good shading conditions near and downstream of important groundwater flow inputs to maintain cool water temperatures for as long as possible downstream.

The positive effect of minimizing runoff and infiltrating water into the ground to increase base flows is well documented. Maintaining or enhancing groundwater recharge through local and regional land use practices and infiltration of stormwater/reclaimed water in some places may help provide temperature benefits in a shorter timeframe than riparian shading. In addition, enhancing groundwater recharge may mitigate the effects of inadequate shade where it is not possible to provide substantial tree cover.

4.1.7.1. IMPLICATIONS AND PRIORITIES

Protecting the existing groundwater flow from the White River is a key priority. More information on the location, quality, and volume of flow is very important to understand how to protect this flow, as it appears most of the former White River channel pathway has already been developed, but this flow still exists. Then, providing floodplain connections for potential groundwater recharge is a second critical priority. This will be small in scale, but may contribute groundwater discharge during base flows. Setting back levees and allowing more gravel bars in the river can also increase the exchange of hyporheic flow. While these actions are not likely to reduce daily average temperatures, it could reduce the larger variability of maximum highs and low temperatures.
5. WATER QUALITY

5.1. WATER TEMPERATURE

The Green River watershed has undergone extensive habitat alterations over the past 150 years. Historically, streamside tree cover along the Lower and Middle Green River included red alder, black cottonwood, big leaf maple, vine maple, red alder, and willow (Coffin et al. 2011). Riparian habitat plays a valuable role in protecting stream water quality and moderating the negative impacts occurring in a stream basin. Adequately-sized and healthy riparian buffers help filter out fine sediment and other pollutants, provide shade to moderate stream temperatures, provide overhead cover to aquatic species, and provide a source of LWD for the proper biologic and hydraulic functioning of a healthy watershed.

The Washington Department of Ecology (WDOE) water temperature standard is 63.5° F (17.5° C) for salmonid spawning, rearing and migration (September 16 to June 14) and 60.8° f (16° C) for core salmonid summer habitat (June 15 to September 15; WDOE 2012). This is similar to Environmental Protection Agency (EPA) guidance that recommends daily maximum temperatures not exceed 64° F (18° C; USEPA 2003) in waters where adult salmon migration and non-core juvenile rearing occurs. A review of temperature requirements and effects on salmonids by Carter (2005) indicates that 50 percent mortality of Chinook occurs around 77° (25° C), but coho are more tolerant and 50 percent mortality occurs at 82° F (28° C). NOAA (1996) considers optimal temperatures for salmonids to be 50-57° F (10-14° C). Beyond acute mortality, high water temperatures cause a variety of physiological effects (sub lethal) that are harmful to salmon survival and reproduction as well as increasing the potential for disease. Disease risk becomes high at temperatures from 64-68° F (18-20° C; USEPA 2003).

The federal Clean Water Act (CWA) requires that a total maximum daily load (TMDL) be developed for each of the water bodies on the 303(d) list. The 303(d) list is a list of "impaired" water bodies, which do not meet state water quality standards. The Middle and Lower Green River segments have both been identified as temperature impaired water bodies. The Green River water temperature TMDL (Coffin et al. 2011) is intended to help focus efforts to protect and enhance cold water habitat for resident and anadromous salmonids.

In the TMDL analysis (Coffin et al. 2011), stream temperature data from field monitoring supported the development of QUAL2Kw, a water quality model, which was used to describe existing conditions and compare how different hypothetical meteorological, shade, and flow conditions would affect the temperature along 54 miles of the Middle and Lower Green River below Howard Hanson Dam. In particular, scenarios of riparian shading along the river were considered. Water temperatures vary diurnally in response to changes in weather conditions and river flows. Since the maximum temperatures most dramatically affect aquatic species, the criteria evaluated in the TMDL analysis are expressed as the highest seven-day average of the daily maximum temperatures (7-DADMax) occurring in a water body.

The beneficial uses to be protected and the corresponding thresholds that were evaluated in the TMDL analysis included:

1. Core Summer Salmonid Habitat - protects summer season (June 15 through September 15) salmonid spawning, incubation, emergence, and adult holding; summer rearing habitat by one or more salmonids; or foraging by adult and sub-adult native char. To protect these designated
aquatic life uses, the highest 7-DADMax temperature must not exceed 16°C (60.8°F) at a probability frequency of more than once every ten years on average; and

2. Salmonid Spawning, Rearing, and Migration - protects salmonid spawning, incubation, and emergence that may occur outside of the summer season (September 16 – June 14) and protects rearing and migration during this period. To protect these designated aquatic life uses, the highest 7-DADMax temperature must not exceed 17.5°C (63.5°F) at a probability frequency of more than once every ten years on average.

The 16°C criterion applies to the Green River upstream of the Mill Creek confluence at about RM 24; downstream of Mill Creek the 17.5°C criterion applies.

The TMDL analysis used effective shade as a surrogate measure of heat flux from solar radiation. Effective shade is defined as the fraction of potential solar shortwave radiation that is blocked by vegetation and topography before it reaches the stream surface. Monitoring indicated that a shade deficit occurred throughout the Middle and Lower Green River, but was especially prevalent below the city of Auburn (below RM 26) due to the extensive channelization and levee construction. Continuous temperature data were recorded throughout the summer of 2006. All thirteen of the stations monitored by WDOE on the Green River mainstem exceeded the seven-day average temperature standard (Table 2). Modeling and data analysis determined that portions of the Green River failed to consistently meet state water quality standards and provide unsuitable and sometimes lethal temperatures for salmonids that use these waters for migration, spawning and rearing.

The TMDL model demonstrated that temperatures in the lower reaches of the Green River approach and sometimes exceed lethal conditions for salmonids during the critical summer/fall months. Lowering water temperatures will help to reduce salmonid mortality and improve habitat and provide a means of restoring and improving the basin’s salmon production. The model used in the Green River temperature TMDL analysis shows that under current conditions daily maximum water temperatures in excess of the 16°C water quality standard occur along the entire Middle and Lower Green River basin (Table 14). The 17.5 °C standard below Mill Creek protecting salmonid spawning, rearing, and migration is also exceeded. The lower 8 miles of the river are also predicted to exceed the 22°C threshold for lethality under existing conditions during high summer temperatures and low flow conditions.
Table 14. Highest 7-day of daily maximum temperature recorded in the Green River during the summer 2006 (from Coffin et al. 2011).

<table>
<thead>
<tr>
<th>Station ID</th>
<th>Location</th>
<th>Temperature (°C)</th>
<th>Highest 7-DADMAX</th>
<th>WQ Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Middle Green River</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>09-GRE-DAM</td>
<td>Below Tacoma Headworks Dam</td>
<td>17.76</td>
<td></td>
<td></td>
</tr>
<tr>
<td>09-GRE-KAN</td>
<td>At Cumberland-Kanaskat Rd.</td>
<td>19.22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>09-GRE-FLA</td>
<td>At Flaming Geyser Park</td>
<td>19.74</td>
<td></td>
<td></td>
</tr>
<tr>
<td>09-GRE-WHI</td>
<td>At Whitney Bridge</td>
<td>21.83</td>
<td></td>
<td></td>
</tr>
<tr>
<td>09-GRE-GRE</td>
<td>At Green Valley Road</td>
<td>21.58</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Lower Green River</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>09-GRE-8TH</td>
<td>At 8th St. NE, Auburn</td>
<td>20.98</td>
<td></td>
<td></td>
</tr>
<tr>
<td>09-GRE-277</td>
<td>277th St. Bridge</td>
<td>20.94</td>
<td></td>
<td></td>
</tr>
<tr>
<td>09-GRE-167</td>
<td>Highway 167 Bridge</td>
<td>21.42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>09-GRE-OLD</td>
<td>Meeker St. near “Old Fishin’ Hole”</td>
<td>21.59</td>
<td></td>
<td></td>
</tr>
<tr>
<td>09-GRE-212</td>
<td>At S. 212th St.</td>
<td>22.16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>09-GRE-180</td>
<td>At SE 180th St. (SW 43rd St.)</td>
<td>22.61</td>
<td></td>
<td></td>
</tr>
<tr>
<td>09-GRE-FOR</td>
<td>Interurban Ave. Bridge near Fort Dent</td>
<td>22.84</td>
<td></td>
<td></td>
</tr>
<tr>
<td>09-GRE-COM</td>
<td>42nd Ave S. Bridge at Tukwila Community Center</td>
<td>23.14</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The model shows that even with comprehensive and wide potential riparian planting scenarios, the water temperature are still predicted to exceed the 16° criterion by 2 to 3 degrees. Current conditions within these reaches exceed the criterion by approximately 5.5 degrees. The 17.5° criterion below the confluence with Mill Creek is nearly achievable when using 32 m tree height as a modeling parameter to create a system potential shade scenario. If taller and broader 42 m tree height is used, compliance with the 17.5° criterion can potentially be met.

Under all scenarios the maximum water temperatures remain below lethal limits for salmonids upstream of Mill Creek, but would still likely have sublethal effects. Even when all riparian areas along the middle and lower basin, except the levees, are vegetated with full site potential shade, lethal temperatures will still occur from approximately RM 11-14 of the Green River. Until the federal levee vegetation maintenance policy can be changed to allow for growth of large trees on these structures, or the levees are set back to allow for planting, or the County removes levee facilities from PL84-99 program, or some other mitigation technique can be implemented, temperatures are not likely to meet the identified standards in the lower Green River and will reach lethal temperatures in warmer years.

The TMDL study evaluated approaches to reducing temperature in the middle and lower reaches of the river, which will in turn improve dissolved oxygen, establishment of mature full riparian vegetation for shade, and microclimate. The TMDL models show that the combined effects of mature riparian vegetation along the entire riparian corridor and the associated microclimate improvements result in the greatest temperature improvements in the river. It should be noted that such recommendations are long term solutions that will require decades to implement and achieve. Regardless, planting or restoring riparian vegetation of any buffer size that is deemed feasible can still provide value and is encouraged.

Also, the TMDL model shows that decreasing the temperatures and increasing the flows in the tributaries helps to maintain lower temperatures in the mainstem. In order to protect and enhance the salmonid resources of the Green River Basin, the tributaries must also supply an adequate flow of cool clean water. The main tributaries in the Middle and Lower Green River are Mullen Slough, Mill Creek,
Soos Creek, and Newaukum Creek. Newaukum Creek also has a recently completed temperature TMDL. Individual water temperature and dissolved oxygen TMDL’s are currently being prepared for Soos Creek, which WDOE will document in separate reports.

5.2. SHADE MODELING

5.2.1. MUCKLESHOOT TRIBE SUN MODEL

The Muckleshoot Indian Tribe (Fox Draft 2013) prepared a sun exposure model to identify and map critical areas for providing forested riparian zone to maximize the potential shading of the Lower Green River from RM 15 to 34. This simple tool calculates the aspect of the river oriented to North, South, East, West coordinates – areas with more southerly exposure are considered critical for shading. Figures 5-1 through 5-4 show the results from the sun model that identifies priority areas where it is most critical to provide forested riparian zone and shade. It is important to note that this simple tool does not account for differing bank topography, or combined effects of both banks being vegetated and is simply based on the orientation of each bank of the river.

Notable locations identified as critically important for shade in Reach 2 include RM 14 to 14.5, RM 15 to 15.5, RM 16 to 18, RM 18.4 to 19.5, RM 20.8 to 21.3, RM 22 to 23., and the majority of the left bank from RM 23 to 26. Notable locations identified as critically important for shade in Reach 3 include the majority of the left bank from RM 26 to 29, RM 29.2 to 29.8, RM 30 to 30.5, and the majority of the left bank from RM 30.7 to 33. The locations where the sun model coincides with poor conditions for the existing riparian vegetation and shading are predominantly at RM 27.4 to 27.7, RM 29.8 to 30 and RM 30 to 30.2.
Figure 5-1. Sun model critical shade needs for downstream half of Reach 2 (2A).
Figure 5-2. Sun model critical shade needs for upstream half of Reach 2 (2B).
Figure 5-3. Sun model critical shade needs for downstream half of Reach 3 (3A).
Figure 5-4. Sun model critical shade needs for upstream half of Reach 3 (3B).
5.2.2. Potential Shade GIS Model Overview

Elevated water temperatures are a chronic problem in the Lower Green River. To better understand potential shade provided by riparian trees along both banks of the river, the project team and advisors built upon the concepts developed by the Muckleshoot Tribe’s sun model (Fox Draft 2013) relative to orientation of the river and angle of the sun and developed a GIS model that analyzes the potential shade cast by existing trees during daylight hours (on August 1st) within an 150-foot riparian zone. The raster GIS model and its underlying code reflect TMDL work for the Green River, completed in 2011 (see preceding section for additional detail). Model output summarizes the potential for various vegetation scenarios to shade the river and assigns a categorical value of: Poor, Fair, Good or Very Good to potential shade conditions.

This shade modeling tool can also be used to support the evaluation of proposed changes to riparian vegetation (i.e. planting of additional trees, removal of trees, etc.) and the anticipated effects to potential shade provided to the river.

An overview of Potential Shade GIS model:

1. The right bank and left bank of the Lower Green River were each assigned 150-foot wide riparian buffer zones. Each 150-foot riparian buffer was further split into six equal 25-foot wide buffer increments. Riparian vegetation height is set at 32 meters (105 feet) to be consistent with the TMDL (Coffin et al. 2011).

2. 2013 high hit return LIDAR data was clipped to each 25-foot buffer increment, within the 150-foot zone.

3. The model is structured to run using the sun elevation and azimuth on August 1st, from the first hour after sunrise to the last hour before sunset, 7:30AM to 8:30PM. (14 hours in total).

4. Solar Radiation values were generated for each of the 14 hours on August 1st, 2014, representing clear sky radiation above the Lower Green River before interception by vegetation (provided by Washington State’s Department of Ecology Solar Radiation model – solrad_ver16.xls).

5. For each hour, the ESRI Hillshade tool was used to model shadows cast by each 25 foot buffer, right and left bank, on each grid cell representing the surface of the river.

6. During each hour the cumulative reduction in incoming solar radiation was calculated for each river grid cell by reducing the radiation by 50 percent each time a buffer casts a shadow on the cell (50% reduction based on published canopy density-buffer width relationship).

7. The sum of the radiation reaching each river grid cell was divided by the total incoming (above tree canopy) solar radiation over the course of the day to generate a shade value for each 3-foot rasterized grid cell (1 minus this number is the potential shade or the amount of solar radiation blocked by riparian vegetation).

8. Each grid cell’s shade value was presented as a function of its shade potential and categorized as Poor, Fair, Good or Very Good. The categories are based on the evaluation of the system’s potential shading with 105 foot-tall vegetation used as the primary analysis scenario in the TMDL where the Lower Green River maximum effective shade is approximately 70%.

Results of the modeling are available for Reaches 2 and 3 of the Lower Green River and shading on the river is categorized as poor, fair, good, or very good (Table 15 and Figures 5-5 through 5-8). The categories are based on increments of the system potential shading (105 feet [32 meter] tall trees as modeled in the TMDL; Coffin et al. 2011) where the Lower Green River maximum effective shade is
approximately 70%. The Lower Green River is sufficiently wide that even trees over 100 feet in height on both banks cannot shade the river entirely; and, as the sun moves across the horizon, the sun can shine directly down on the river during the middle of the day. The GIS-based shade model has results for shading that range from 0 to 1 (index values); the categories of poor, fair, good, or very good are equal increments from the minimum to maximum values of shade that result from the GIS analysis.

Reach 2 has very poor shade conditions with the vast majority (63%) of the reach in poor conditions or fair conditions (33%). Less than 5% of Reach 2 has good or very good condition. The only small patches of good conditions are located at RMs 13.2, 13.8 in PL84-99 levee system #1, and RM 23.6 and along the left bank edge around Horseshoe Bend, in the Agricultural Production District. These locations are all associated with patches of trees on the left bank. Fair conditions are present adjacent to the treed hill slope near RM 11.6 and 12.5, adjacent to a tree patch from RM 13.6-13.8, at RM 17.8-17.9, the forested patch from RM 19-19.5, at the golf course from RM 20.9 to 21.5, from RM 22 to 23, RM 23.5-23.6, RM 24.2 to 25, and from RM 25.4 to 25.8.

Reach 3 has the majority of area with fair (56%) or good (24%) shade conditions, but also nearly 20% of the reach has poor shade conditions, both along the PL84-99 levee system #5 and other areas. Less than 1% is in very good condition. Notable patches with good conditions occur at RM 26 to 26.5 in North Green River Park, at RM 28.5, near RM 29, RM 30.5, 31.5, and 31.8. Notable poor condition areas are at RM 27.4 to 27.6, RM 29.1, 29.8 to 30.1, and 30.5-30.6.

Table 15. Existing shade conditions in study area.

<table>
<thead>
<tr>
<th>Shade Category</th>
<th>Index Range</th>
<th>Percent of Maximum</th>
<th>Actual Percent Effective Shade</th>
<th>River Area Reach 2 (Acres)</th>
<th>Percent Area (Reach 2)</th>
<th>River Area Reach 3 (Acres)</th>
<th>Percent Area (Reach 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Good</td>
<td>0.81-1.0</td>
<td>80-100%</td>
<td>61-75%</td>
<td>0.1</td>
<td>&lt;1%</td>
<td>1.2</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Good</td>
<td>0.61-0.8</td>
<td>61-80%</td>
<td>46-60%</td>
<td>6.5</td>
<td>4%</td>
<td>22.9</td>
<td>24%</td>
</tr>
<tr>
<td>Fair</td>
<td>0.41-0.6</td>
<td>41-60%</td>
<td>31-45%</td>
<td>52.6</td>
<td>33%</td>
<td>52.3</td>
<td>56%</td>
</tr>
<tr>
<td>Poor</td>
<td>0.2-0.4</td>
<td>20-40%</td>
<td>15-30%</td>
<td>98.7</td>
<td>63%</td>
<td>17.7</td>
<td>19%</td>
</tr>
<tr>
<td>Totals Per Reach:</td>
<td></td>
<td></td>
<td></td>
<td>157.9</td>
<td>100%</td>
<td>94.1</td>
<td>100%</td>
</tr>
</tbody>
</table>

The locations where the results from the sun model coincide with poor conditions for the existing riparian vegetation and shading are predominantly at RM 14 to 15, RM 16 to 17, RM 19.6, RM 21.5 to 22, RM 22.5, RM 23.5 to 24.3, and RM 25. The sun model predicts that more southerly aspects (i.e. south bank of the river) are the highest priority, and the shade model appears to bear this out that even a single line of trees along a south bank can cast a shadow sufficient to create fair to good conditions in the vicinity of the bank – and an even wider or taller riparian zone would likely cast a larger shadow. Although more northerly aspects (i.e. the north bank of the river) were rated as lower priority in the sun model, there are many instances where the shade model indicates that a western exposure (unvegetated) may have a critical influence on the lack of shade even on north banks, so understanding where western bank exposure is a critical priority is also important.
Figure 5-5. Current effective shade conditions in downstream half of Reach 2 (2A).
Figure 5-6. Current effective shade conditions in the upstream half of Reach 2 (2B).
Figure 5-7. Current effective shade conditions in the downstream half of Reach 3 (3A).
Figure 5-8. Current effective shade conditions in the upstream half of Reach 3 (3B).
5.3. **OTHER WATER QUALITY PARAMETERS**

The Lower Green River study area and its tributaries are listed on the 303(d) list of impaired waterbodies (Ecology 2014) for fecal coliform bacteria and dissolved oxygen (both require TMDLs), and there is concern about PCBs, mercury, and Bis-(2-Ethylhexyl) phthalate in the vicinity of the Boeing facility (approximately RM 16). Dissolved oxygen is of most serious concern for salmonids, but is generally confined to the lowest portion of the study area, approximately RM 11 and the Black River, although also in stretches within Springbrook Creek, Mullen Slough, and Mill Creek (Auburn). Efforts to reduce temperature will likely have benefits to dissolved oxygen as they are inversely related.

5.4. **CONCLUSION**

Water temperature is a critical limiting factor in the study area. High water temperatures stress adult salmon and reach lethal temperatures during hot summers. High temperatures also substantially reduce rearing habitat potential and cause juvenile salmonids to migrate downstream more quickly than is likely desired in the late spring and summer. Smolts that can feed and rear in the river on their way downstream enter marine waters at a larger size and are typically more fit to grow rapidly and survive better (Beamer and Larsen 2004).

However, from GIS shade modeling conducted for this study, even smaller patches of tall trees can increase shading. Good conditions result from greater than 100 foot wide fully forested riparian zones. However, even patches ranging from 50-100 feet in width can make incremental improvements in shading such as from poor to fair or fair to good. Also, the taller the trees are, the more shade that is cast. It is also very important to consider the long afternoon exposure to the sun from the west and ensure that even north-south trending stretches of river have forested riparian along the western shoreline. Native tree species that reach tall heights such as Douglas fir (*Pseudotsuga menziesii*), big-leaf maple (*Acer macrophyllum*), western red cedar (*Thuja plicata*), and Sitka spruce (*Picea sitchensis*) are particularly good at providing shade and are long-lived species that may be more resistant to breakage and wind-throw.
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6. OPPORTUNITIES

The WRIA 9 Green/Duwamish and Central Puget Sound Watershed Salmon Habitat Plan (WRIA 9 Steering Committee 2005) identified a number of priority actions for the Lower Green River. Since 2005, the WRIA 9 stakeholders have implemented several projects and updated their work plans with new priorities. For the purposes of the Green River SWIF, it will be important to identify potential aquatic habitat enhancement or restoration measures that can be undertaken within the context of simultaneously improving the reliability and function of flood management facilities, or in the context of increasing floodplain connectivity and function.

Specific to this assessment, the following aquatic habitat objectives are proposed with the limiting factors that could be addressed by the objectives (Table 16).

Table 16. Habitat limiting factors, objectives for enhancement, and potential measures.

<table>
<thead>
<tr>
<th>Habitat Limiting Factor</th>
<th>Enhancement Objectives</th>
<th>Restoration Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>High water temperatures</td>
<td>• Increase forested riparian habitats for shading (including width, height, and density);</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Increase and maintain groundwater inputs/recharge</td>
<td>• Plant native riparian trees and shrubs in all feasible locations within 200 feet of river</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Retain and plant overhanging vegetation such as willows</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Protect White River groundwater flows</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Promote floodplain reconnection and groundwater recharge to augment and cool low flows</td>
</tr>
<tr>
<td>Lack of aquatic habitat diversity, particularly lack of pools and low-velocity edge habitats</td>
<td>• Increase aquatic habitat diversity, particularly low-velocity shallow water edge habitats and pools</td>
<td>• Remove or setback levees/revetments or reduce slope to increase shallow water and reduce velocities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Do not put in new shoreline armoring structures where one doesn’t already exist</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Place large wood in-channel mimicking natural wood structures (versus typical bank protection) where feasible to create hydraulic diversity and cover including low velocity areas and pools</td>
</tr>
<tr>
<td>Lack of floodplain and off-channel habitats</td>
<td>• Increase floodplain connections</td>
<td>• Remove or setback levees/revetments and create benches</td>
</tr>
<tr>
<td></td>
<td>• Restore existing tributary and slough habitats</td>
<td>• Restore connections to floodplain wetlands</td>
</tr>
<tr>
<td></td>
<td>• Restore floodplain wetlands</td>
<td>• Enhance tributary and slough habitats</td>
</tr>
</tbody>
</table>
### Habitat Limiting Factor | Enhancement Objectives | Restoration Measures
--- | --- | ---
Lack of riparian vegetation | • Increase large wood recruitment  
• Provide shading and cover  
• Increase insect and detrital production  
• Provide and enhance wildlife corridors | • Restore riparian habitats to a mixture of trees and shrubs  
• Reconfigure levees and revetments, to allow restoration of riparian vegetation in more natural proximity to water to improve likelihood of vegetation survival and functional contribution to salmon habitat

Modified hydrology and hydraulics | • Increase floodplain connectivity wherever feasible | • Promote floodplain reconnections for mainstem and tributaries to promote groundwater recharge and backwaters/off-channel hydraulics for fish rearing and refuge

Lack of spawning habitat | Restoring and enhancing sediment recruitment (particularly spawning gravels) by reconnecting sediment sources to the river will reduce channel down-cutting, increase shallow habitats, improve access to tributaries, and improve spawning habitat, thereby leading to greater juvenile salmon residence time, greater growth, and higher survival | • Set back levees to reconnect natural sediment sources  
• Set back levees to allow for side channel formation and LWD recruitment  
• Increase connectivity to sediment sources upriver

Every possible location for removal of non-native vegetation and plantings of native trees and shrubs should be considered as water temperatures and lack of shading are critical problems both reaches. The west bank is particularly important. The following are preliminary locations identified in this existing conditions evaluation.

Preliminary locations to consider for a combination of reducing the slope of the bank along with riparian plantings and wood placement could include from RM 11 (Black River confluence) to 12 on both banks; right bank both upstream and downstream of the I-405 crossing with the possibility for wetland reconnection, floodplain and shallow water habitat; RM 13.9 left bank wetland; RM 15.9 right bank; RM 16.2 left bank; RM 16.5 to 17.2 left bank where new development may be occurring could be an opportunity for shallow sloping banks and riparian vegetation; RM 17 to 18 left bank; RM 18 to 19 riparian improvements with potential to reconnect to wastewater treatment mitigation site (wetlands and floodplain); RM 19 left bank wetland area; and RM 20 to 22 both banks. At approximately RM 22.5, the Agricultural Production District is present along the left bank and Mullen Slough and Mill Creek join the Green River at RM 21.7 and 23.9, respectively. There are opportunities for riparian restoration, off-channel habitat, and instream enhancement up to approximately RM 24. Additional opportunities include RM 24 right bank and the whole left bank along the south curve of Horseshoe Bend, including the narrow neck of land at RM 26; RM 26 to 28; tree planting from RM 30 to 31 left bank, and protection of patches of trees that exist along both banks.
Protecting and maintaining cooler water from the Middle Green and White River groundwater flows by increasing riparian shading starting at the upstream end of the Lower Green River is likely to be more effective than trying to shade only in the lower part of the study area. Shading cannot typically cool water down, but can maintain cooler temperatures for further distances downstream.

An analysis of bioengineered segments of levees in Appendix C indicates that when active repairs are made in a bioengineering context that the total vegetation cover increases and native vegetation species cover increases. However, this can take many years, so it is important to minimize loss of existing forested riparian or existing willow/overhanging vegetation until various planting, setback, or floodplain projects can catch up to provide shading and other functional benefits.

Appendix D includes a literature review of vegetation on levees. There have been incidences of wind-throw and tree breakage, but reducing levee slopes can provide a more stable growth medium for trees and trees on the lower portion of a levee slope are also more stable. Providing trees as close as possible to the river provides better shading potential as well as other benefits such as cover and detrital and insect inputs. Creating a planting bench could also be a desirable feature in a levee to reduce potential risks to the levee prism itself, while providing suitable native trees and shrubs in close proximity to the river.
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7. REFERENCES


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