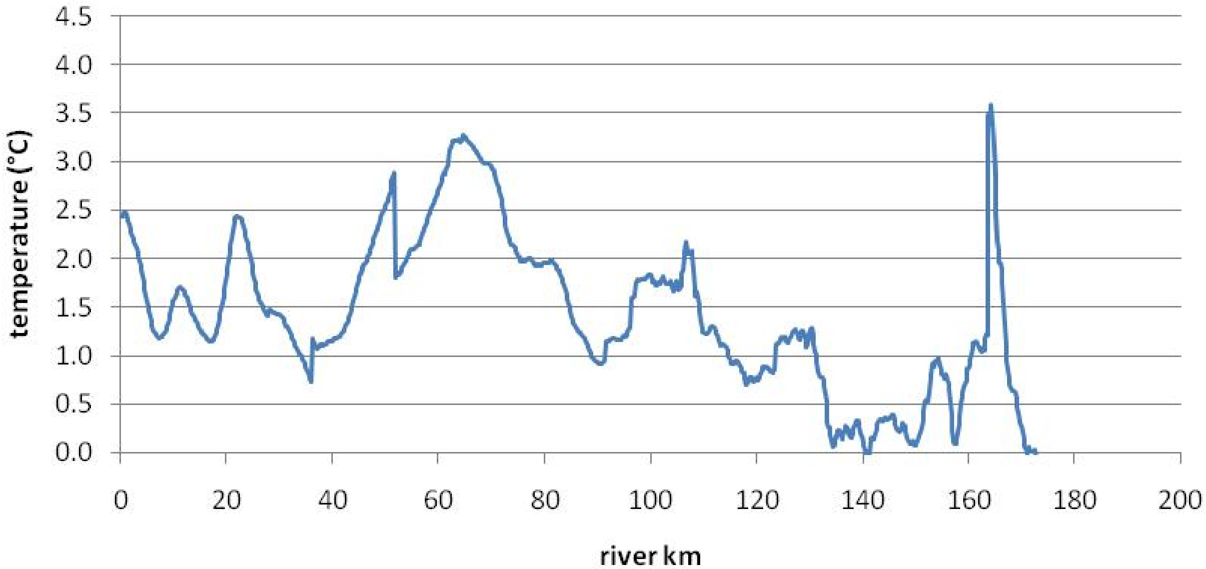
Figure B-29. Comparison of 'current', natural thermal potential (NTP) and the biologically based criteria (dashed line) at four locations on the North Fork John Day River using the rolling 7DADM during the model period.



Divergence from standard

The differences between the maximum 7DADM current temperatures and the applicable criteria in the water quality temperature standard are shown in (**Figure B-30**). The areas with the largest differences could merit prioritized restoration opportunities.

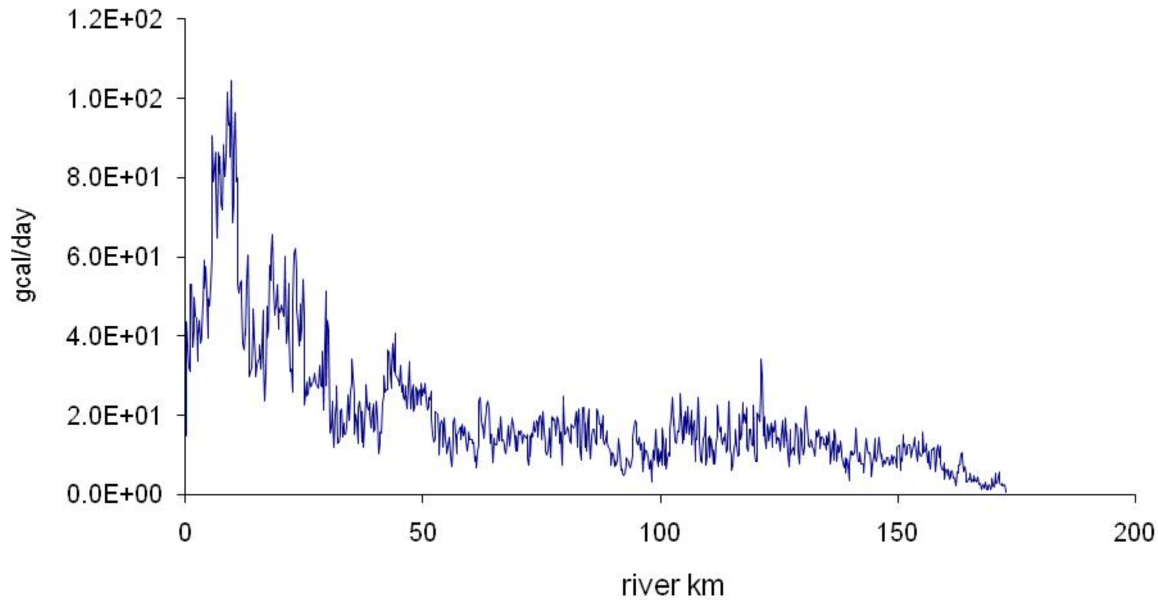
Figure B-30. Differences between the current maximum 7DADM temperature during the modeled period and applicable criterion. Current model results produced every 100 m and average to every 200 m. NTP model results produced every 200 m.



Background solar load

The natural background solar load is the amount of solar radiation received immediately above the stream surface area under NTP conditions. To calculate this figure, at each modeled interval, the average daily solar radiation flux immediately above the stream surface was multiplied by the wetted width under NTP conditions and converted to a daily solar load. On July 1, 2002, the modeled North Fork John Day River received an average daily solar load according to **Figure B-31**. In total, the modeled North Fork John Day River received a total solar load of 17,459 gcals/day. The natural background solar load is one of the components to determine Loading Capacity of the river.

Figure B-31. North Fork John Day River solar load on July 1, 2002. Model results produced every 200 m.



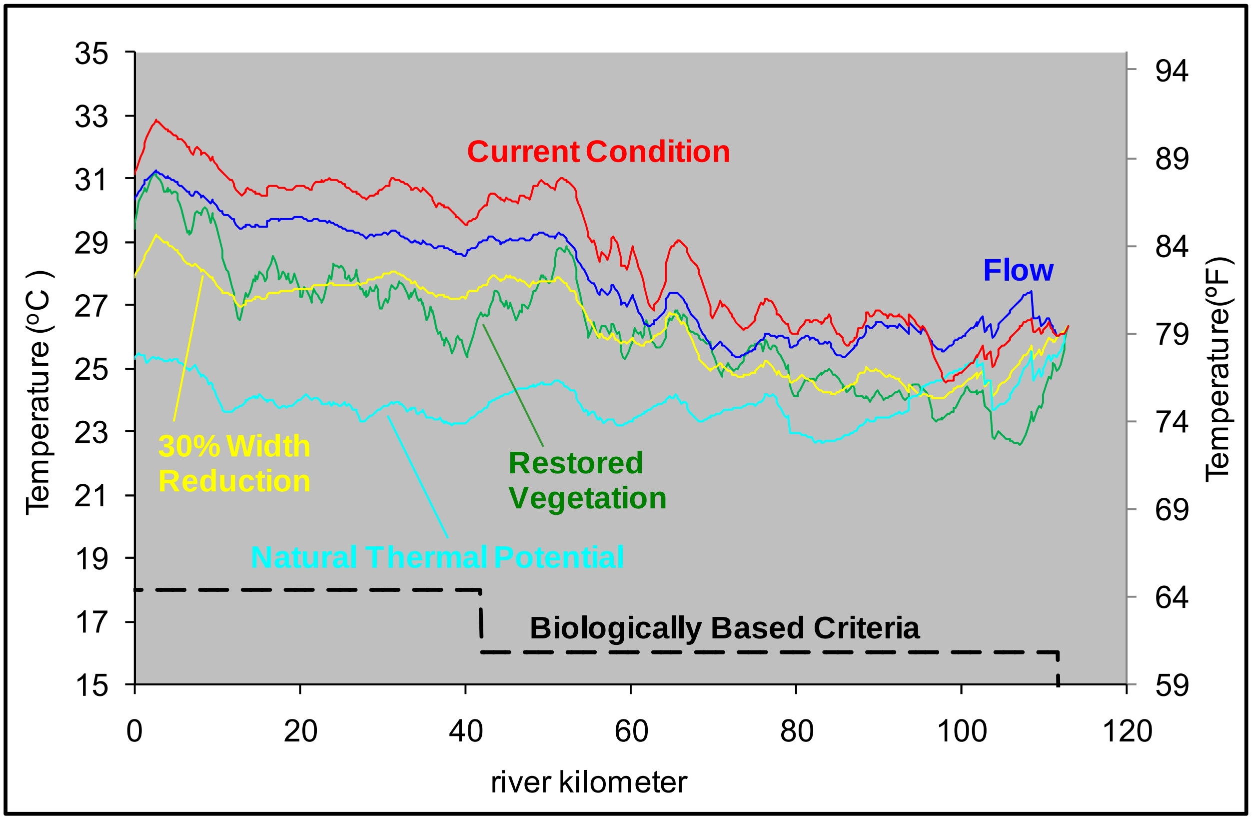
6.3 Middle Fork John Day River

The Heat Source model was used to predict the influence of various factors on stream temperature in the Middle Fork John Day River. The model setup was the same as described in the current calibrated conditions in **Appendix A**, except as described in **Table B-10**. Further discussion of the scenarios is provided below. The maximum 7DADM temperatures during the model period resulting from various John Day River scenarios are shown in **Figure B-32**. The model predicts that NTP temperatures are warmer than the biologically-based criteria along the entire river during the model period and therefore the natural condition criteria applicability is established, for the warm season. Other criteria still apply, for instance in seasons where modeling was not conducted – this is primarily relevant to point sources, as discussed in **Chapter 2** of the main document.

Table B-10. Simulated Scenario Definitions

"Current"	Current Calibrated Condition (see **Appendix A** for details). Model results were produced every 0.5 min and 200 m. The model extent was 112.95 km.
"Restored Vegetation"	System Potential Vegetation and increased hyporheic exchange in meadow reaches (see **Section 2** and below for details).
"Restored Flow"	No points of diversion or ditch inputs and tributary flows adjusted to OWRD's estimates of natural flow (see **Section 3** for details)
"Restored Morphology"	Bankfull widths reduced by 10-50% while cross sectional area preserved (see **Section 4** for details).
"NTP"	Natural Thermal Potential: combining the inputs of system potential vegetation, natural stream flow, and range of reduced bankfull width estimates (see **Section 5** for details). Hyporheic flow restored in meadow reaches. No other temperature adjustments were made to tributary inputs.
"Pre-restoration"	Scenario estimating instream temperatures before major current restoration projects were started.
"Post-restoration"	Scenario estimating instream temperatures when major current restoration projects near natural thermal potential.

Figure B-32. Predictions for Middle Fork John Day River scenarios for the maximum 7DADM during the model period, 2002. Model results produced every 200 m.



"Restored Vegetation" Scenario

The natural potential vegetation within the riparian corridor is assigned according to the methodology described in **Section 2**. As described in **Section 2**, natural potential vegetation was assigned based on EP Types, based on valley form and ecoregion. EP Type reach breaks were established for the modeled rivers. Breaks were located at each ecoregion boundary, and further delineated by valley form determination based on 10-m DEM assessment. The resultant reaches are listed in **Table B-11** and mapped in **Figure B-33.** The Middle Fork John Day River is expected to have reaches of wetland meadow complexes which were identified based on gradient, valley form and current and historical conditions (see **Appendix C**). The meadow complexes were incorporated into the restored vegetation model scenario. A large restored meadow is expected to have an increase in hyporheic flow. To simulate this, the percent of flow moving through the hyporheic zone was increased from 0% to 1% (of stream flow at each model input node) per 200 meters in the meadow reaches. **Figure B-34** shows the potential percent shade and corresponding daily average solar flux simulated by this vegetation scenario. The solar flux is the solar radiation that reaches the stream and is inversely proportional to percent effective shade.

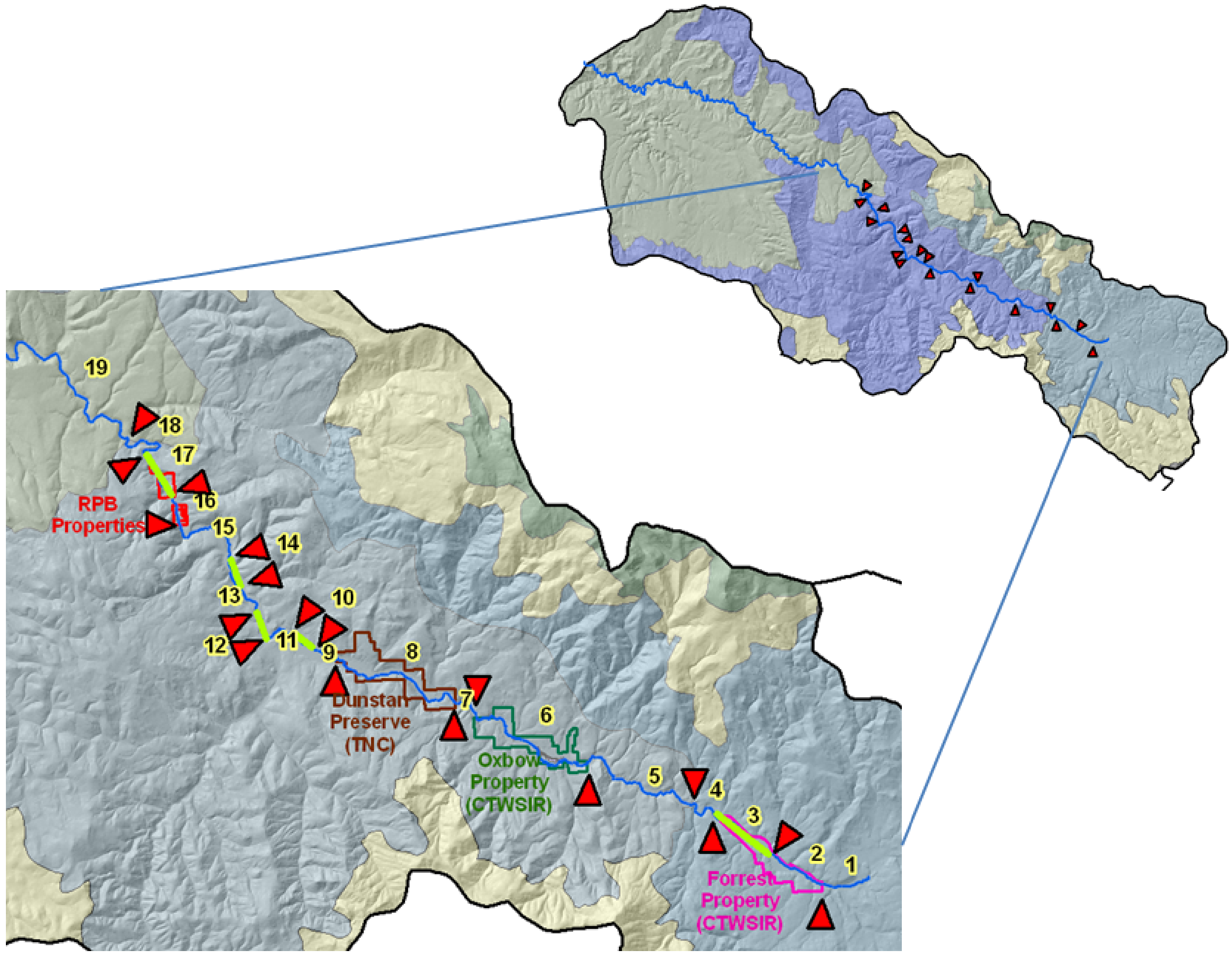
Table B-11. Middle Fork John Day River Potential vegetation by reach (reach identification numbers correspond to those in Figure B-33)

	Middle Fork John Day River, classified into reaches based on ecoregion, valley gradient and subtype breaks								
Reach ID #	Upper node	Lower node	Model node range (meters from mouth)		Level 4 Ecoregion	Valley sub-type	Ecoregion-Physiographic Type	Land Cover Height in meters (stream length in %)	Foliage Density (%)
1	model boundary	top of CTWSIR Forrest Property	112950	110650	11d	D	49.5	24.7 (100)	80
2	top of CTWSIR Forrest Property	top of valley gradient <0.3%	110600	107850	11d	A	47.5	16.3 (100)	90
3*	top of valley gradient <0.3%	bottom of CTWSIR Forrest Property & bottom of valley gradient < 0.3%	107800	104300	11d	A	64	0.7 (100)	90
4	bottom of CTWSIR Forrest Property & bottom of valley gradient < 0.3%	ecoregion transition	104250	102500	11d	D	49.5	24.7 (100)	80
5	ecoregion transition	top of CTWSIR Oxbow Property	102450	96600	11b	D	11	21.9 (100)	80
6	top of CTWSIR Oxbow Property	bottom of CTWSIR Oxbow Property	96550	89850	11b	A	8.5	13.1 (100)	85
7	bottom of CTWSIR Oxbow Property	top of TNC Dunstan Property	89800	88450	11b	D	11	21.9 (100)	80
8	top of TNC Dunstan Property	bottom of TNC Dunstan Property	88400	82050	11b	A	8.5	13.1 (100)	85
9	bottom of TNC Dunstan Property	top of valley gradient <0.3%	82000	81000	11b	A	8.5	13.1 (100)	85
10*	top of valley gradient <0.3%	bottom of valley gradient < 0.3%	80950	79750	11b	A	64	0.7 (100)	90
11	bottom of valley gradient < 0.3%	top of valley gradient <0.3%	79700	78550	11b	D	11	21.9 (100)	80
12*	top of valley gradient <0.3%	bottom of valley gradient < 0.3%	78500	77200	11b	D	64	0.7 (100)	90
13	bottom of valley gradient < 0.3%	top of valley gradient <0.3%	77150	75650	11b	D	11	21.9 (100)	80
14*	top of valley gradient <0.3%	bottom of valley gradient < 0.3%	75600	74300	11b	A	64	0.7 (100)	90
15	bottom of valley gradient < 0.3%	top of RPB property	74250	70750	11b	D	11	21.9 (100)	80
16	top of RPB property	top of valley gradient <0.3%	70700	69350	11b	A	8.5	13.1 (100)	85
17*	top of valley gradient <0.3%	bottom of RPB property, bottom of valley gradient < 0.3%	69300	67100	11b	A	64	0.7 (100)	90
18	bottom of valley gradient < 0.3%	ecoregion transition	67050	64450	11b	D	11	21.9 (100)	80
19	ecoregion transition	mouth	64400	0	11a	D	8	27.4 (80)	85
								2.5 (20)	85

green shading indicates areas undergoing broad scale restoration

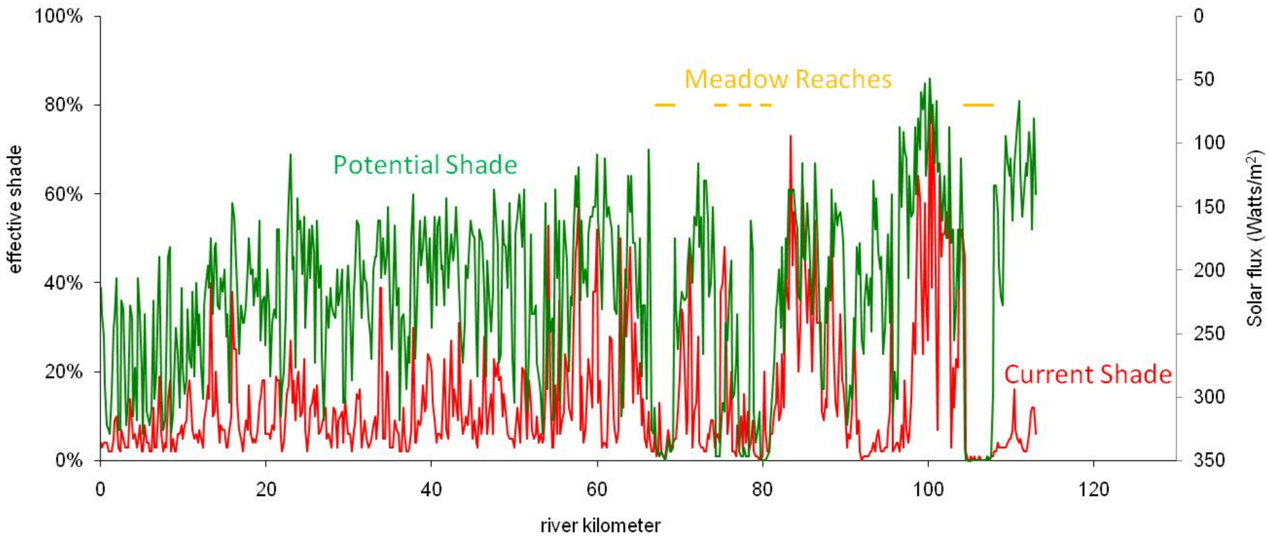
* wetland meadow complex

Figure B-33. Middle Fork John Day River potential vegetation reaches



Under the system potential vegetation scenario, effective shade was increased by an average of 24% (**Figure B-34**). Wetland meadow complexes are clearly represented along the longitudinal profile.

Figure B-34. Middle Fork John Day River comparison of current and potential shade and corresponding daily average solar flux on August 1. Model results produced every 200 m.



"Restored Flow" Scenario

In order to provide a better estimate of natural thermal potential, estimates of natural flow inputs to the John Day River from its tributaries were derived as discussed in **Section 3**. All points of diversion (described in **Appendix A**) were eliminated. To supply the volume of water from the tributaries, commensurate with the OWRD monthly estimates of natural flow instream, the tributary flows were increased by calculating the ratio between the OWRD estimate of natural flow to the current flow rate on August 1, then applying that ratio to each daily flow during the model period (**Table B-12**). OWRD did not estimate natural flow for several tributaries. For these tributaries, the current flow was doubled as an estimate of natural flow. The calibration flows, representing natural river processes of gaining and losing reaches, were also doubled. In general, these adjustments to flow made the instream monthly flow estimates from OWRD match the predicted results from the model scenario. In addition, all points of diversion were eliminated. These model inputs resulted in the instream flows at four points on the Middle Fork John Day River shown in **Figure B-35**. The longitudinal profile of predicted flows is presented in **Figure B-36**.

Table B-12. Middle Fork John Day River inflows from tributaries to simulate natural flows

Inflow	Calibration factor
Granite, Slide, Indian, Big, Camp, Big Boulder, Granit Boulder, Vinegar, Clear Creeks	Ratio between OWRD estimate and current flow on August 1
Bridge, Davis, Vincent, Dead Cow, TIR pool, Deerhorn, Little Boulder, Little Butte, Hunt, Butte, Ruby, Beaver, Ragged, Dry, Dunston, Gibbs, Quartz, Deep, Armstrong, Big, Huckleberry, Cross Hollow, Hansen Canyon, Lick, Flower, Spring (LB), Upper Ritter H.S., Ritter Hot Springs, Long, Spring Complex (LB) Creeks	Current flow doubled
Calibration flows	Current flow doubled

Figure B-35. Comparison of TMDL-input natural flow for the Middle Fork John Day River flow (blue lines) at several points with estimated natural flows (OWRD 2002). The OWRD estimated natural flows (red lines) represent the 50% exceedance stream flow.

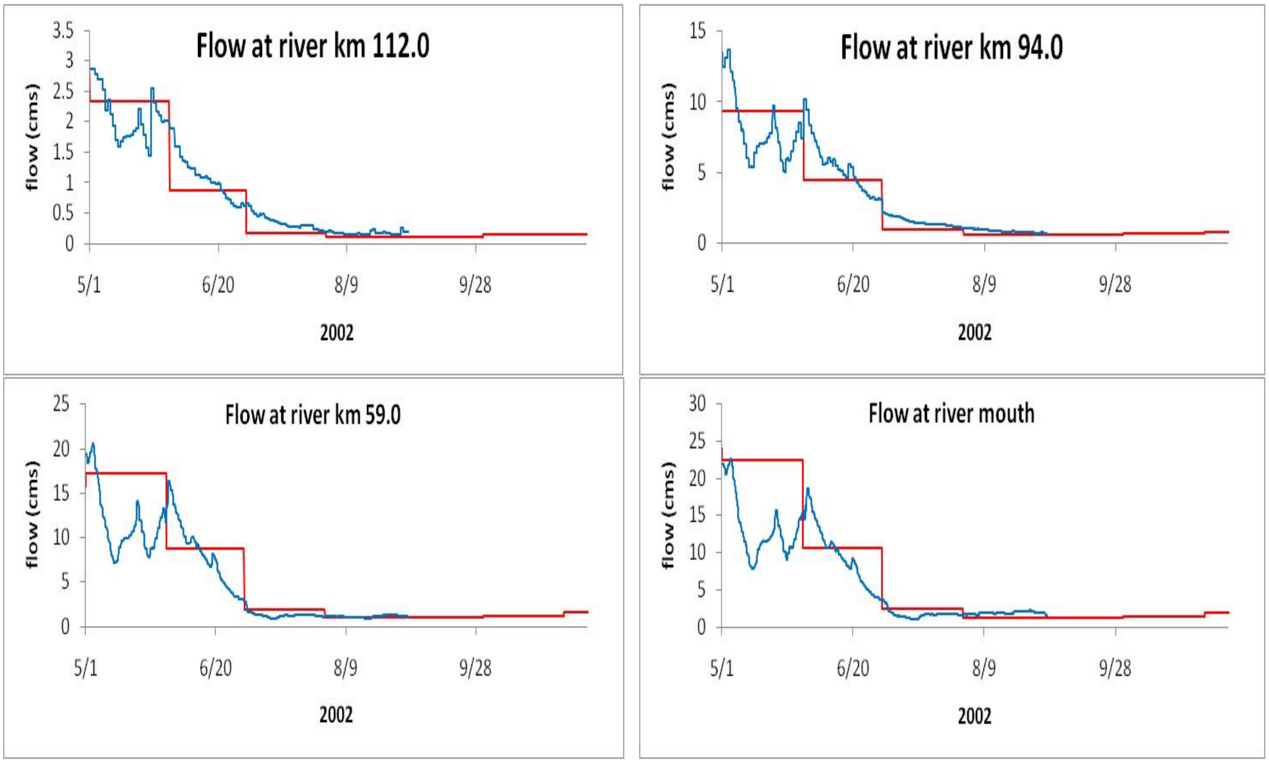
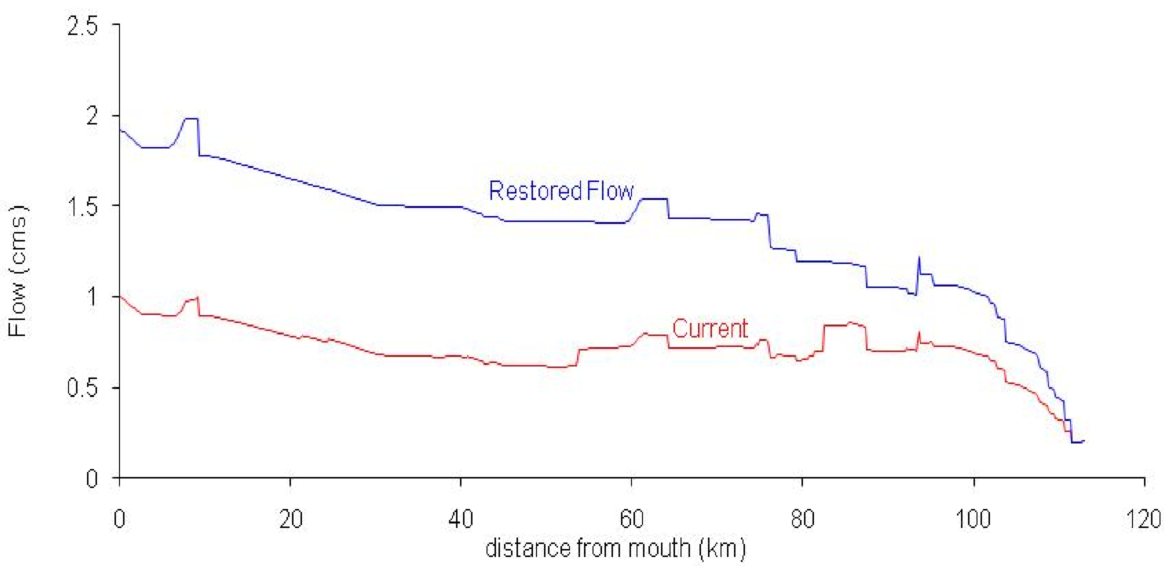


Figure B-36. Estimated natural flow potential compared to current flow conditions along the Middle Fork John Day River on 8/1/2002. Model results produced every 200 m.



"Restored Morphology" Scenario

To test the sensitivity of river temperature to morphological changes, five scenarios were run with the bankfull widths incrementally decreased from 10% to 50% (**Section 4**). When changing the bankfull widths, the shade provided by the vegetation and the flow in the morphology scenarios do not vary widely from current conditions (**Figure B-37** and **Figure B-38**, selected dates). A 10% - 50% channel width reduction results in a range of average decreases in maximum 7DADM temperatures during the model period from 1.3 °C – 3.8 °C, respectively (**Figure B-39**).

Figure B-37. Range of percent effective shade on August 1 resulting from various channel width reductions. Model results produced every 200 m.

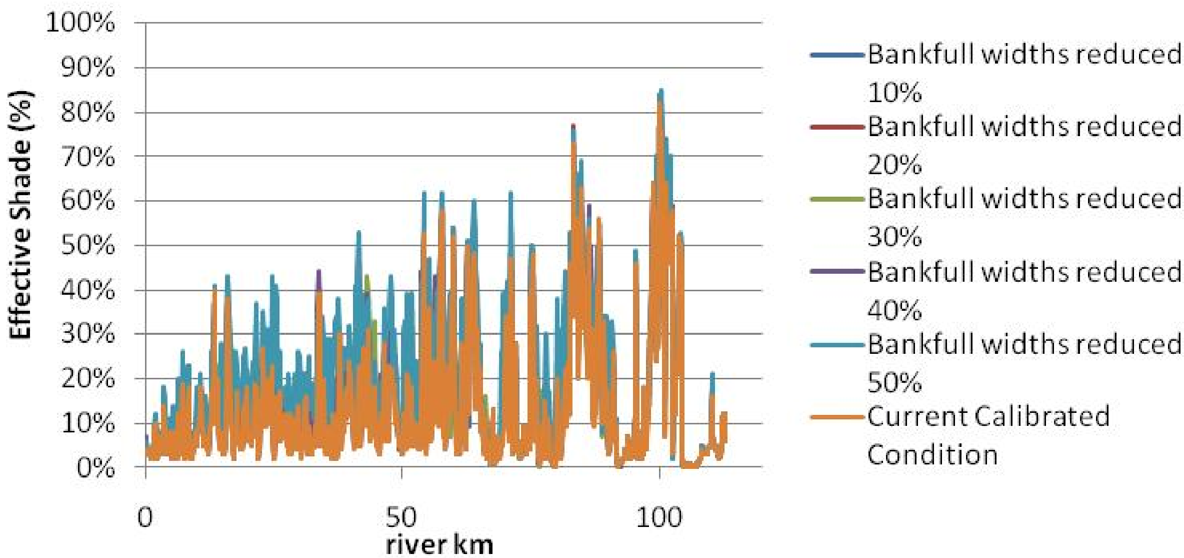


Figure B-38. Range of flows on August 1 resulting from various channel width reductions. Model results produced every 200 m.

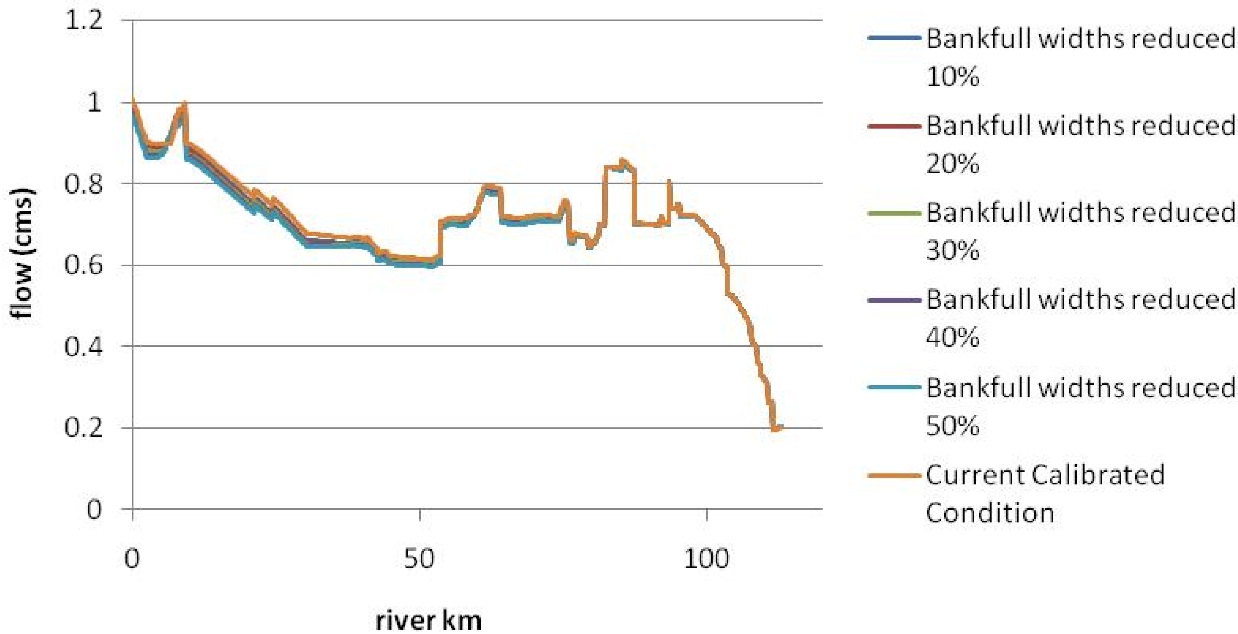
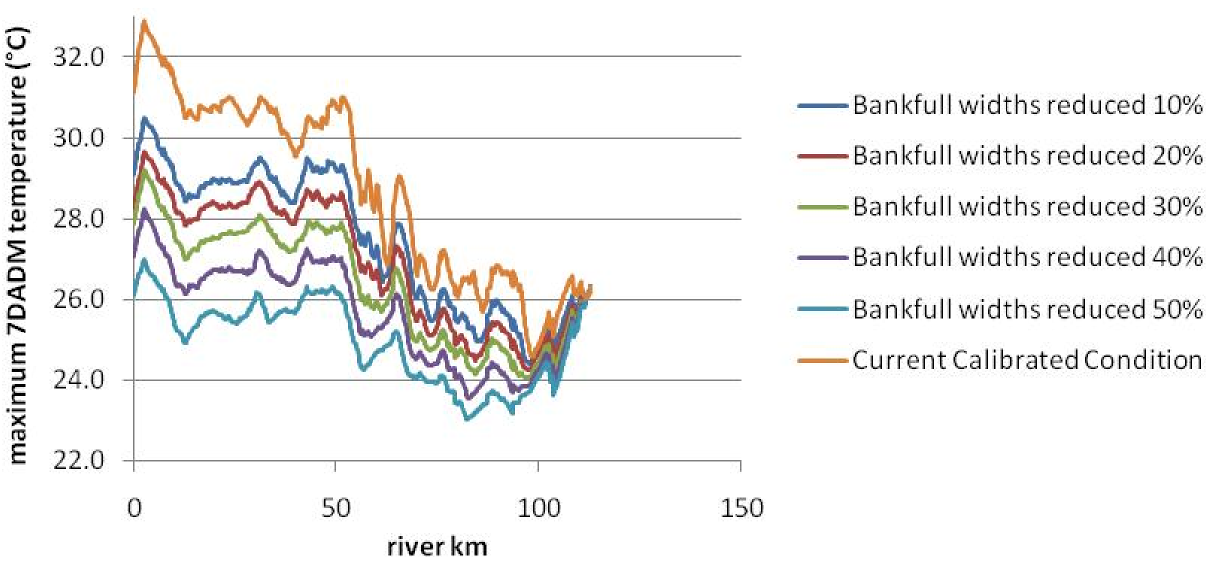


Figure B-39. Range of maximum 7DADM during the modeled period resulting from various channel width reductions. Results presented every 200 m.



Natural Condition Criteria

As described previously, the NTP model inputs includes the restored flow and vegetation parameter values, and each of the potential morphological scenarios is represented. When the channel is in its natural condition, the meadow reaches are expected to have increased hyporheic flow through them. The percent hyporheic exchange was increased modestly from 0% to 0.1% per 200 meters through the potential meadows. The effective shade and flow results on August 1 from the range of morphological scenarios are shown in **Figure B-40 and Figure B-41**. The range of NTP maximum 7DADM temperatures during the model scenario is shown in **Figure B-42**. The 30% width reduction scenario was used to represent the average NTP values when only one NTP scenario was required. In order to compare the 7DADM temperatures corresponding to individual potential vegetation, flow and morphological scenarios with the full NTP scenario at 30% width reduction, refer to **Figure B-32.**

Figure B-40. Range of percent effective shade on August 1 resulting from various channel width reductions under NTP conditions. Model results produced every 200 m.

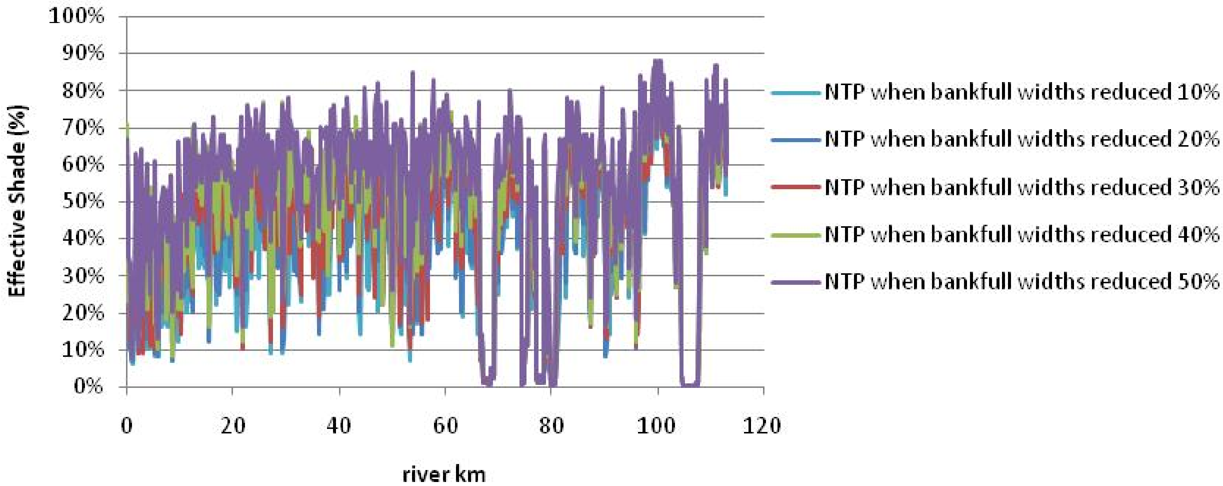


Figure B-41. Range of flows on August 1 resulting from various channel width reductions under NTP conditions. Model results produced every 200 m.

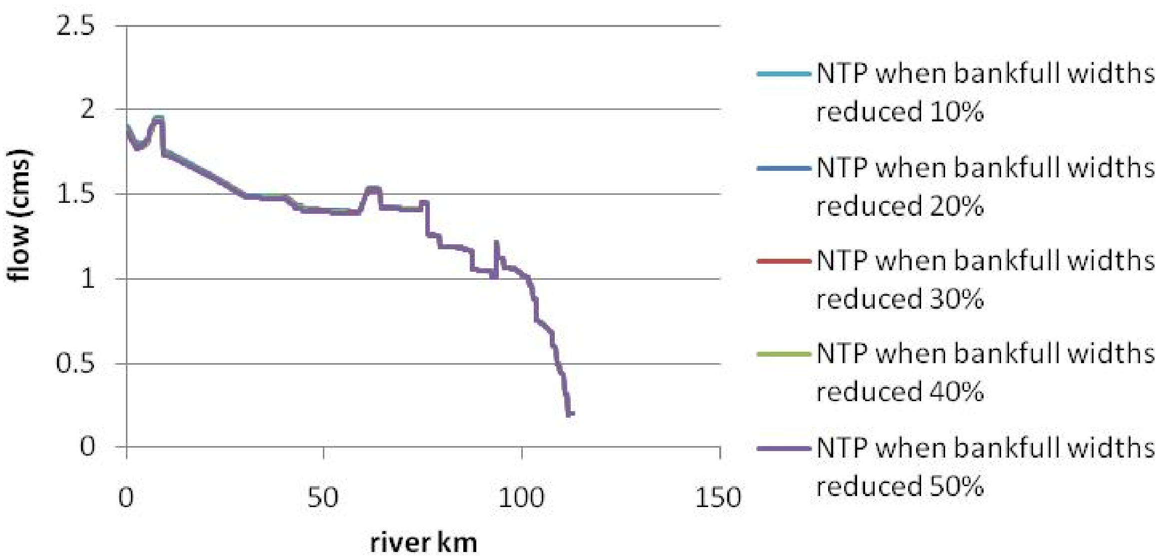
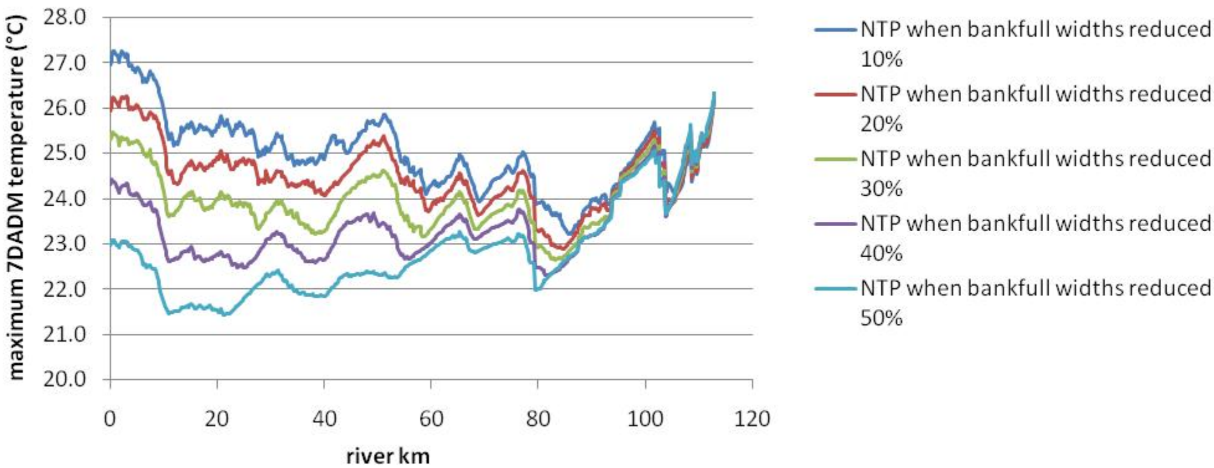


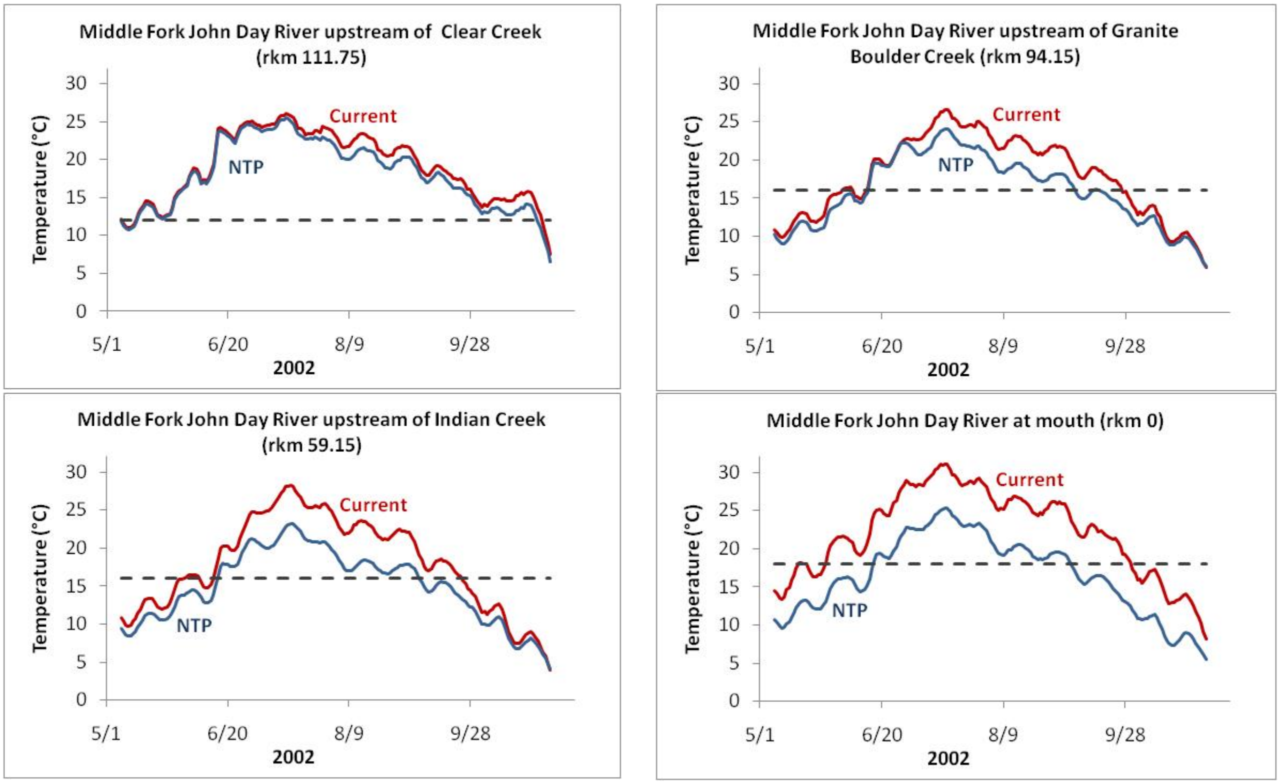
Figure B-42. Range of maximum 7DADM temperatures during model period under NTP conditions. Model results produced every 200 m.



Temporal Variability

The water quality temperature standard has several criteria which vary in time and space. The suite of biologically based criteria and the natural condition criterion, as well as the 'protecting cold water' criterion, all have relevance in this TMDL. Determining which criteria are applicable sometimes depends on whether NTP exceeds biologically based criteria. As described in **Chapter 2**, for this TMDL, the natural condition criteria is invoked at the Basin scale. This provides for load allocations that address nonpoint source heating throughout the basin as well as enabling natural temperatures on the modeled corridors where the natural condition criteria clearly applies through much of the river length. However, for point sources located where NTP is less than biologically based criteria, the biologically based criteria may be applied if it does not impede criteria attainment where NTP is applicable, or at times when NTP has not been determined. Comparisons of time series at several points are below (**Figure B-43**). No scenarios were run during the spawning time period. For further discussion, refer to **Chapter 2**.

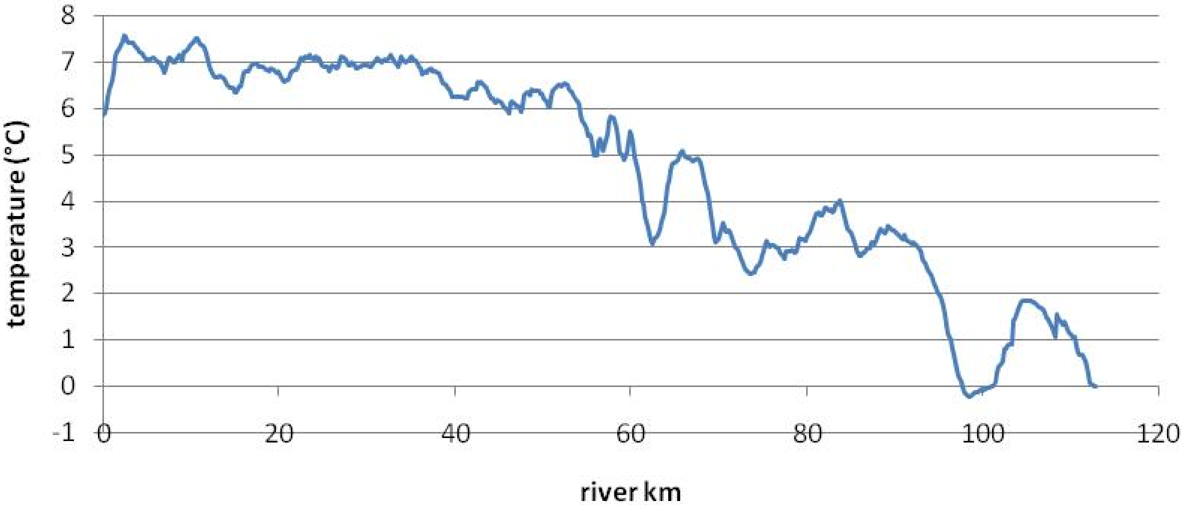
Figure B-43. Comparison of 'current', natural thermal potential (NTP) and the biologically based criteria (dashed line) at four locations on the Middle Fork John Day River using the rolling 7DADM.



Divergence from standard

The differences between the maximum 7DADM current temperatures and the applicable criteria in the water quality temperature standard are shown in (**Figure B-44**). The areas with the largest differences could merit prioritized restoration opportunities.

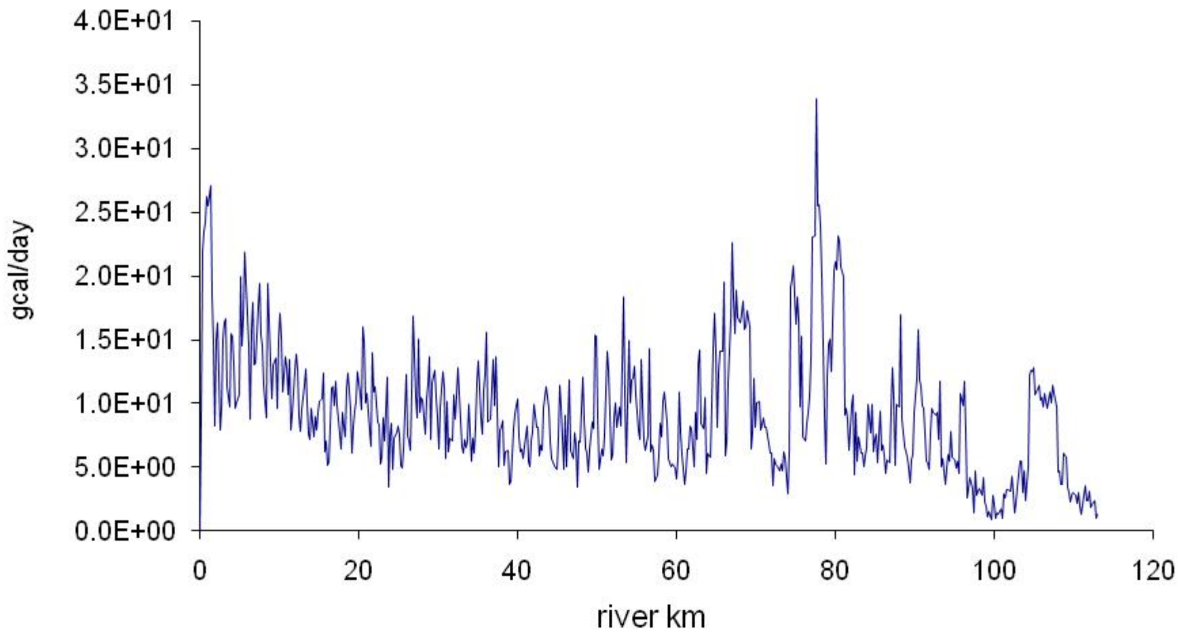
Figure B-44. Differences between maximum 7DADM temperature current temperature and applicable criterion during the modeled period.



Background solar load

The natural background solar load is the amount of solar radiation received immediately above the stream surface area under NTP conditions. To calculate this figure, at each modeled interval, the average daily solar radiation flux immediately above the stream surface was multiplied by the wetted width under NTP conditions and converted to a daily solar load. On July 1, 2002, the modeled Middle Fork John Day River received an average daily solar load according to **Figure B-45**. In total, the modeled Middle Fork John Day River received a total solar load of 5,248 gcals/day. The natural background solar load is one of the components to determine Loading Capacity of the river.

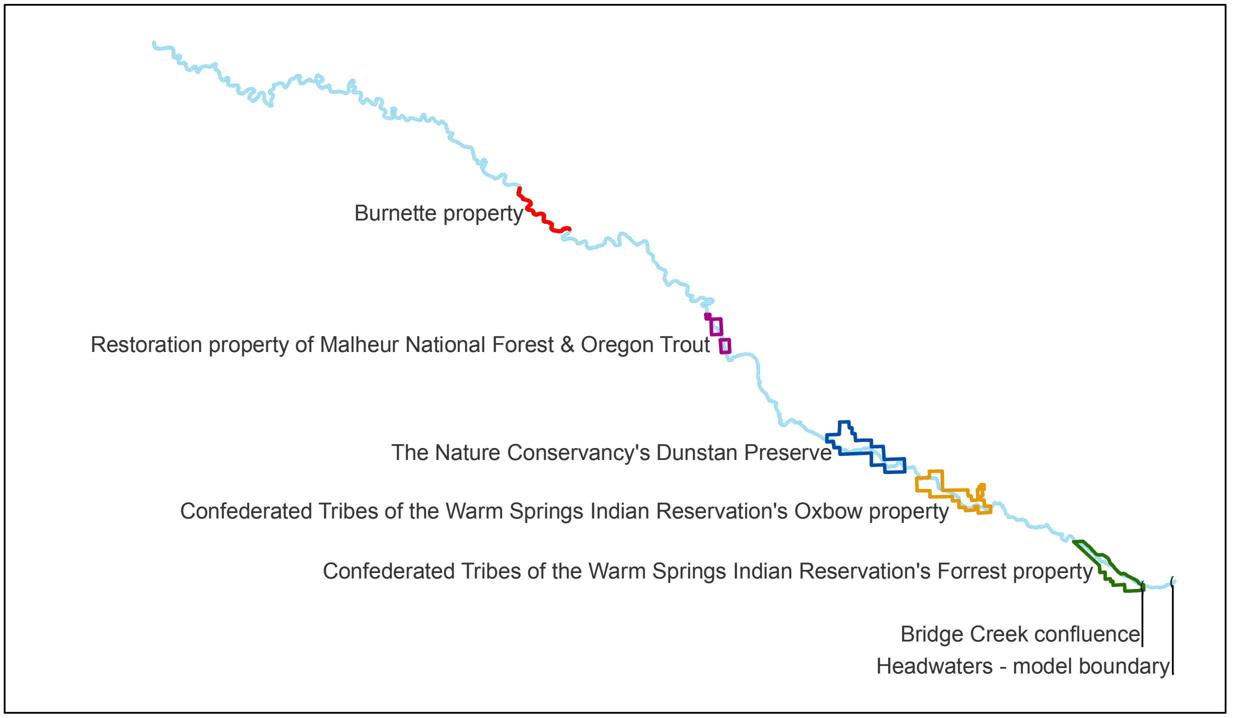
Figure B-45. Middle Fork John Day River solar load on July 1, 2002. Model results produced every 200 m.



"Pre-Restoration" & "Post-Restoration" Scenarios

The "Restoration" scenarios account for several major restoration efforts currently underway in the Middle Fork John Day River. The extent of this scenario's restoration efforts were defined in a GIS layer as shown in **Figure B-46**. The effect these efforts will have on the Middle Fork temperature was estimated by comparing the temperature affect of land use decisions on the specified land parcels 20-40 years before and after the current conditions. It was assumed that 20-40 years ago, the land parcels were bare of vegetation. It was projected that 20-40 years in the future, these land parcels would be approaching natural thermal potential conditions. The Pre- and Post-Restoration scenarios were modeled using climate and flow from the summer of 2002 from 7/1 – 8/15. Results were produced every 0.5 min and 200 m for 112.95 km.

Figure B-46. Spatial extent of restoration properties represented in the model [Middle Fork John Day River from near Austin (lower right) to the mouth (upper left)].



For this scenario, we modified the Current Calibrated Conditions model. We assumed elimination of all vegetation within the "parcels" yielding zero height, density and overhang over the existing channel. This was called the Pre-restoration Scenario. The Post-restoration Scenario replaced all vegetation within the "parcels" from bare earth to Natural Thermal Potential under the 30% bankfull width reduction scenario. In addition, other restoration efforts were represented by changing the temperature and flow of tributaries, boundary conditions and hyporheic flow according to **Table B-13**. The current calibrated conditions model did not include any hyporheic flow. Based on a central Oregon Cascades analog basin (Lookout Creek),S. Wondzell provided rough estimates of the percent of the river flow that would flow through the hyporheic zone every 50 m under natural conditions in the "parcels" (pers. comm. 2009[1]). These estimates of percent hyporheic exchange did not exceed 2.3% hyporheic exchange, and were calculated using the following equation:

$$\text{Percent hyporheic exchange per 50 m} = 16.48e^{-3.8 * \text{instream flow (cms)}}$$

Table B-13. Projects represented in Post-restoration Scenario

Project Name	Approximate river km	Project Description	Represented in Post-restoration Model
Phipps Meadow -- above temperature model upper boundary	112.95	Riparian fencing in 1996	Model boundary temperatures decreased by 2°C
Austin Ranch --	112.95	Instream water rights of 5 CFS	Model boundary flow

[1] Data sources used to relate hyporheic exchange flows to stream discharge are from Kasahara & Wondzell (2003), Wondzell (2006), and Wondzell & Swanson (1996).

1027 acres private land above temperature model upper boundary		dedicated to spring Chinook spawning	increased by 5 CFS
Bates Pond -- 131 acres on Bridge Creek acquired by OSPR 2008	110.70	Remove Bates Pond temperature impacts to Bridge Creek	Bridge Creek temperature inputs to the model changed to data measured by the North Fork John Day Watershed Council, upstream of Bates pond between 7/1 -7/20
Forrest Ranch Conservation Area, acquired by CTWSIR in 2002, 786 acres	104.35-110.60	• riparian fencing 2001 • CREP planting 2007 • Placer to Dead Cow LWD placement and rock jetty removal 2008	Vegetation restored to Natural Thermal Potential & hyporheic flow increased according to S. Wondzell methodology
Oxbow Conservation Area, acquired by CTWSIR in 2001, 1022 acres	89.90-96.55	• riparian fencing 1994 • mine tailing leveling 1994 and 2007 • CREP planting 2007	Vegetation restored to Natural Thermal Potential & hyporheic flow increased according to S. Wondzell methodology
Dunstan Preserve, 1199 acres	82.05-88.40	• livestock exclusion 1993 • Middle Fork LWD placement 2007	Vegetation restored to Natural Thermal Potential & hyporheic flow increased according to S. Wondzell methodology
Restoration property of Malheur National Forest & Oregon Trout (began approximately 2006-2007)	67.80-68.05 68.20-69.45 69.85-70.70	• planned channel relocation upper • conservation easement lower • livestock exclusion	Vegetation restored to Natural Thermal Potential & hyporheic flow increased according to S. Wondzell methodology
Ron Burnett property – 5 miles on right bank of Middle Fork just above Ritter Junction		Riparian fencing	Vegetation restored to Natural Thermal Potential

The modeled restoration efforts currently underway are expected to improve instream maximum 7DADM temperatures during the model period according to **Figure B-47**. Compared to the Current Calibrated Condition, the Pre-restoration scenario showed that before restoration was undertaken on the five parcels with re-vegetation projects, the instream temperatures were higher, particularly around the Dunstan Preserve and the Restoration property of Malheur National Forest and Oregon Trout properties. According to the Post-restoration scenario, when the modeled restoration projects are near natural thermal potential, the rolling 7DADM temperatures will be cooler by an average of 1.2°C during the model period (**Figure B-47**). Substantially greater improvement is seen at the river mouth in the simulation output of **Figure B-48**.

Figure B-47. Longitudinal maximum 7DADM temperatures during model period from restoration scenarios. Model results produced every 200 m.

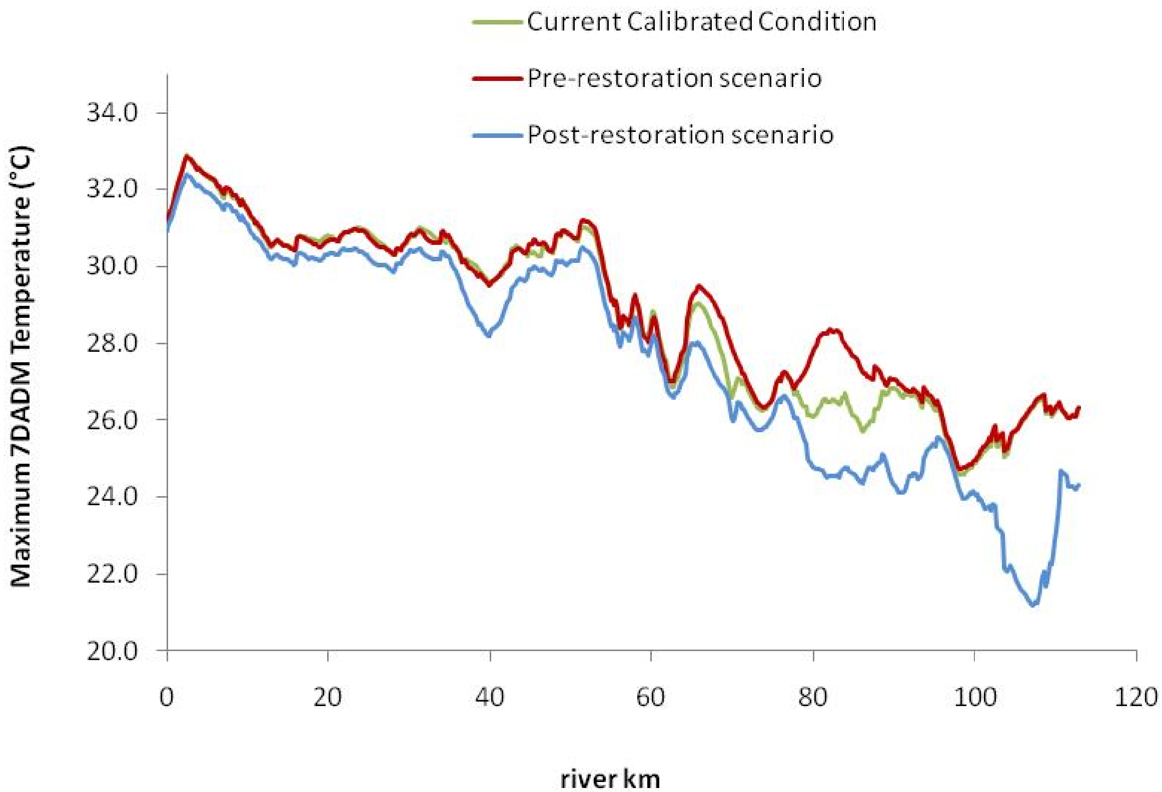
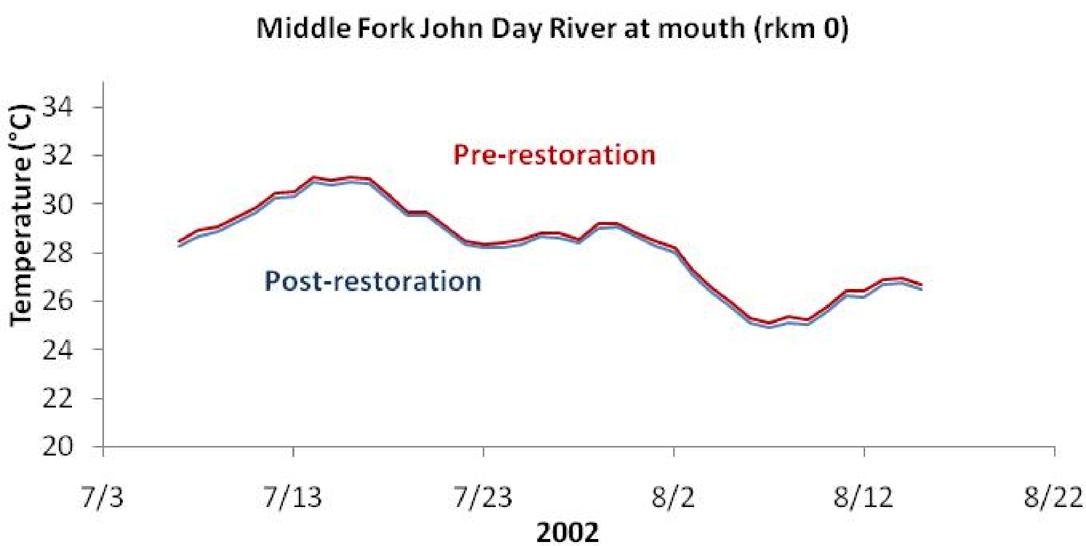


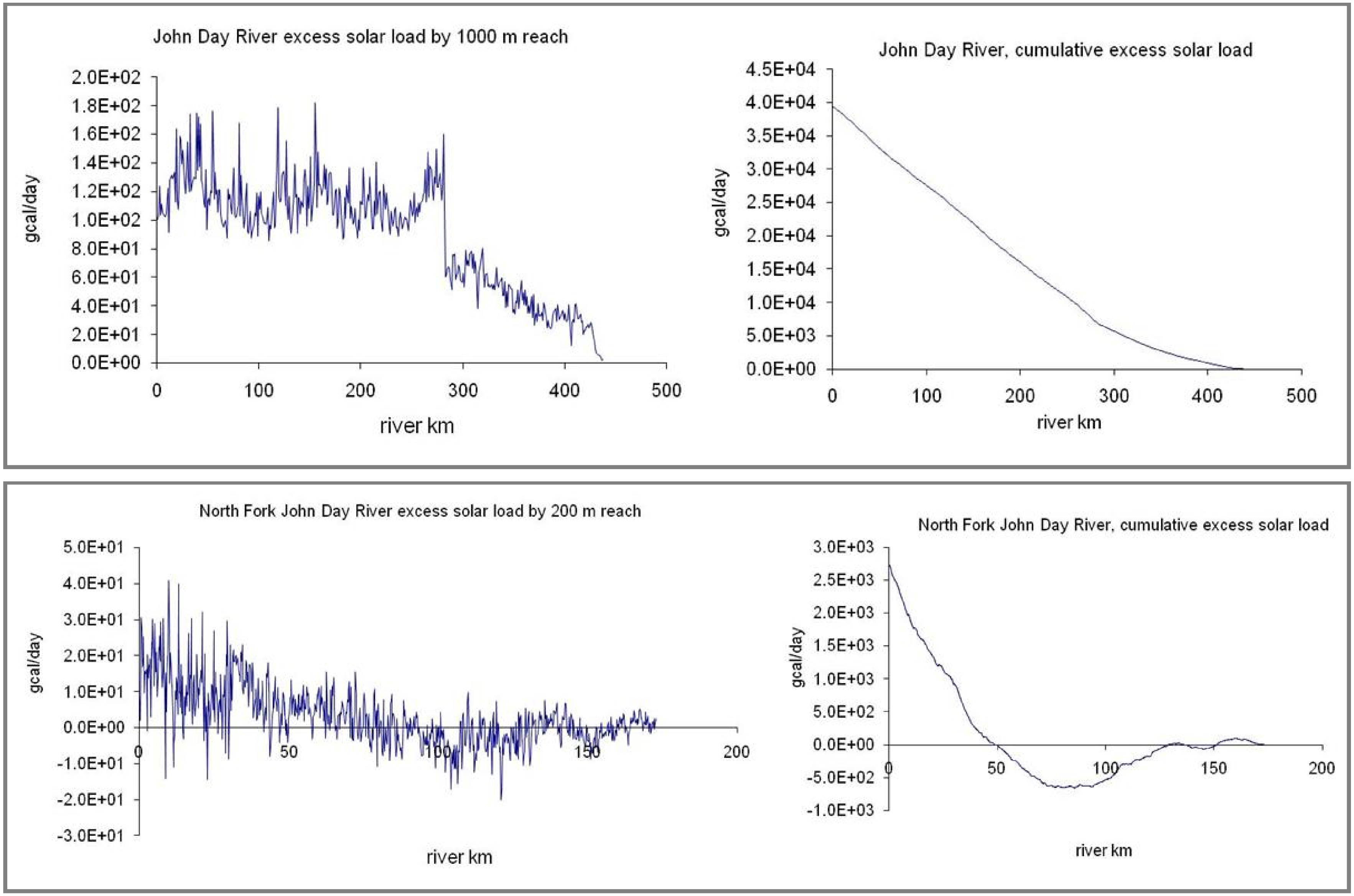
Figure B-48. Temporal comparison of rolling 7DADM temperatures at river mouth during model period from restoration scenarios.

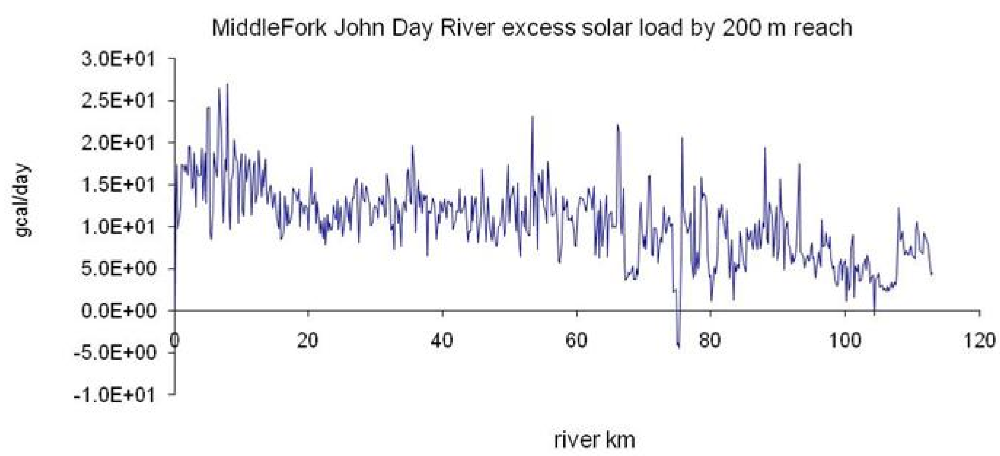


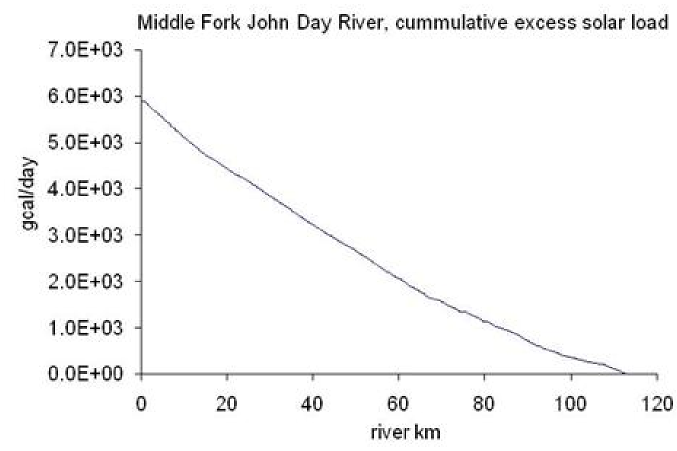
6.4 Excess Solar Loads in Modeled Reaches

The amount of daily solar energy the river surface receives is dependent on the date, the amount of sun during the day, the amount of shade, and the surface area. The difference between the solar energy that currently reaches the river and under NTP conditions is the excess solar load. The excess solar load (longitudinally and cumulatively) compared to the shade produced under the NTP scenario on July 1st (the day in the three model periods closest to the summer solstice) is shown in **Figure B-49** for all three of the modeled reaches. It should be noted that for some reaches in the North Fork and Middle Fork John Day Rivers, the potential stream wetted width is predicted to be wider than current (due to increased flow). In some places, this representation caused the amount of radiation that reaches the surface under NTP conditions to be greater than under the current condition scenario. The heat energy difference expressed in **Figure B-49** reflects the energy load for each model distance step (John Day River = 1000 m, North Fork = 200 m, Middle Fork = 200 m).

Figure B-49. Excess solar load for all of the modeled reaches.




MiddleFork John Day River excess solar load by 200 m reach
gcal/day
3.0E+01
2.5E+01
2.0E+01
1.5E+01
1.0E+01
5.0E+00
0.0E+00
-5.0E+00
-1.0E+01
0
20
40
60
80
100
120
river km


Middle Fork John Day River, cummulative excess solar load
gcal/day
7.0E+03
6.0E+03
5.0E+03
4.0E+03
3.0E+03
2.0E+03
1.0E+03
0.0E+00
0
20
40
60
80
100
120
river km

6.5 Load Allocations - Shade Curves

The John Day River Basin Temperature TMDL incorporates other measures in addition to "*daily loads*" to fulfill requirements of the Clean Water Act §303(d). Although a loading capacity for heat energy is derived (e.g. gigacalories), it is of limited value in guiding management activities needed to solve identified water quality problems. In addition to heat energy loads, this TMDL allocates "*other appropriate measures*" (or surrogate measures) as provided under EPA regulations (40 CFR 130.2(i)).

Effective shade is the surrogate measure employed for this TMDL that translates linearly into solar heat load. It is simple to measure effective shade at the stream surface using a relatively inexpensive instrument called a Solar Pathfinder™. The term 'shade' has been used in several contexts, including its components such as shade angle or shade density. The role of effective shade in this TMDL is to prevent or reduce heating by solar radiation and serve as a linear translator to heat loads.

Effective Shade Simulations

Site Specific Effective Shade

Figure B-50 shows the simulated percent effective shade estimated on August 1 on modeled streams by river kilometer. The "system potential vegetation" (green line) represents the maximum possible effective shade for a given location, assuming the vegetation is fully mature. The "Natural Disturbance Range" indicates the shade levels that could potentially occur in the event of natural disturbances. The lower end of that range represents that amount of shade that the stream would receive if topographic land forms were the only shade-producing feature (i.e., no vegetation). The effective shades expressed in **Figure B-50** reflect the modeled distance step (John Day River = 1000 m, North Fork = 200 m, Middle Fork = 200 m), except for the North Fork Topographic and Current Condition model results, which were produced every 100 m.

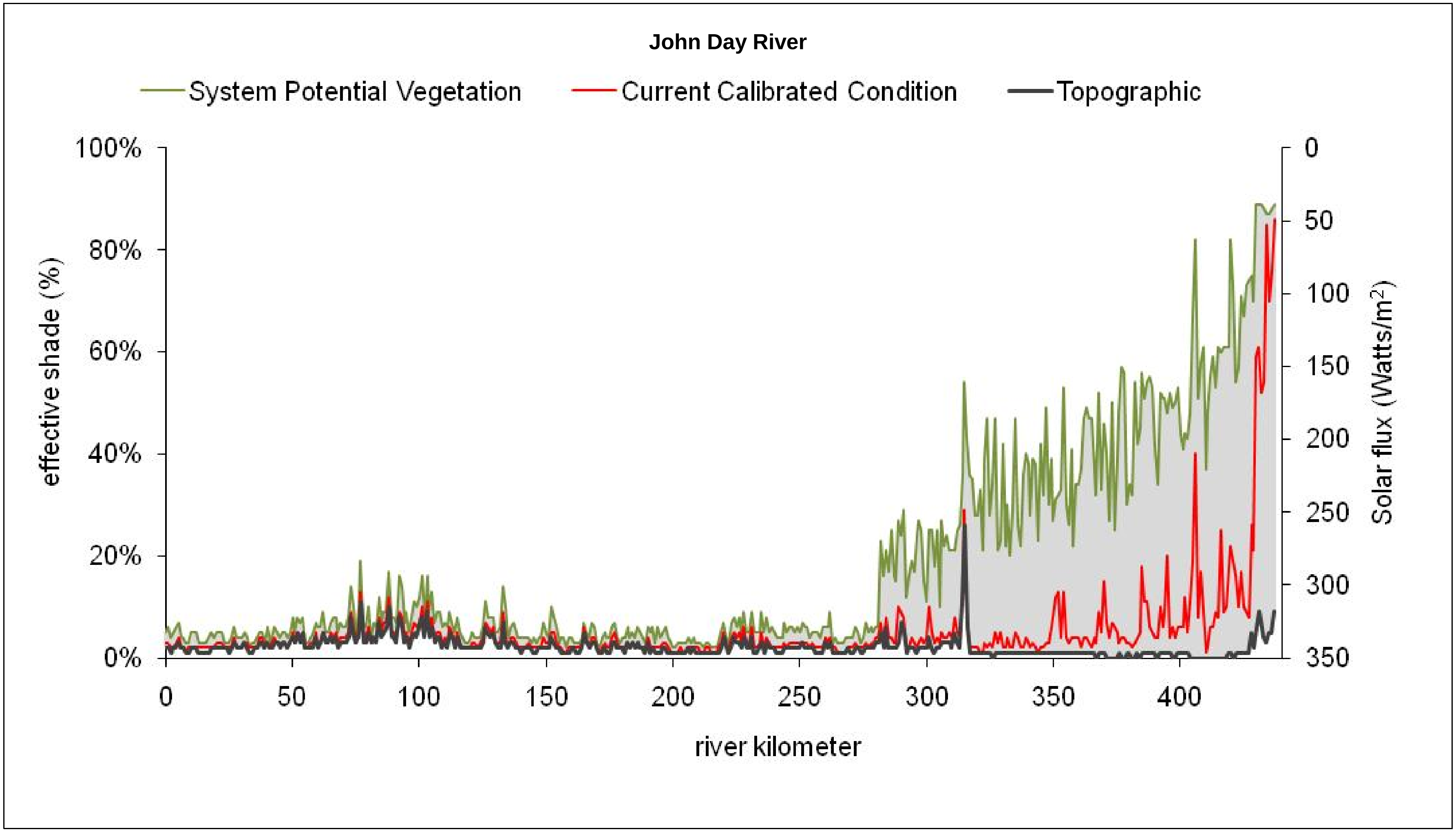
Effective Shade Curves

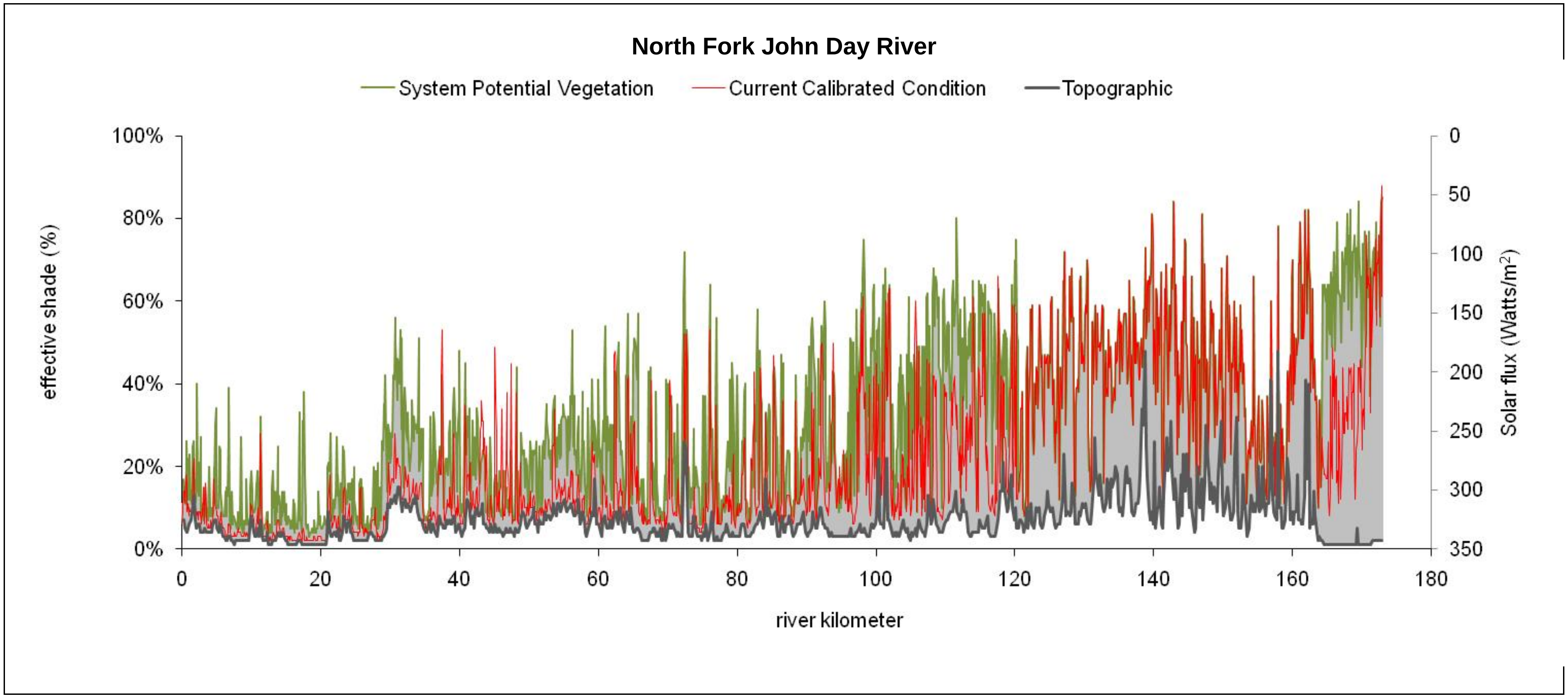
Effective shade curves are general heat load allocations applicable to any stream that was not specifically simulated for temperature. From a practical perspective, this enables coverage of much larger landscapes than the data-rich thermal modeling of the site-specific shade simulations. The heat load and effective shade surrogates of this approach are specific to EP Types and reflect the natural potential vegetation identified for each type. See **Appendix C** and **Chapter 2** for more information on derivation of EP Types.

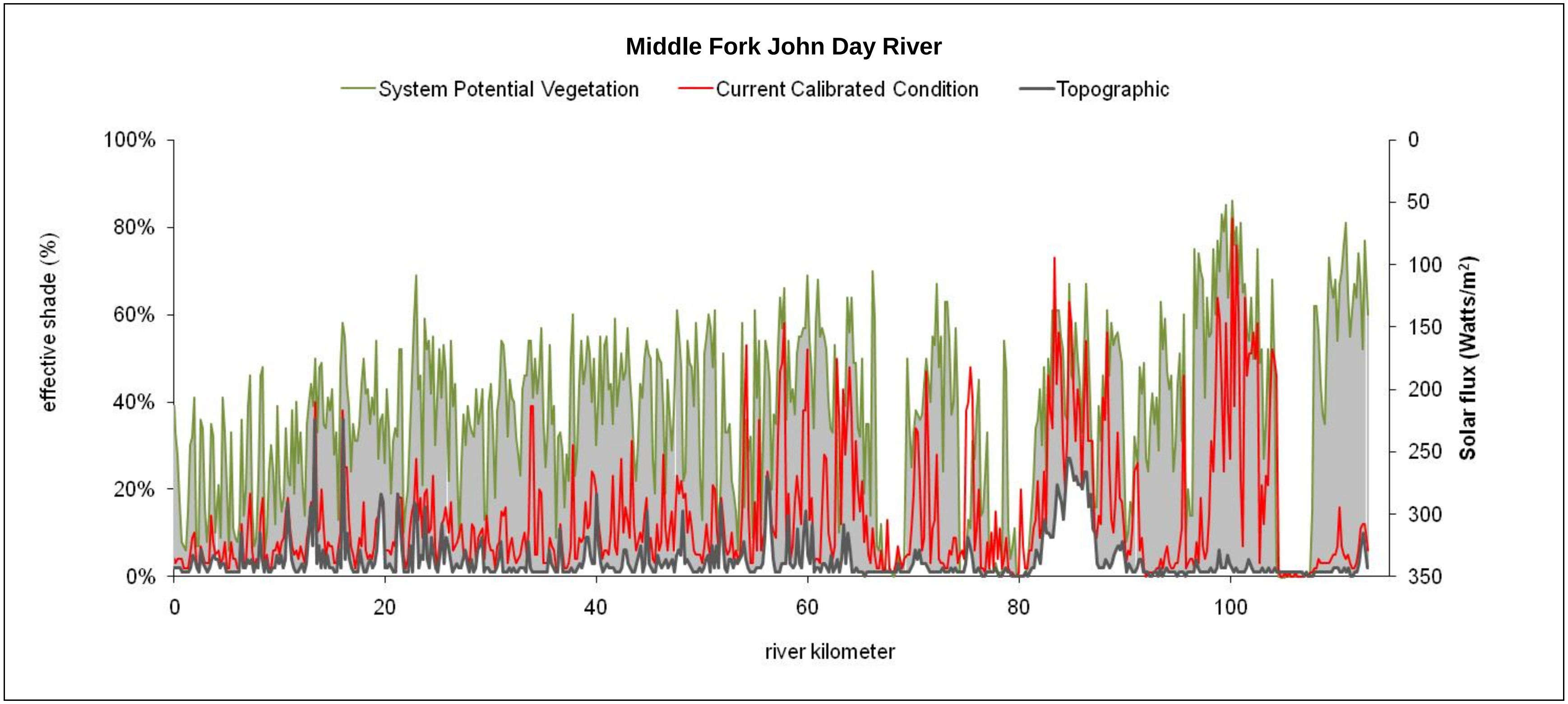
Each effective shade curve shows the percent shade expected on August 1 on a stream within the given height and density (see **Figure 2.1-13, Chapter 2**). The effective shade curves were developed in Heat Source 6.0. Model results were produced every 10 minutes. The percent shade is expected to vary depending on bankfull width and physical orientation. A range of bankfull widths and orientations were simulated to provide results for several possible combinations of conditions. The bankfull widths were simulated to be "full", so the wetted widths were equal to the bankfull widths. The corresponding daily average solar flux on August 1 was modeled in Heat Source 8.0 at a time step of 10 min and is shown opposite the percent shade. The received solar flux is the amount of radiant energy above the vegetation and land forms that reaches the stream per unit surface area per unit time.

Effective shade curves represent the *maximum* possible effective shade everywhere for a given vegetation type. The values presented within the effective shade curves represent the effective shade that would be attained if the vegetation were at its stated potential height and density. In reality, natural disturbances will lead to a variety of tree heights and densities and effective shade levels. Even with human disturbance minimized, many reaches will exhibit less shade than the estimated natural potential, or somewhere within the "Natural Disturbance Range". Reductions in effective shade caused by natural disturbance are not considered a violation of the TMDL or water quality standards.

Figure B-50. Effective shade targets and corresponding daily average solar flux for waterbodies for which temperature was simulated. (next 3 pages)




North Fork John Day River
System Potential Vegetation
Current Calibrated Condition
Topographic
effective shade (%)
100%
80%
60%
40%
20%
0%
0
20
40
60
80
100
120
140
160
180
river kilometer
0
50
100
150
200
250
300
350
Solar flux (Watts/m²)


Middle Fork John Day River
System Potential Vegetation
Current Calibrated Condition
Topographic
effective shade (%)
100%
80%
60%
40%
20%
0%
0
20
40
60
80
100
river kilometer
0
50
100
150
200
250
300
350
Solar flux (Watts/m2)

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