Dixie and Hanks Creeks Temperature TMDLs


Healthy riparian conditions on Hanks Creek

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1.0 Introduction

4.0 Background

Section 303(d) of the Clean Water Act requires each state to develop a list of water bodies that need additional work beyond existing controls to achieve or maintain water quality standards, and submit an updated list to the Environmental Protection Agency (EPA) every two years. The Section 303(d) List provides a comprehensive inventory of water bodies impaired by all sources. This inventory is the basis for targeting water bodies for watershed-based solutions, and the TMDL (Total Maximum Daily Load) process provides an organized framework to develop these solutions. CFR (Code of Federal Regulations) 40 Part 130.7 requires states to develop TMDLs for the waterbody/pollutant combinations appearing in the 303(d) List. This document presents temperature TMDLs for Dixie and Hanks creeks located in northeastern Nevada (Figure 1).

Both Dixie and Hanks Creeks are listed as impaired due to elevated stream temperatures (Table 1). As required by the Clean Water Act, this document presents TMDLs for these listed parameters. Dixie and Hanks Creeks are included on Nevada's 2006 303(d) List due to exceedances of the state temperature standards. While the South Fork Hanks Creek is not on the 303(d) List (no temperature data are available), conditions in the SF Hanks Creek are believed to be a source for elevated temperatures in Hanks Creek. Therefore, the TMDL also address loadings in the SF Hanks Creek.

Table 1. Summary of Waters and Associated Standards Addressed in this TMDL

Waterbody	Dixie Creek	Hanks Creek	SF Hanks Creek
Waterbody ID	NV04-SF-62_00	NV04-MR-98_00	None assigned (not on 303(d) List
Applicable Water Quality Standards	Under the Tributary Rule (NAC 445A.145), the water quality standards for the SF Humboldt River (NAC 445A.125) apply to Dixie Creek	Under the Tributary Rule (NAC 445A.145), the water quality standards for Marys River (NAC 445A.125) apply to Hanks Creek and SF Hanks Creek	
Beneficial Uses	Propagation of aquatic life, contact recreation, non-contact recreation, propagation of wildlife, municipal and domestic drinking water, irrigation, stock watering, industrial uses.		
Parameter of Concern	Temperature		
Beneficial Use of Concern	Propagation of aquatic life		
Year Added to 303(d) List	2006		Not applicable

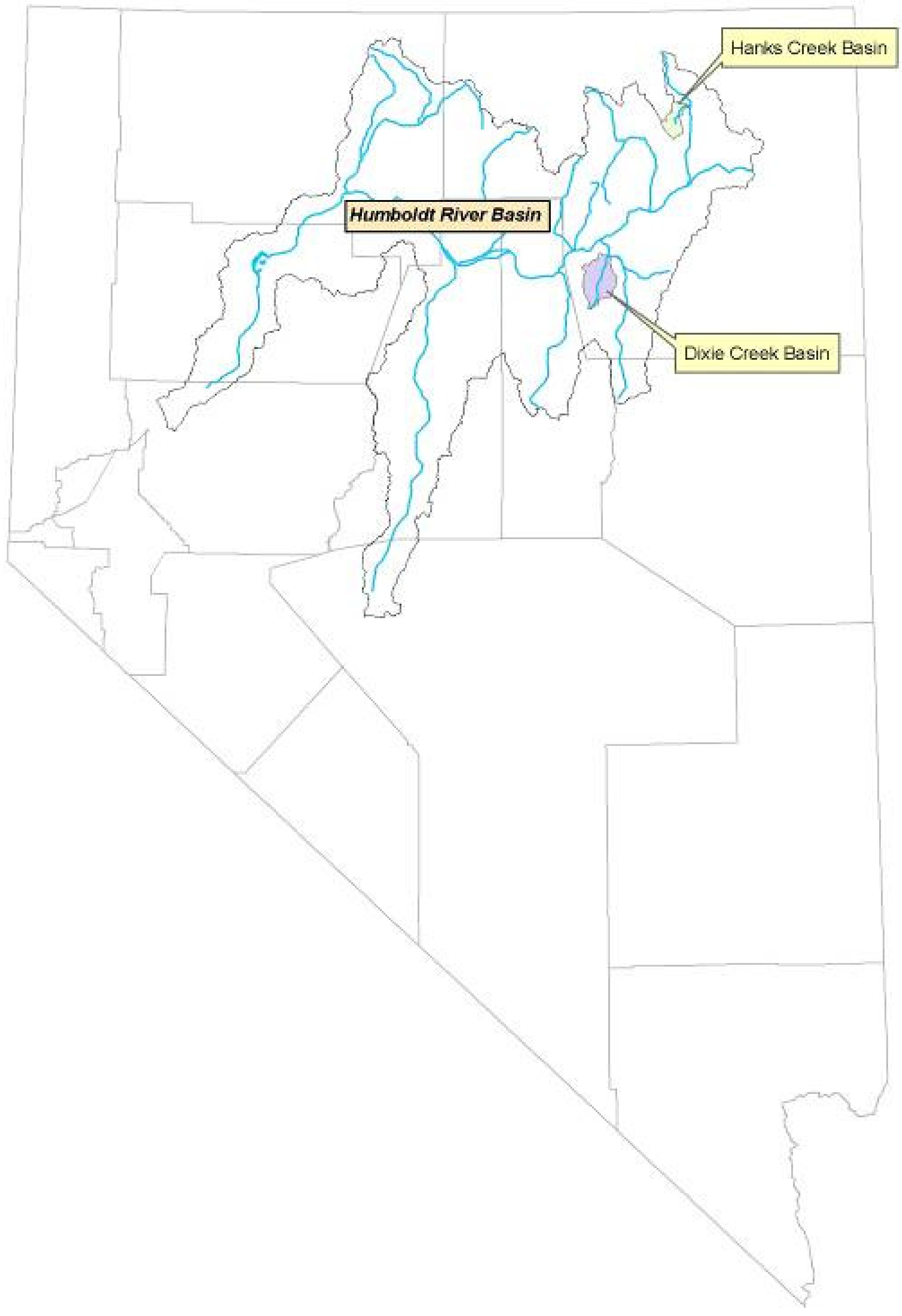

Figure 1. Location Map

While none of these creeks are explicitly identified in the Nevada Administrative Code (NAC), the tributary rule (NAC 445A.145) applies and these streams were evaluated using temperature standards applicable to downstream waters. In the case of Dixie and Hanks creeks, the applicable temperature standards were established in the 1970s and no documentation has been found which justifies these values. Significant work would be needed to review these standards for appropriateness and to determine if these standards (or revisions) would be achievable in Dixie and Hanks creeks. NDEP is strategizing on efforts to review the aquatic temperature standards statewide and seek potential revisions as part of a long range plan. However, any standards modifications are likely years out. Even if modifications were to occur, they may not result in a delisting of Dixie and Hanks creeks.

NDEP has been interested in testing a new approach that has been used in Idaho, Washington and Oregon for temperature TMDLs. Rather than using the numeric water quality criteria (which may or may not be appropriate; or even achievable) as the target, these states have used a measure of riparian vegetation health as a surrogate target. The thought is that if riparian vegetation (and channel form) is healthy, the resulting stream temperatures will generally be as good as can be expected for that system (without changes in flow management). Under the Clean Water Act, NDEP has no control over flows, but channel form, function and riparian conditions can be addressed through land management/restoration activities.

Dixie and Hank creeks were selected as pilot temperature TMDLs for 2 different reasons. Dixie Creek has significant riparian vegetation problems and a TMDL could assist in BLM's efforts to partner with the private landowners to improve riparian conditions. Hanks Creek has a much different situation. While most of Hanks Creek is under BLM jurisdiction and much of the lower stream is meeting BLM's riparian vegetation goals, the stream temperatures are still exceeding state water quality standards.

1.2 Total Maximum Daily Load (TMDL) Defined

TMDLs are an assessment of the amount of pollutant a water body can receive and not violate water quality standards. Also, TMDLs provide a means to integrate the management of both point and nonpoint sources of pollution through the establishment of waste load allocations for point source discharges and load allocations for nonpoint sources. TMDLs are to be established at levels necessary to attain and maintain the applicable narrative and numerical water quality standards with consideration given to seasonal variations and a margin of safety. For this TMDL document, vegetation health is used as a surrogate target for the numeric temperature criteria.

Once approved by the U.S. Environmental Protection Agency, TMDLs are implemented through existing National Pollutant Discharge Elimination System (NPDES) permits for point source discharges to achieve the necessary pollutant reductions. Nonpoint source TMDLs can be implemented through voluntary or regulatory nonpoint source control programs, depending on the state. In Nevada, the nonpoint source program is voluntary.

For the Dixie and Hanks Creeks lands managed by the BLM, implementation of these TMDLs is through BLM's management and restoration activities. For the privately owned lands within Dixie Creek, the BLM hopes to work with the land owner in the future to improve the riparian corridor conditions. One significant benefit of this TMDL document is that its existence increases the availability of NDEP nonpoint source grant funds (Clean Water Act Section 319(h) funds) for projects needed to me the TMDLs.

2.0 Methodology

The Dixie and Hanks creeks temperature TMDLs use a measure of vegetation health as a surrogate target (or desired goal), rather than the numeric water temperature standards (which may not be appropriate or achievable). Given the concerns about the appropriateness of the temperature standards, it is believed that riparian vegetation health is a more acceptable and workable target.

An additional concern about using the temperature standards a target is the inherent complexities in modeling water temperatures in streams. As discussed in the following background section, there are numerous factors which can impact water temperature that would need to be accounted for in a temperature modeling effort. Of the many factors, riparian vegetation is the primary factors that can be potentially managed. While streamflow may also be factor in determining stream temperatures, streamflow is not directly addressable under the Clean Water Act.

4.0 Background

Key to the approach taken in this TMDL is the fact that riparian vegetation has a direct effect on stream temperature. However, the temperatures found in streams can be highly variable with time and space depending upon cumulative influence of a myriad of upstream factors related to the heat budget.

A waterbody heat budget is rather complex and consists of 5 basic thermal processes: 1) radiation; 2) evaporation; 3) convection; 4) conduction; and 5) conversion of energy from other forms of heat (Figure 2; Theurer et al. (1984)). Of these processes, radiation from the sun is a major component of a water's overall heat budget. For this reason, shading from riparian vegetation can have a significant impact on stream temperatures.

There has been significant debate over the role of air temperature in controlling stream temperatures. While a good correlation can exist between air temperature and water temperature, Johnson and Wondzell (2005) have found that direct solar radiation (not air temperature) was the largest contributor to changes in daily temperature. As Johnson and Wondzell concluded "…*just because air and stream temperatures are correlated does not mean that there is a cause-and-effect relationship*".

One reason air temperature can correlate well with stream temperature is that air temperature is well correlated with elevation, basin area (surrogates for time water is exposed to solar radiation, etc.) Though the exchange of heat between the air and the water (convection) represents a small portion of the heat budget, air temperature affects other heat flux components such as atmospheric radiation and evaporation.

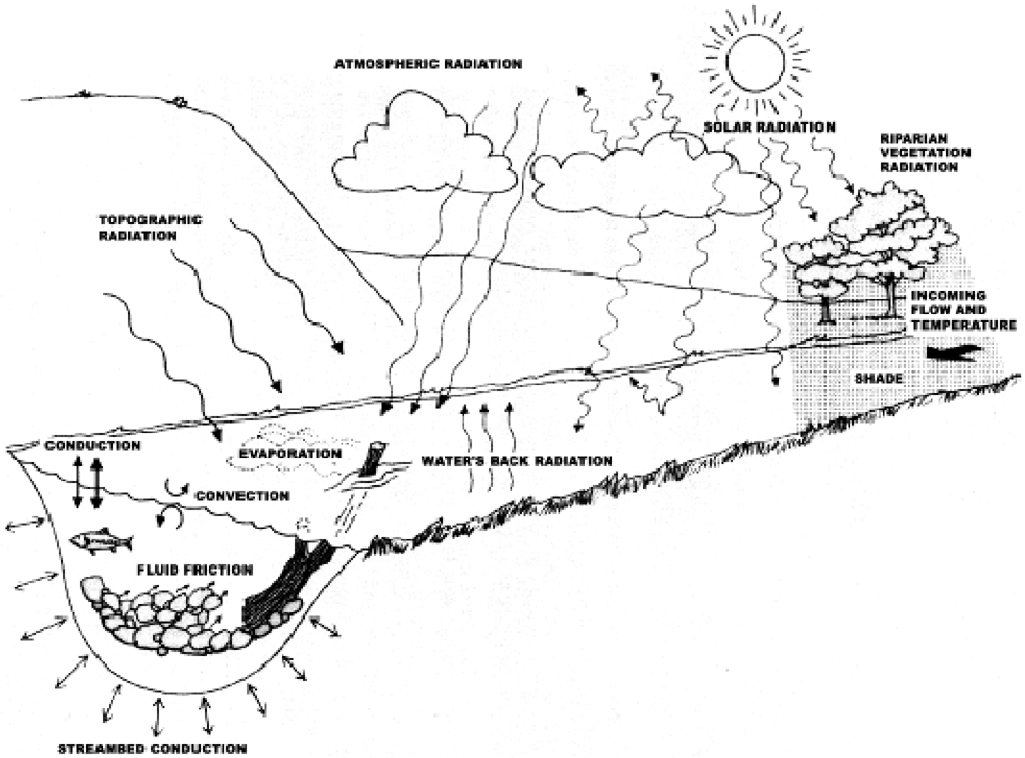

Figure 2. Stream Heat Flux Components (from Bartholow, 2000)

2.2 Methodology Steps

The methodology used for the Dixie and Hanks creeks temperature TMDLs consisted for 4 main steps:

- Step 1 – Determine existing riparian vegetation conditions
- Step 2 – Estimate existing shade and solar radiation loads
- Step 3 – Establish target riparian vegetation conditions as surrogates for temperature standards
- Step 4 – Estimate desired shade and solar radiation loads (and associated load reductions) at target riparian vegetation conditions

Following are details on each of the steps.

Step 1 – Determine Existing Riparian Vegetation Conditions

For purposes of these TMDLs, existing riparian vegetation conditions along Dixie and Harnks creeks are based upon assessment protocols developed and used by BLM (2002) for over 25 years throughout northeastern Nevada. BLM has used the results of their field assessments to evaluate and develop land management improvement strategies for stream and riparian habitats. While the field procedures involve collecting a wide variety of stream and riparian conditions, the following description focuses only on that portion of the methodology directly related to riparian vegetation and streambank conditions. Appendix A presents a more detailed description of the BLM methodology.

At each survey site, five cross-sectional transects (T1 – T5) are placed 100 feet apart with T1 at the downstream point (Figure 3). At each transect, a bank cover rating and a bank stability rating are estimated for both the left bank and the right bank extending 50 feet above and below the transect. Ratings vary from 0.5 to 2.0 as shown in Tables 2 and 3. The overall bank cover rating for the site is equal to the sum of the 10 subreach cover ratings, and the overall bank stability rating is equal to the sum of the 10 subreach stability ratings. A maximum rating of 20 can be achieved if all subreaches have a rating of 2.0. From the bank cover and bank stability ratings, BLM calculates a riparian condition rating by adding the bank cover and bank stability ratings and dividing by the total number of points. The resulting riparian condition calculation can vary from 25% to 100% of optimum. See Appendix A for example photographs for each rating.

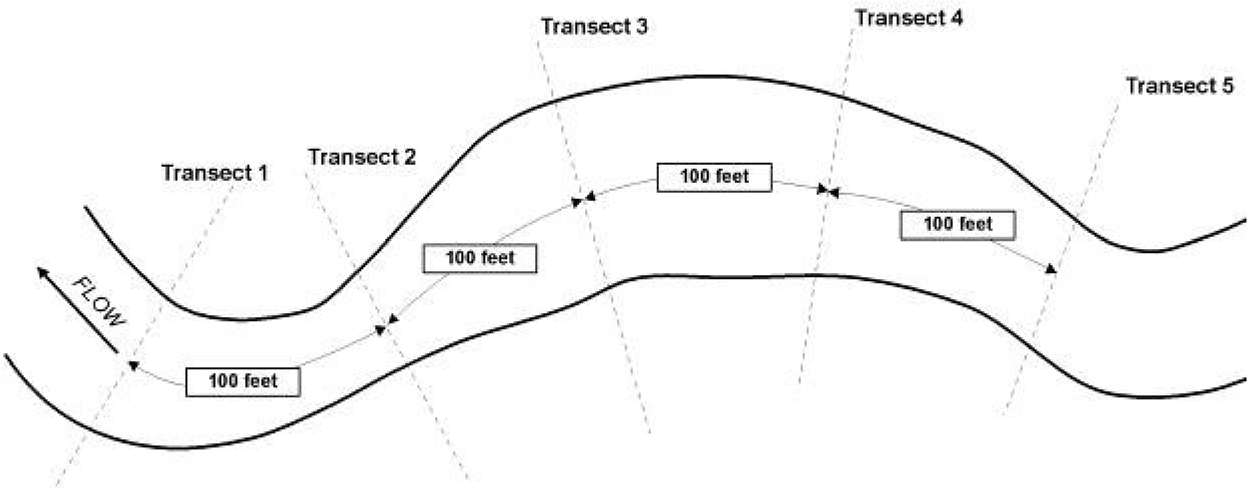

Figure 3. Transect Layout for BLM Habitat Surveys

Table 2. Streambank Cover Ratings and Descriptions (BLM, 2002)

Rating	Type	Description
0.5	Exposed	Bank is covered with scattered low to medium shrubs, forbs, or grasses, or bank is exposed.
1.0	Grass	Bank is medium to heavily covered with low to medium shrubs, forbs, or grasses, or a combination of these plants.
1.5	Brush	Banks have scattered trees and/or tall (>7 feet) shrubs. A scattered density is considered to have 2 or more 10-foot openings. A few trees or tall (>7 feet) shrubs scattered along the streambank does not warrant a rating of 1.5.
2.0	Forested	Bank is medium to heavily covered with trees and/or tall (>7 feet) shrubs. Banks with no more than one continuous 10-foot opening are considered medium dense. In addition to one 10-foot opening, there may be several smaller openings less than 10 feet in length.

Table 3. Streambank Stability Ratings and Descriptions (BLM, 2002)

Rating	Description
0.5	Bank is totally unstable. Heavy erosion and bank sloughing occurring on most of the streambank length. Erosion constant.
1.0	Less than 50% of the bank is stable. Moderate to heavy erosion and bank sloughing taking place during high and low flows.
1.5	More than 50% of the bank is stable. Some erosion present but usually associated with high flows. Banks are recovering naturally.
2.0	Bank is totally stable. Minimal evidence of bank erosion at any flow condition.

BLM commonly uses a stream's riparian condition rating to guide their management decisions. For example, BLM has established long term objectives for Hanks Creek which include a riparian condition rating in the good to excellent condition (65% of optimum or higher) (BLM, 2009).

A goal of this TMDL document is to develop comprehensive information on the existing riparian vegetation conditions of both Dixie and Hanks creeks. One way to achieve this goal would be to perform extensive field surveys at numerous locations. However, this approach is thought to be resource intensive and not realistic given some of the access issues due to the topography (particularly for Hanks Creek). For these temperature TMDLs, an alternative approach has been tested which relies heavily on available aerial imagery with some field ground □rothing. In order to apply this approach, a quantitative relationship between imagery characteristics and BLM's riparian condition ratings was needed.

Fortunately, recent aerial photography was available to test this approach. During the summer of 2006, the U.S. Department of Agriculture produced 1-meter resolution aerial imagery throughout Nevada as part of the NAIP (National Agriculture Imagery Program) efforts. Products consisted of two sets of imagery – natural color and color infrared (Figure 4). While natural color imagery shows those colors visible to the naked eye, the color infrared (CIR) includes an invisible near infrared band. CIR imagery is commonly used in vegetation study, as healthy vegetation is depicted in red and generally stands out from the rest of the land cover.

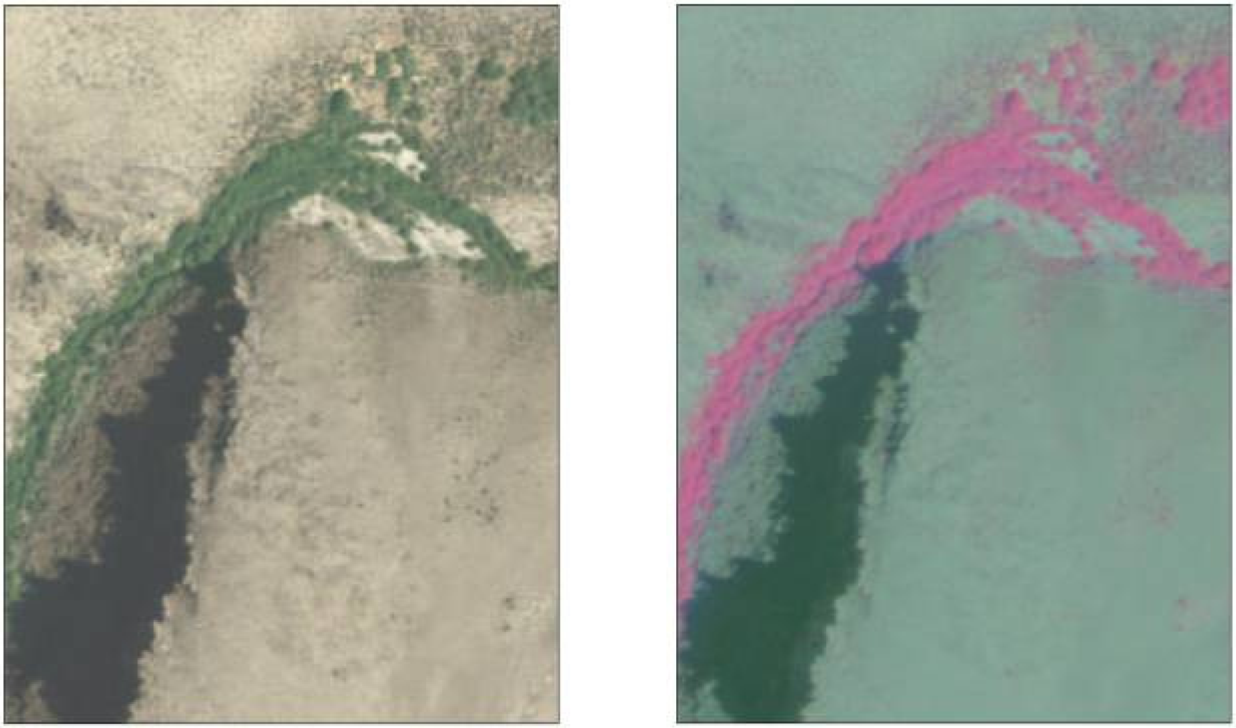

Figure 4. Sample NAIP Natural Color and Color Infrared Imagery on Hanks Creek

As discussed earlier, BLM's riparian condition rating incorporates both the bank cover rating and the bank stability rating. However, it was determined that bank stability conditions could not be readily estimated from the NAIP imagery, but bank cover conditions could. Therefore, the bank cover rating has been selected as the surrogate for the riparian condition rating. An evaluation of the nearly 30,000 datapoints in the BLM database indicated a good correlation between riparian condition rating and the bank cover rating (see Figure 5). This is not surprising as the bank cover scores make up ½ of the riparian condition ratings. Also, channel health is needed to facilitate vegetation health so one would expect a reasonable relationship.

The success of the desired approach relied on the ability to develop a reasonable relationship between characteristics derived from the NAIP imagery and the BLM bank cover ratings. To test the ability to use NAIP imagery for assessing vegetation conditions, a series of information was extracted from the NAIP images for selected BLM habitat survey sites in northeastern Nevada. While BLM has performed over 700 habitat surveys, only 46 were considered appropriate for seeking a relationship between the NAIP imagery and the habitat survey data (specifically bank cover) for purposes of this TMDL. The primary reasons for selecting these sites were: 1) BLM surveys were performed within one year of NAIP imagery acquisition (2005-07); and 2) BLM survey sites had not experienced wildfires between time of imagery acquisition and bank cover surveys

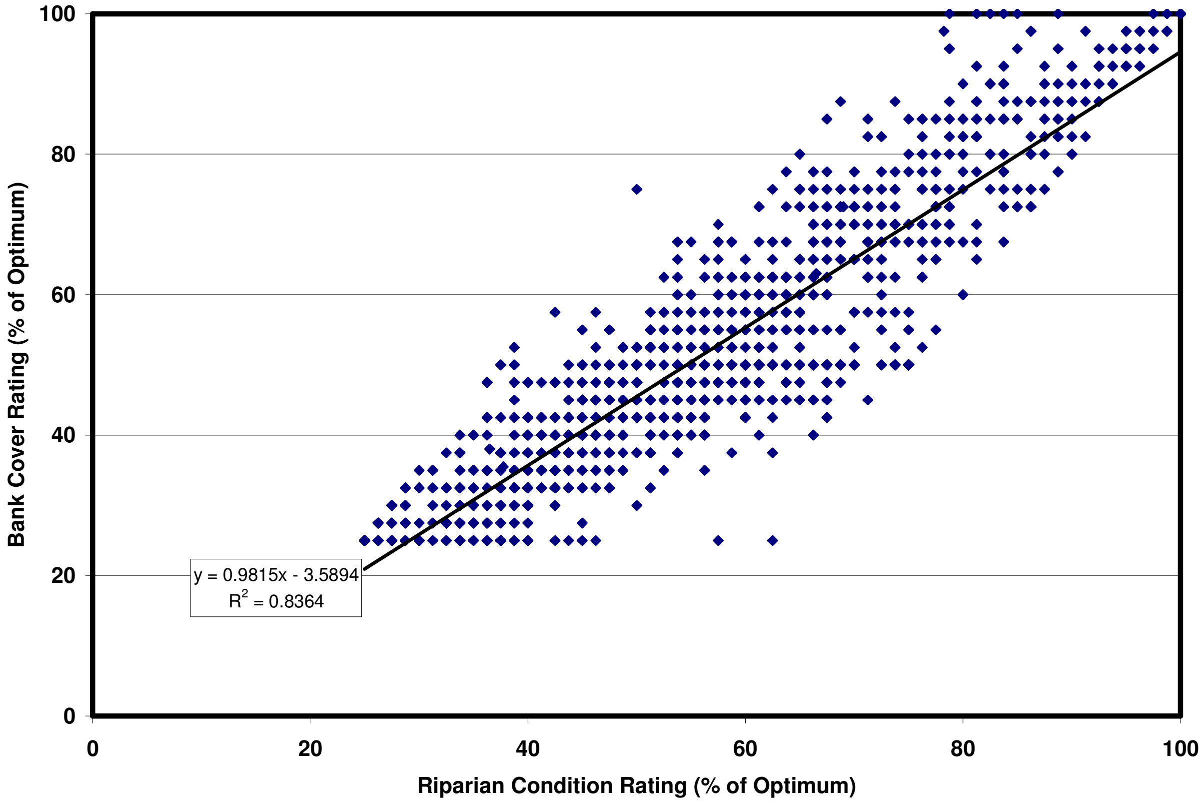

Figure 5. Bank Cover Rating vs. Riparian Condition Rating

The first step in developing a possible predictive relationship involved extracting information from the imagery associated with each of the 500-foot survey sites. Using GIS software, 10-foot buffers (from the bankfull[1] limits) were digitized for the 500-foot reaches. While actual riparian areas are often less than 10 feet wide, the 1 meter resolution in the imagery makes it difficult to analyze to a finer level. It is first of all, difficult to accurately digitize the edge of bankfull let alone digitize a narrow buffer from 1-meter resolution imagery. Delineation of the extent of woody vegetation was also difficult at this resolution.

For each buffer zone, the following information was derived in hopes of finding relationships between these metrics and BLM's bank cover rating for the selected sites:

- % of area with riparian vegetation
- % of area with woody vegetation

Percent Riparian Vegetation: Healthy riparian vegetation (grasses, sedges, willows, etc.) within the buffer zones was identified using the Normalized Difference Vegetation Index (NDVI). NDVI has

[1] Dunne and Leopold (1978) provided the following definition: "*The bankfull stage corresponds to the discharge at which channel maintenance is the most effective, that is, the discharge at which moving sediment, forming or changing bends and meanders, and generally doing work that results in the average morphologic characteristics of channels.*" Vegetation is one of the indicators commonly used in the field to estimate bankfull limits. In part, bankfull limits for Dixie and Hanks creeks were estimated on the NAIP imagery based upon the limits of the riparian vegetation.

been used for years to assess vegetation cover from multispectral aerial imagery, and is calculated as follows using channels in the CIR imagery.

NDVI = (Near Infrared Band – Red Band) / (Near Infrared Band + Red Band)

Index values can range from -1.0 to 1.0, but vegetation values typically range between 0.05 and 0.7 (BAE Systems, 2004). Higher index values are associated with higher levels of healthy vegetation cover. NDVI values near zero and decreasing negative values indicate non-vegetated features such as barren surfaces (rock and soil) and water, snow, ice, and clouds. Figure 6 shows the NDVI values for a selected BLM habitat survey site along with its 10-foot buffer.

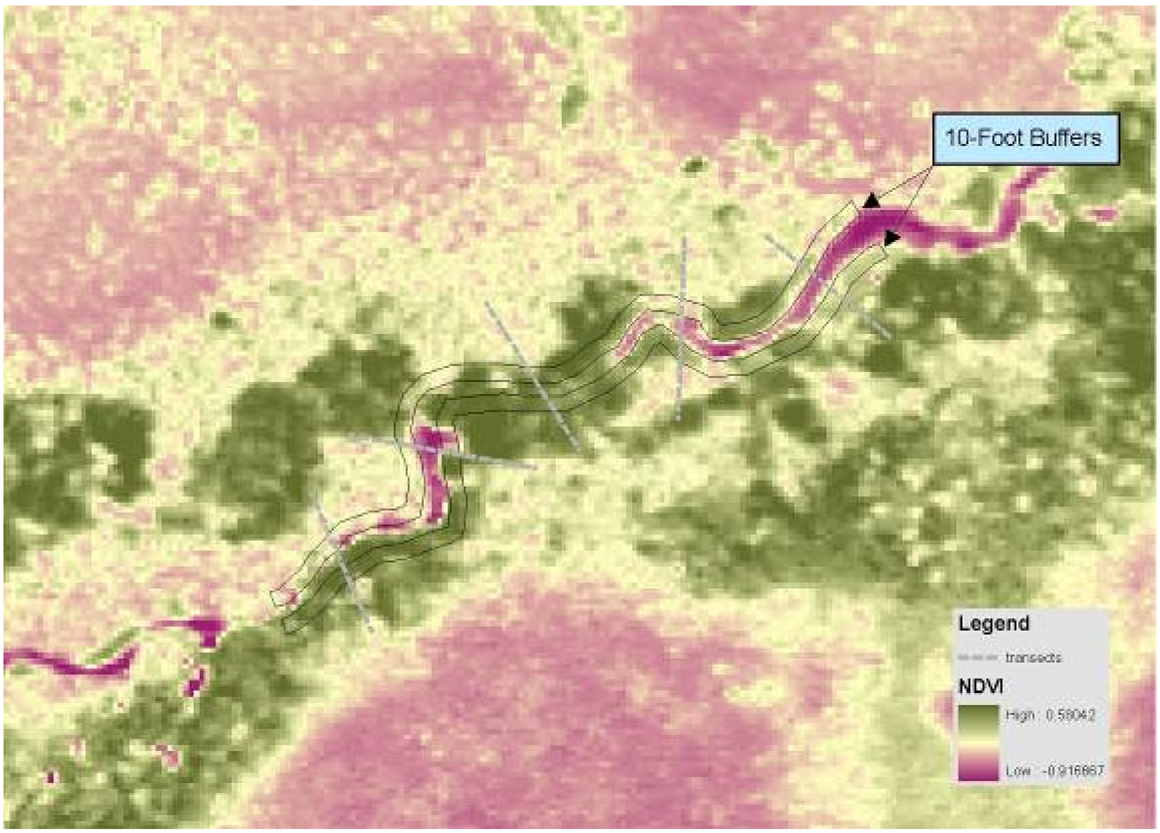

Figure 6. NDVI Results for Sample BLM Survey Site Area

In determining percent riparian vegetation values, a NDVI-threshold of 0.05 was utilized to differentiate healthy riparian vegetation within the buffers from other land covers (Figure 7). Using GIS software, the percentage of the buffer containing healthy riparian vegetation was calculated for the 46 survey sites.

<u>Percent Woody Vegetation:</u> It was initially hoped that woody (primarily willows on these systems) vegetation could be delineated (digitized) throughout each of the 46 selected survey site buffers, and that the same techniques could be used to delineate woody vegetation on Dixie and Hanks creeks. However with the 1-meter resolution, it was not possible to accurately delineate the extent of woody vegetation for a site (Figure 8). Therefore, each buffer was assigned one of five general categories of woody cover (0%, 25%, 50%, 75%, or 100%) based upon visual estimates from the imagery. Nevertheless, use of approximate woody vegetation amounts results in an adequate relationship

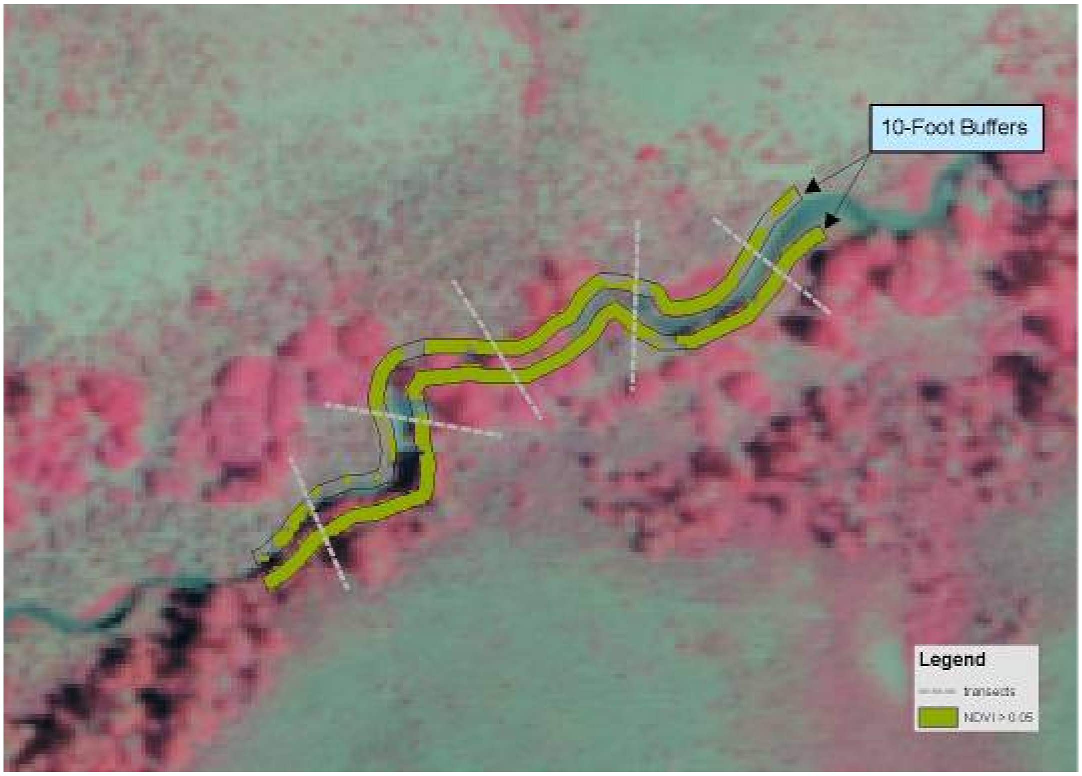

Figure 7. Area with NDVI > 0.05 for Sample BLM Survey Site

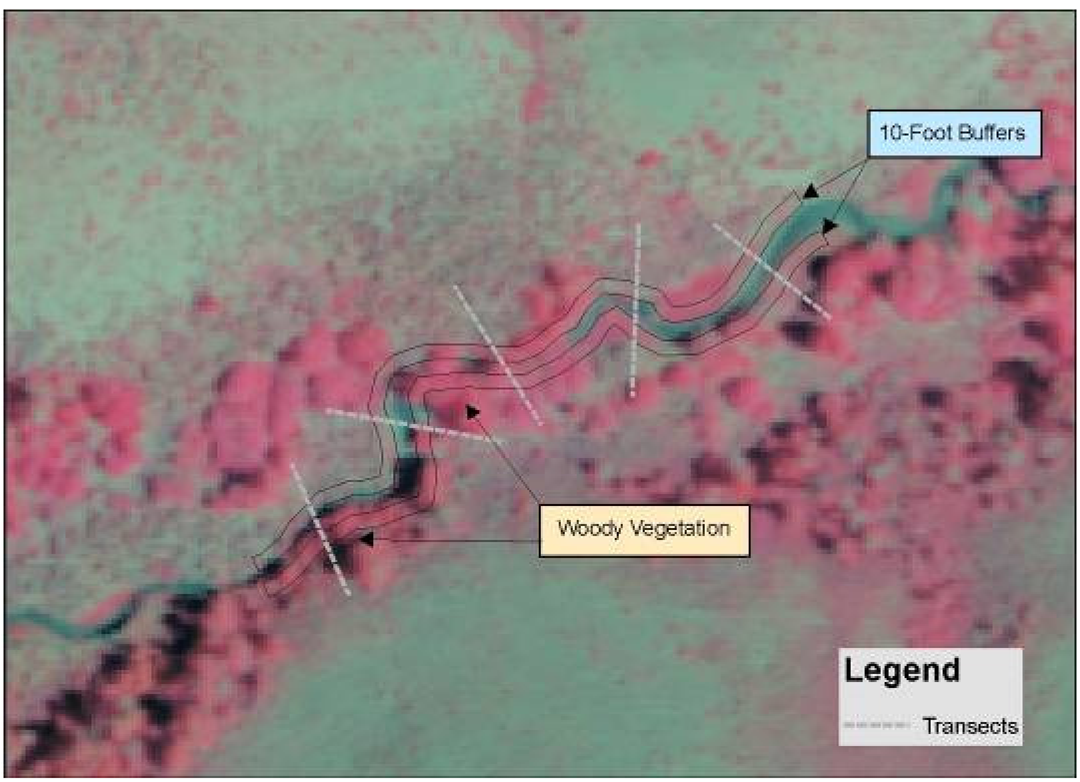

Figure 8. Woody Vegetation for Sample BLM Survey Site

The results of the bank cover rating, percent healthy riparian vegetation and percent woody vegetation estimates for the 46 selected sites are summarized in Figure 9. Using multiple linear regression, a rather good relationship ($R^2 = 0.94$) was developed:

[Eq. 1]

Bank Cover = (0.478 x % Woody Vegetation in Buffer) + (0.264 x % Riparian Vegetation in Buffer) + 25

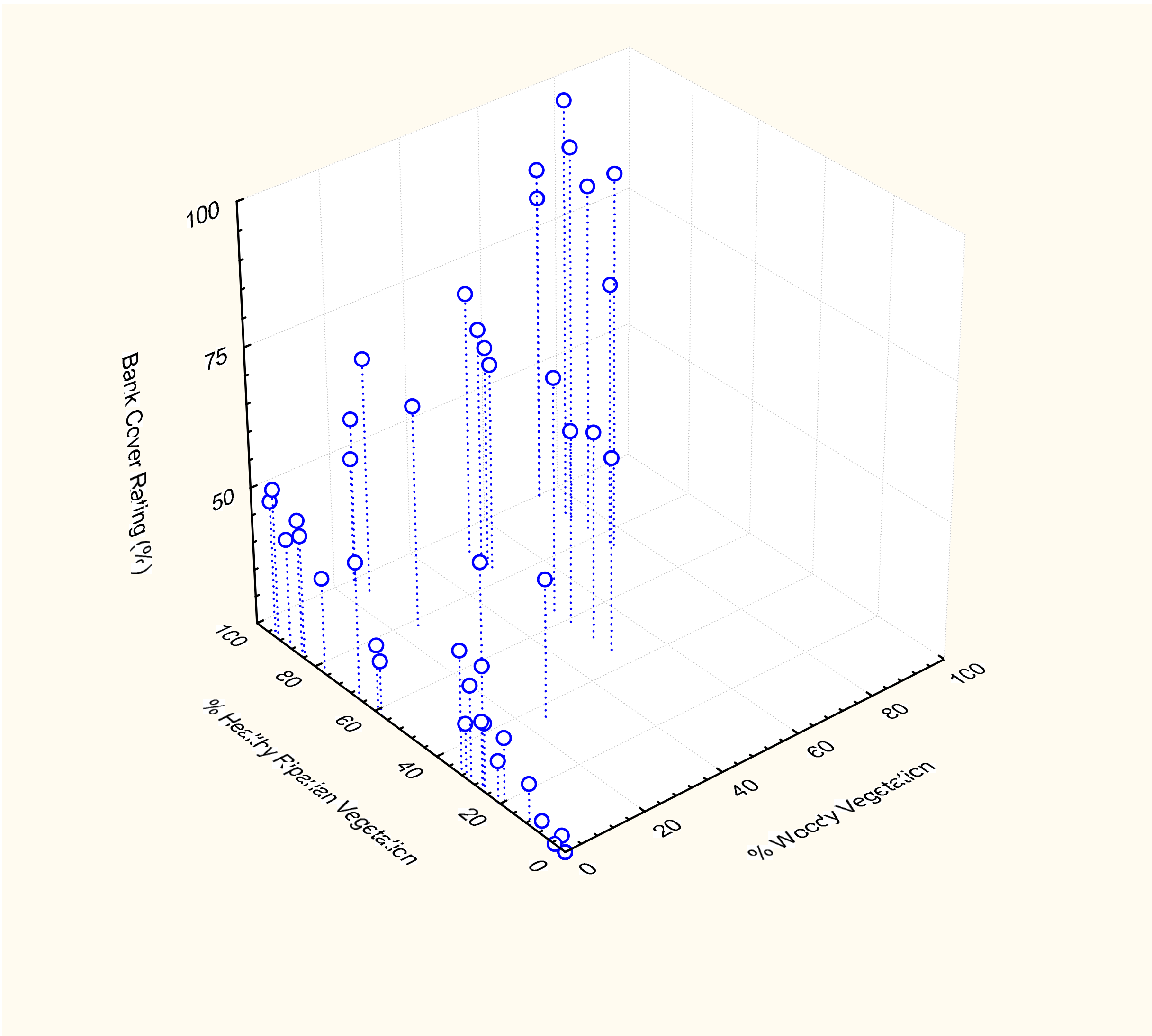

Figure 9. Plot of Bank Cover Ratings and Buffer Characteristics for Selected BLM Survey Sites

When applied to the 46 selected sites, this relationship provided very reasonable estimates of the actual bank cover ratings for those sites (Figure 10). This relationship was deemed to be more than adequate for estimating bank cover conditions throughout Hanks and Dixie creeks.

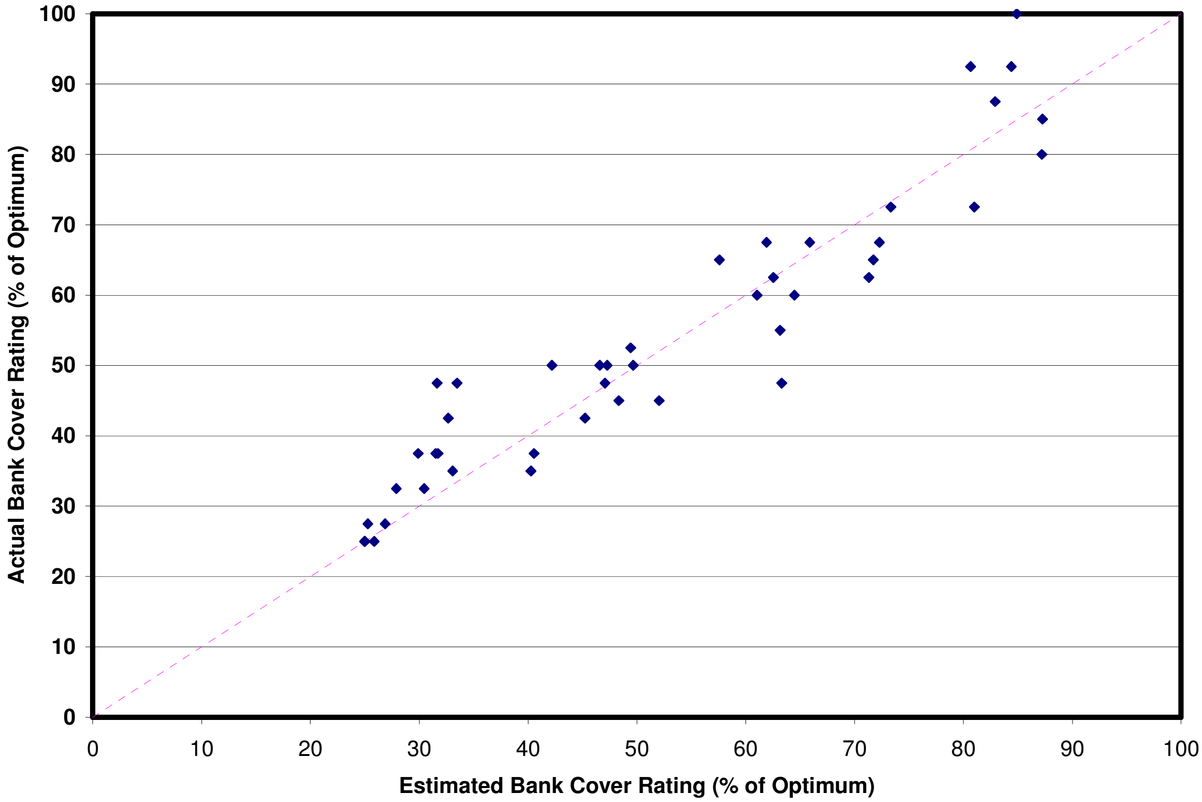

Figure 10. Predicted Bank Cover Rating vs. Actual Bank Cover Ratings

With an adequate predictive relationship available, the next step in the process was to estimate the existing bank cover conditions throughout each stream (divided into 500-foot segments). As with the 46 selected sites, 10-foot buffers were developed throughout Dixie and Hanks creeks. Using the NAIP imagery, the percent healthy riparian vegetation and percent woody vegetation estimates were generated for 500-foot segments of the buffers. By applying Equation 1 to these estimates, bank cover ratings were developed for 500-foot segments throughout each of the TMDL streams. In addition to these estimates, NDEP staff performed a series of field surveys to develop bank cover estimates for comparison to the NAIP imagery derived estimates. Given the three year time difference between the NAIP/CIR imagery and the 2009 surveys, some differences were found between existing conditions and the conditions suggested by the imagery. In some cases, vegetation health appears to have improved since 2006. In other cases, vegetation health appears to have declined due to beaver activity and wildfires.

Step 2 – Estimate Existing Shade and Solar Radiation Loads

Since this is a TMDL document, estimates of existing loads and desired loads reductions are needed. In the case of a temperature TMDL, the loads are from solar radiation. Estimates of existing shade/solar radiation levels were based upon field measurements/observations and computer model predictions utilizing information extracted from the NAIP imagery. Computer model predictions of shade and the associated solar radiation loads were developed using the State of Oregon's Heat Source Model (Boyd and Kasper, 2003). Common solar radiation measurement units are langleys, Btus per square foot, kilojoules per square meter, and watts per square meter. Since the Heat Source Model outputs solar loads in langleys per day, this has been the chosen unit for these TMDLs.

The Heat Source model input includes estimates of a number of metrics known to affect shading and solar radiation levels, such as stream width, vegetation offset, and woody vegetation height (Figure 11). In addition, woody vegetation density, reach orientation (azimuth)[2], and latitude are other significant factors considered in the model. It is recognized that some shading is provided by grasses and sedges, however the shading provided by woody vegetation is far and above the largest portion for the woody-dominated systems.

The following inputs for the Heat Source model were as follows:

- Width: Estimated from the bankfull limits digitized from the NAIP imagery.
- Vegetation offset: Insufficient information available. Assumed = 0.
- Woody vegetation height: Based upon typical heights of woody species as provided in literature.
- Woody vegetation density: Set at 0%, 25%, 50%, 75% or 100% based upon visual estimates from the NAIP imagery.
- Reach orientation: Derived from NAIP imagery.

For this TMDL, June 21 was selected as the reference date for which to base estimates of existing shade/solar radiation load. While the warmest stream temperatures in this area typically occur in July and August, June 21 was selected as this is the time of highest solar radiation.

In addition to the computer model estimates, NDEP performed some field work to estimate shade at a few sites. During the summer of 2009, NDEP staff used a Solar Pathfinder™ to measure shade at some sites on Dixie and Hanks creeks (see Figure 12). The Solar Pathfinder™ is a device that allows one to capture an outline of the shade producing objects and readily convert the information to percent shade (percent of solar radiation that is blocked). However resources did not allow for extensive shade measurements.

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[2] Studies have shown that East-West oriented streams tend to receive more solar radiation than North-South oriented streams (given the same channel and vegetation characteristics) during the summer.

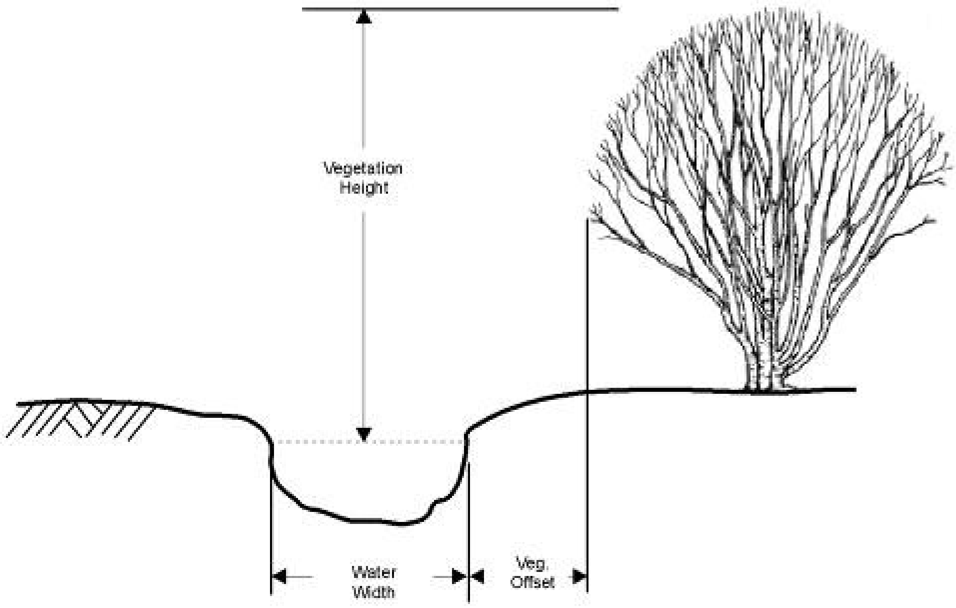


Figure 11. Riparian Cross Section Showing Key Features affecting Shading

Figure 12. Setting Up the Solar Pathfinder

Step 3 – Establish target riparian vegetation conditions as surrogates for temperature standards

For these TMDLs to be approvable by EPA, the targets need to be based upon compliance with Nevada's water quality standards. As discussed earlier, use of the numeric temperature water quality standards as targets was not deemed to be appropriate. The applicable temperature standards were established in the 1970s and no documentation has been found which justifies these values. The approach taken for this TMDL document was to use a riparian vegetation health target that satisfies the following narrative in Nevada's water quality standards (445A.121(8)):

> *The specified standards are not considered violated when the natural conditions of the receiving water are outside the established limits, including periods of extreme high or low flow.*

The thought is that if riparian conditions could be maintained at "natural conditions", then the temperatures that occur under these conditions are the best to be expected – even though the numeric standards are being exceeded. According to the BLM, the lower 9.5 miles stretch of Hanks Creek had not experienced any major fires for several decades (prior to the acquisition of the 2006 NAIP imagery) and has not been grazed from about 20 years. Bank cover conditions for this reach are assumed to be reasonably achievable "natural" conditions and will be used as the target for the Dixie and Hanks creek TMDLs.

Using Equation 1 and 2006 NAIP imagery (collected prior to recent wildfires), bank cover conditions were estimated for Hanks Creek and SF Hanks Creek (Figure 13). Field estimates were also performed during the summer of 2009 at selected sites (Figure 14). For the lower 9.5 miles, bank cover conditions ranged from about 30 to nearly 100. However the low value at HC-10 is due to the existence of a water gap where livestock are allowed access to the stream for drinking water. The other locations with low bank cover values (0.2, 1.1, 5.3 and 8.6 miles) are thought to be part of the natural variability of the system. Excluding the HC-10 location, the bank cover for the lower 9.5 mile portion of Hanks Creek has an average value of 80 and a minimum value of 50. These values will be used as the target for these TMDLs.

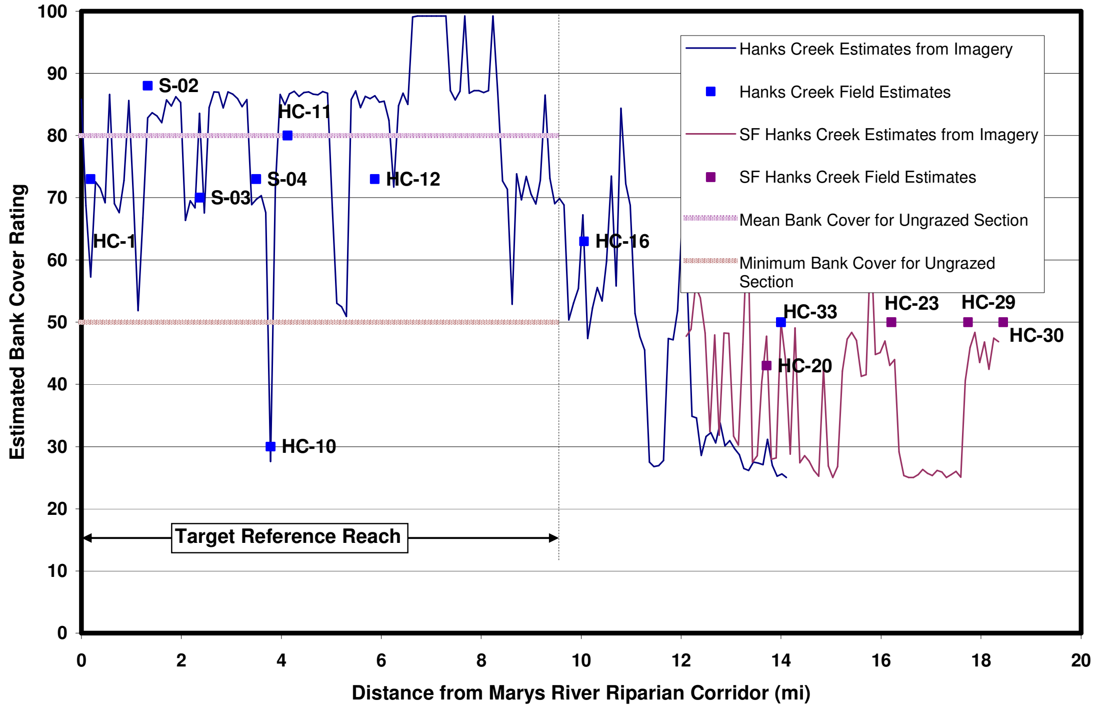


Figure 13. Estimated Bank Cover for the Target Reference Portion of Hanks Creek

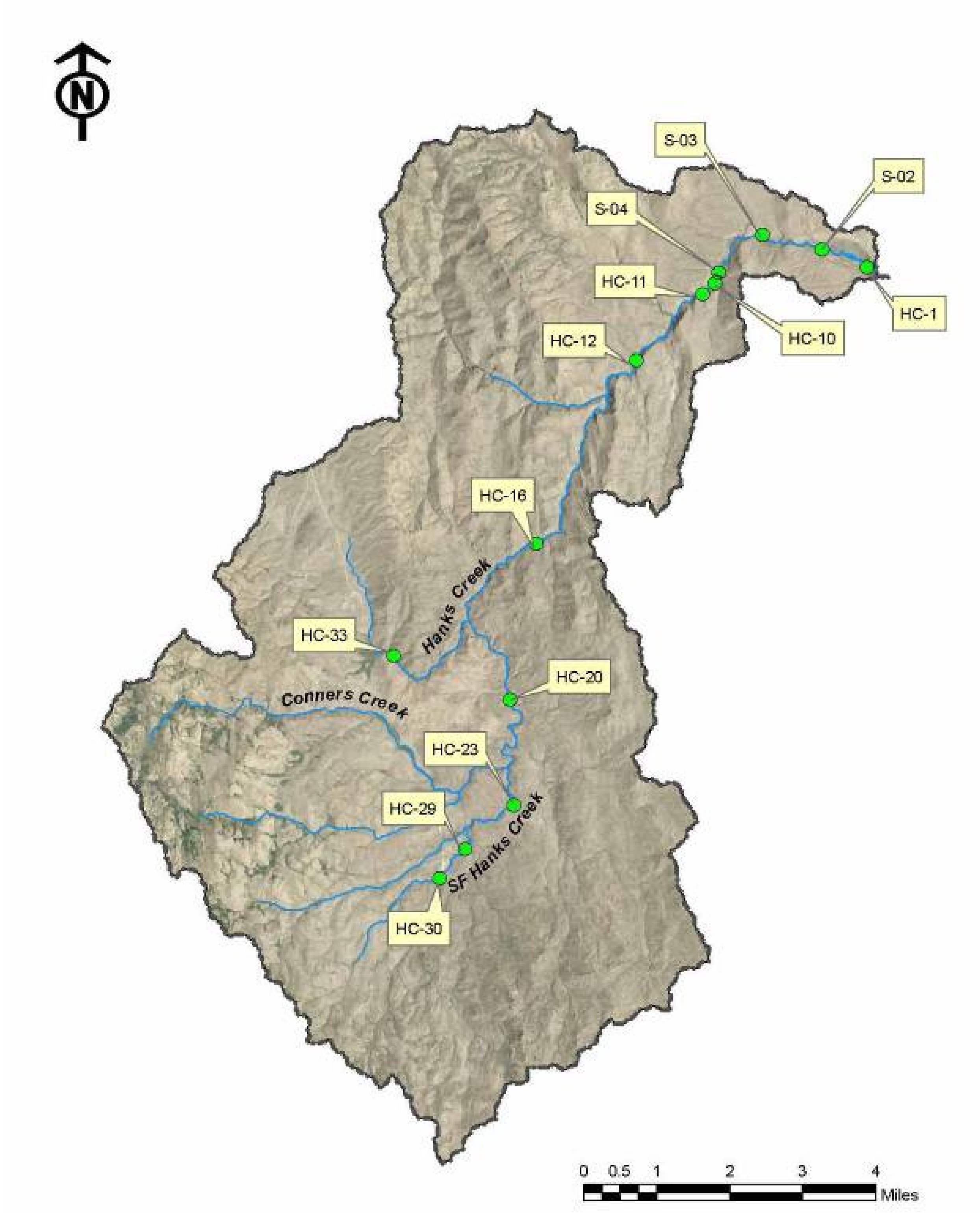


Figure 14. Bank Cover Rating Field Sites for Hanks Creek and SF Hanks Creek

There is considerable uncertainty associated with the individual bank cover estimates (approximately ± 15) depicted on Figure 13. For any given location along the creek, there is a 95% certainty that the actual bank cover value falls within the range represented by the Prediction Interval lines on Figure 15. If the uncertainty associated with individual predictions using Equation 1 were considered, the actual range of bank cover conditions (excluding the HC10 section) could vary from 37 to 100.

It is believed that a target of average bank cover conditions equal to 80 with a minimum of 50 are achievable for willow and other woody dominated systems, such as Dixie and Hanks creeks. However it is recognized that a variety of factors may exist which limit the ability of stream sections to meet this target. These factors include: 1) flow conditions including flood and drought; 2) wildfire damage to riparian areas; 3) beaver activity; 4) soils; and 5) channel conditions. Some of these factors (wildfire) may limit bank cover potential in the short term while others (soils, channel conditions) may limit in the long term. When these conditions are found to exist for given locations, it may not be appropriate to include these reaches when evaluating these streams against the TMDL target.

Time may show that some reaches of Dixie and Hanks creeks may not be capable of supporting a willow-dominated riparian area, but could support a healthy growth of grasses and sedges. In these areas, a maximum bank cover rating of only about 50 is possible. At some time in the future, it may be appropriate to revise the bank cover targets to more accurately reflect reasonably achievable conditions.

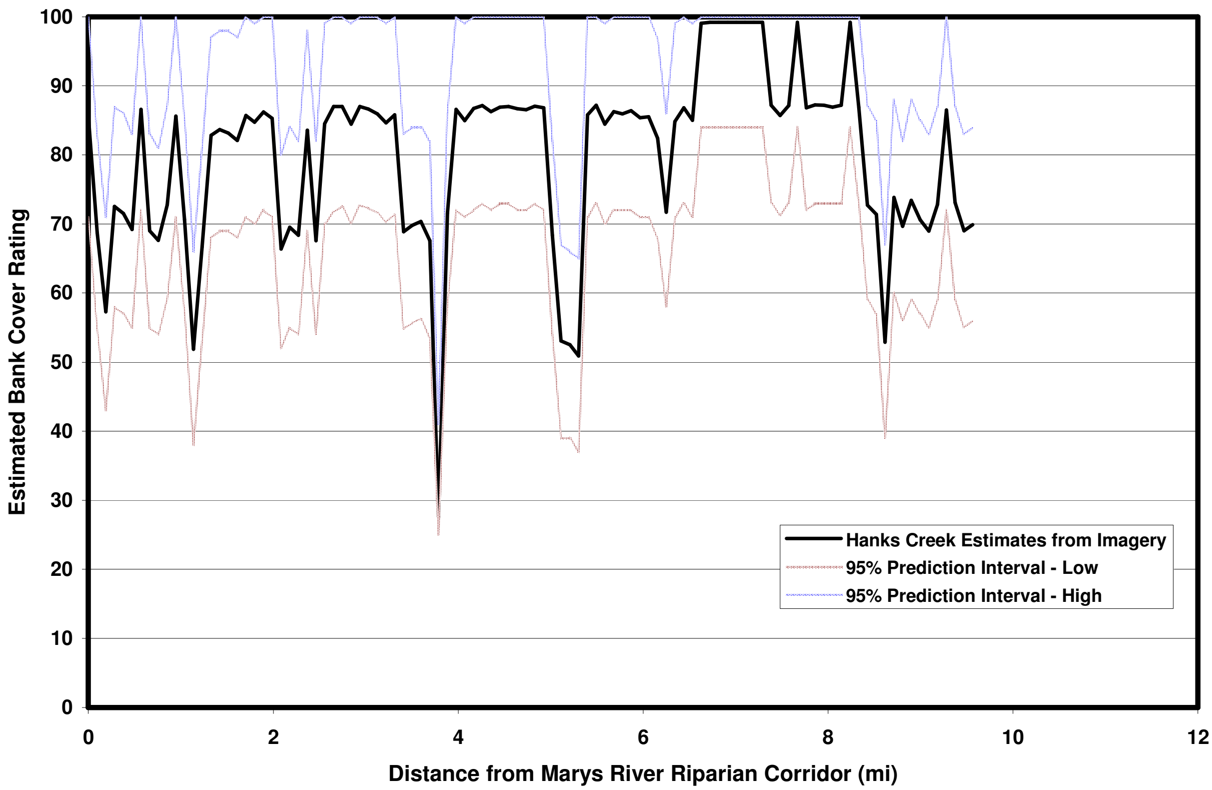


Figure 15. 95% Prediction Interval for Bank Cover Estimates on Lower Hanks Creek

Step 4 – Estimate Target Shade and Solar Radiation Loads, and Associated Reductions

As in Step 2, the State of Oregon's Heat Source Model was used to develop estimates of shading and solar radiation loads under the targeted vegetation conditions. The same input used in Step 2 was used in this step, except for reach width and vegetation density.

Current bankfull widths may not be representative of desired widths for stream sections with riparian conditions at the set target. Impacted streams are typically wider and shallower than healthier stream, and have vegetation shading covering a lower percentage of the water surface. Regional curves relating bankfull width to drainage area are often used to estimate "expected" widths for a given location. Using NDEP's data compiled as part of its biological assessment efforts, Figure 16 has been developed. However, this curve has been developed using all types of sites from the healthy to the highly impacted sites. As a result, most (if not all) of the healthy sites on Dixie and Hanks Creek have bankfull widths which fall below this curve. Target widths for the creeks were derived from relationships similar to Figure 16, however using only healthy sites in the regressions.

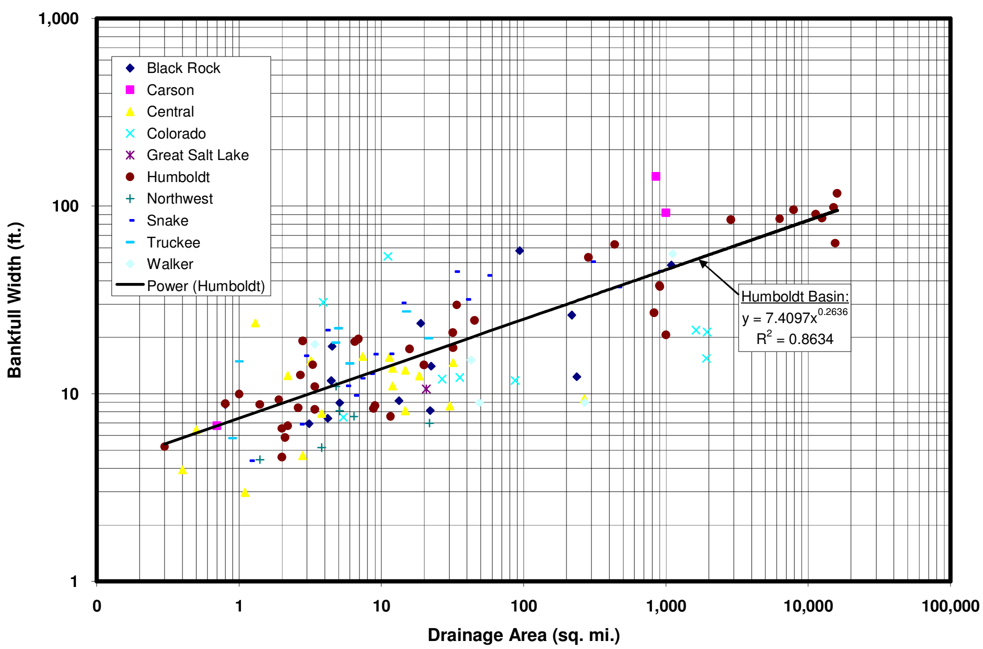


Figure 16. Drainage Area vs. Bankfull Width – All NDEP Biosites

For those reaches at or exceeding the Bank Cover Average Target of 80, existing woody vegetation densities estimated from the NAIP imagery were used in the target shade modeling. For those reaches below the Bank Cover Average Target of 80, target woody vegetation densities were set at 72% based upon the findings of Figure 17. This plot (Figure 17) of estimated bank cover ratings versus % woody vegetation for Hanks Creek suggests that one could expect the % woody vegetation to vary from about 60 to 72 percent when bank cover rating conditions are at the target of 80.

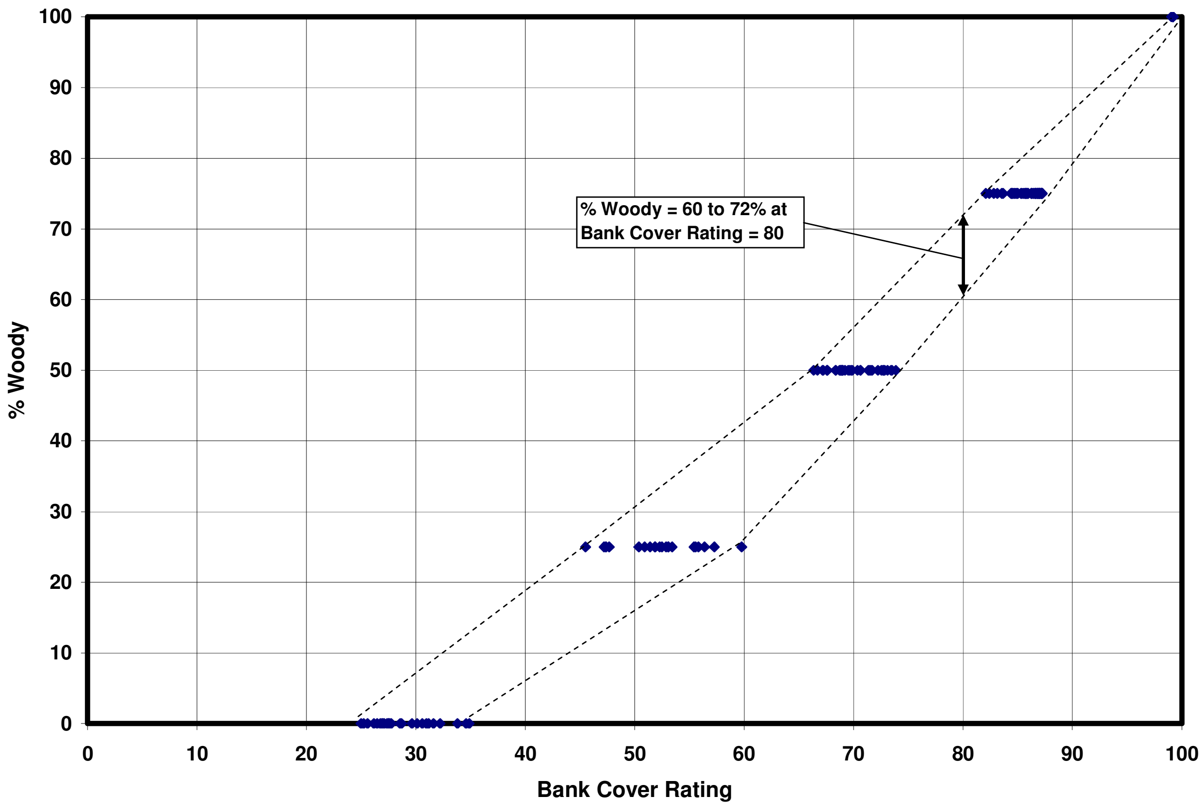


Figure 17. Bank Cover vs. Percent Woody Vegetation – Hanks Creek

4.0 Dixie Creek Temperature TMDL

3.1 Study Area Background

Located in the upper Humboldt River basin, Dixie Creek drains a watershed of approximately 173 square miles in size. Watershed elevations range from about 8700 feet in the Pinyon Range to about 5150 feet at the outlet. While Dixie Creek is the main stream in the watershed, there are a number of unnamed tributaries that may contribute flows during spring runoff or rainfall events (DCNR and USDA, 1963). Following is a discussion of characteristics within the watershed and Dixie Creek.

4.0.4 Land Cover, Ownership and Use

Under the USGS National Gap Analysis Program (2004), 1999-2001 Landsat imagery has been used to develop rather detailed landcover information for the southwestern United States. These data show the Dixie watershed to be dominated by sagebrush-type ecological systems with some areas of Pinyon and Juniper, and invasive grasses (Table 4, Figure 18).

Table 4. Land Cover for Dixie Creek Watershed

Category	Area (sq. mi.)
Intermountain Basins Big Sagebrush Shrubland	69.1
Intermountain Basins Montane Sagebrush Steppe	30.9
Great Basin Xeric Mixed Sagebrush Shrubland	16.4
Intermountain Basins Semi-Desert Grassland	14.7
Great Basin Pinyon-Juniper Woodland	11.9
Intermountain Basins Big Sagebrush Steppe	2.9
Invasive Perennial/Annual Grassland	1.7
Other	0.7

About 2/3 of the Dixie Creek watershed is owned by the BLM, with the remaining 1/3 held by private parties. However, a majority of the riparian area is under private ownership (Figure 19). BLM manages the land uses in the watershed under several allotments (Figure 20). There are grazing systems and exclosures on the public lands along Dixie Creek. However, there are miles of creek on private land that have no such protection and are degraded (BLM, 2007).

The Dixie Creek watershed has experienced a number of wildfires over the last few years that have affected the rangeland and riparian vegetation conditions. The worst of these events was the Sadler Complex fire in August 1999 (Figure 21). Other fires occurred in northeastern Nevada during 2005, 2006 and 2007 but had little impact upon the Dixie Creek riparian areas.

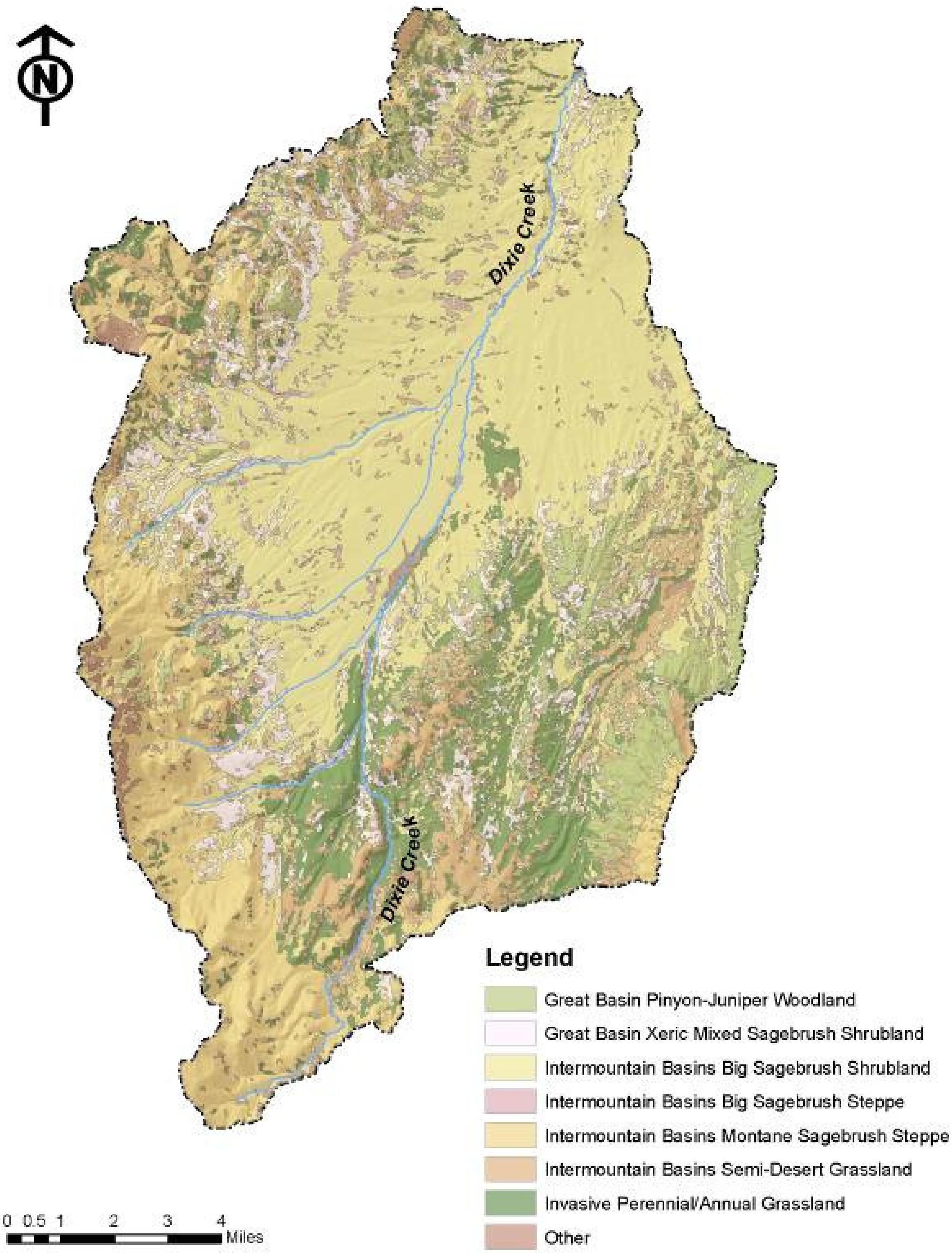


Figure 18. Dixie Creek Watershed Land Cover (USGS, 2004)

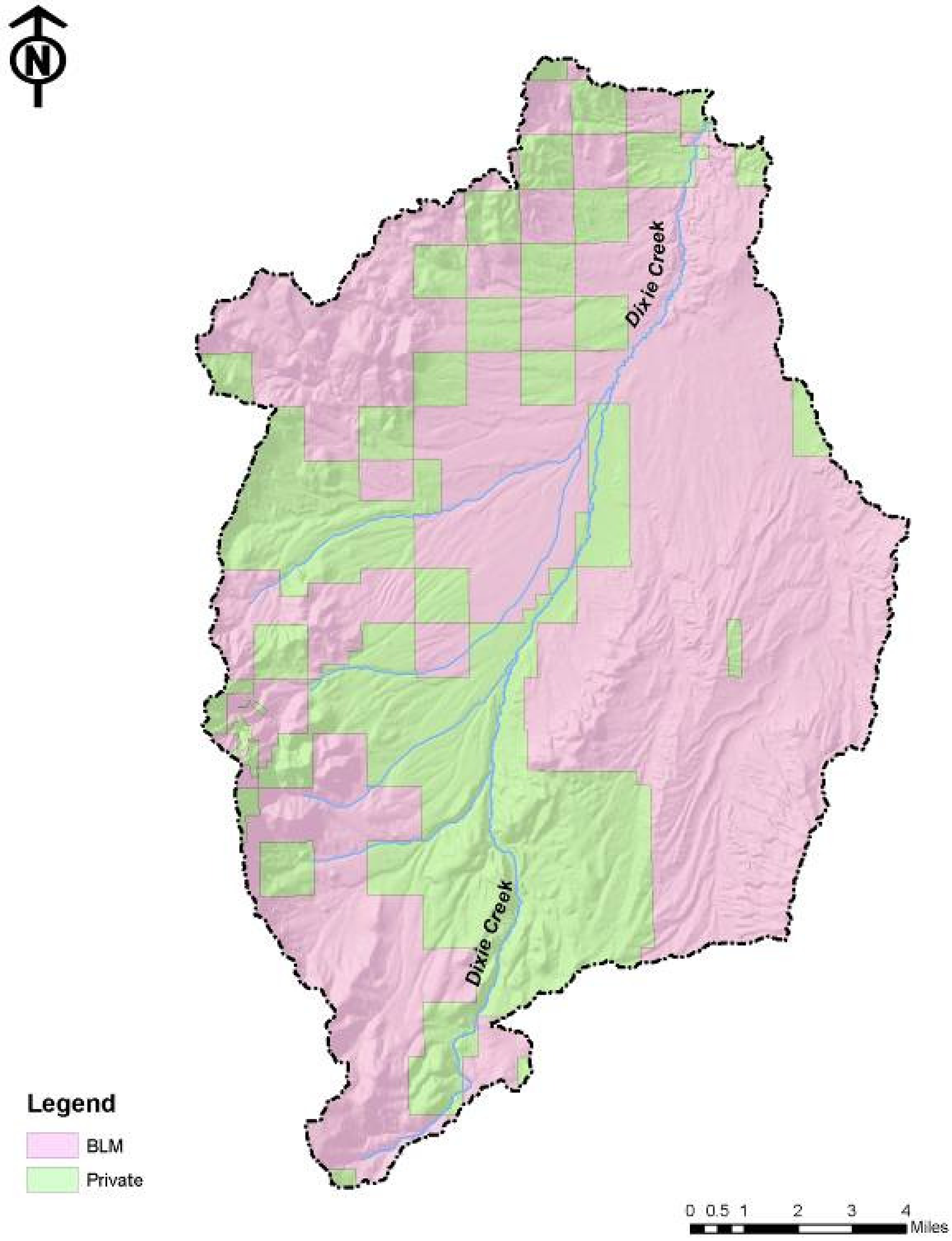


Figure 19. Dixie Creek Watershed Land Ownership

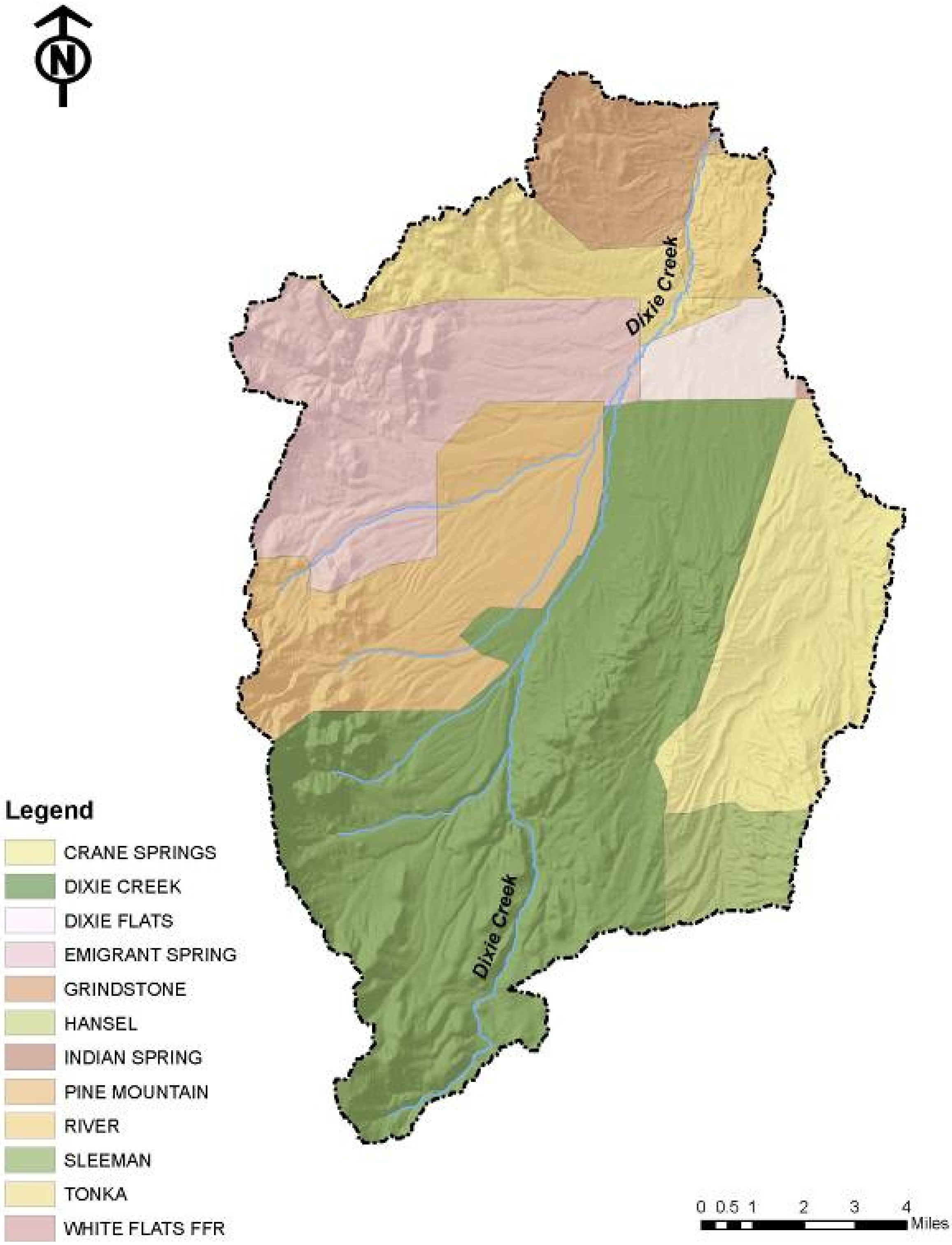


Figure 20. Dixie Creek Watershed BLM Allotments

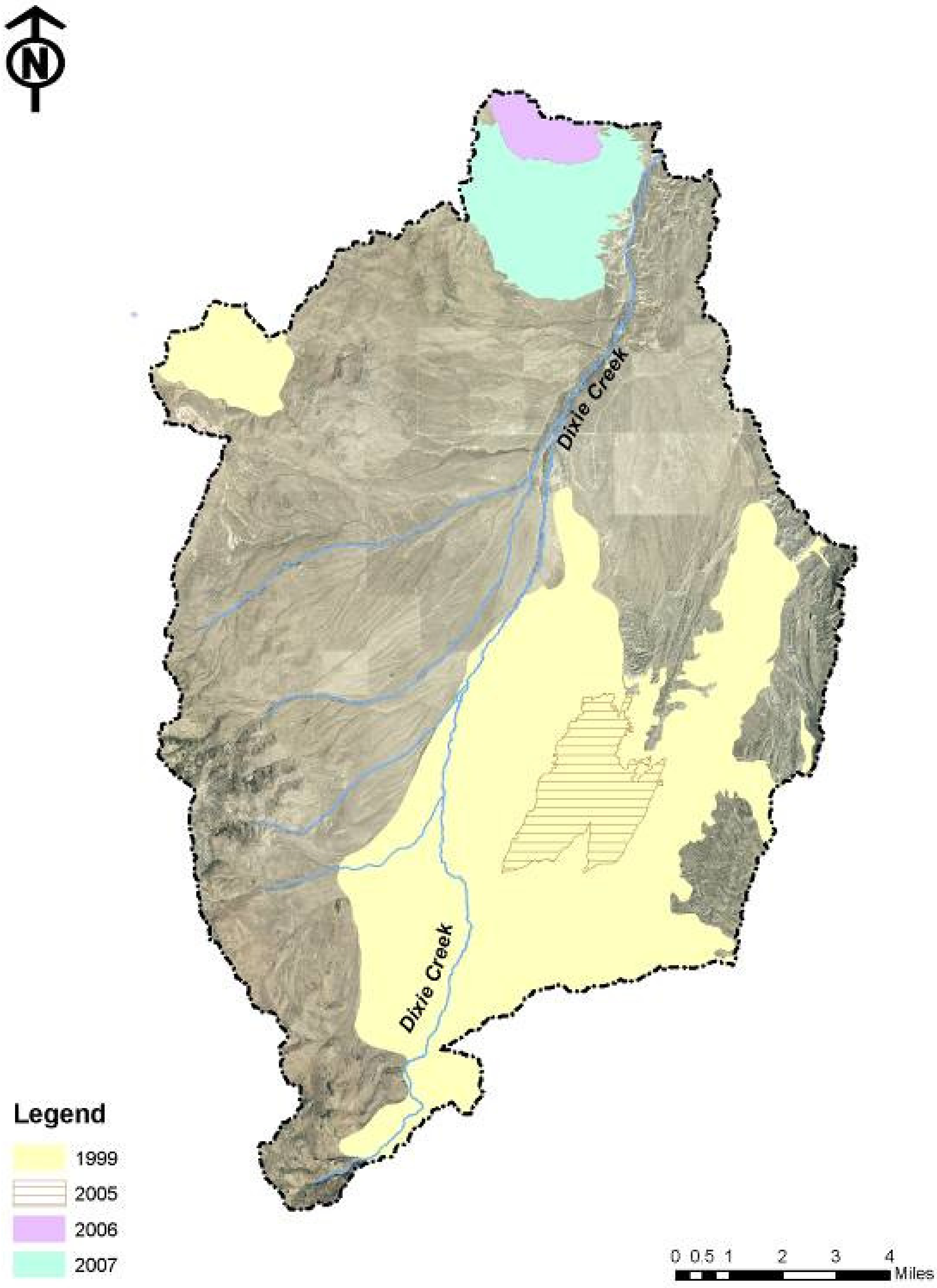


Figure 21. Recent Wildfires in Dixie Creek Watershed

3.1.2 Channel Characteristics

Dixie Creek is a small stream with widths typically less than 6 feet (Schroeter, 2001), and a typical parabolic shape to the stream profile (Figure 22). Slopes range from about 5% in the upper reaches to about 0.05% in the lower 10 miles of the creek. Much of lower 21 miles of Dixie Creek is incised to some degree, with depths as high as ~15 feet in some areas (Figure 23). However, new floodplains have been developed in many reaches providing areas for riparian vegetation establishment.

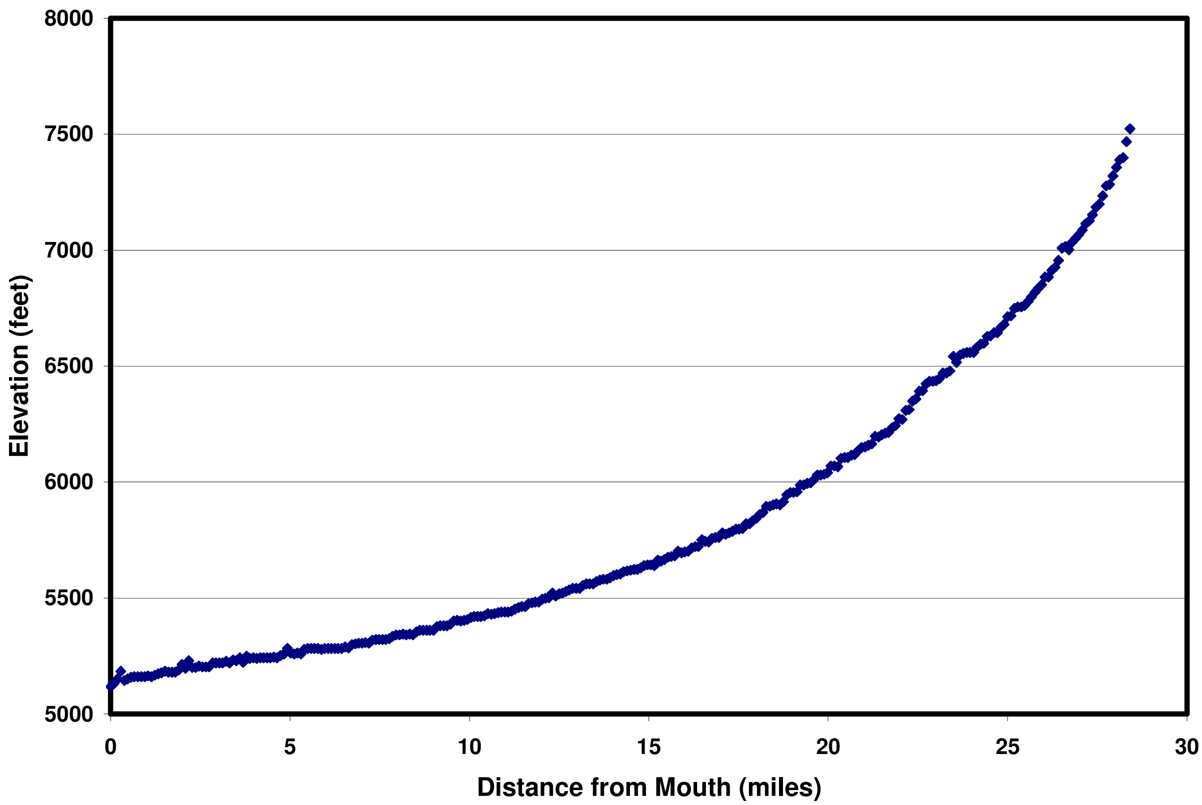


Figure 22. Dixie Creek Stream Profile

Bankfull widths vary from about 1-2 feet in the headwaters to 40 feet and higher in the mid-section of the stream (Figure 24). The higher widths tend to occur in those areas with limited perennial flow.

Figure 23. Deep Incisement in Dixie Creek about 6.5 Miles from Mouth

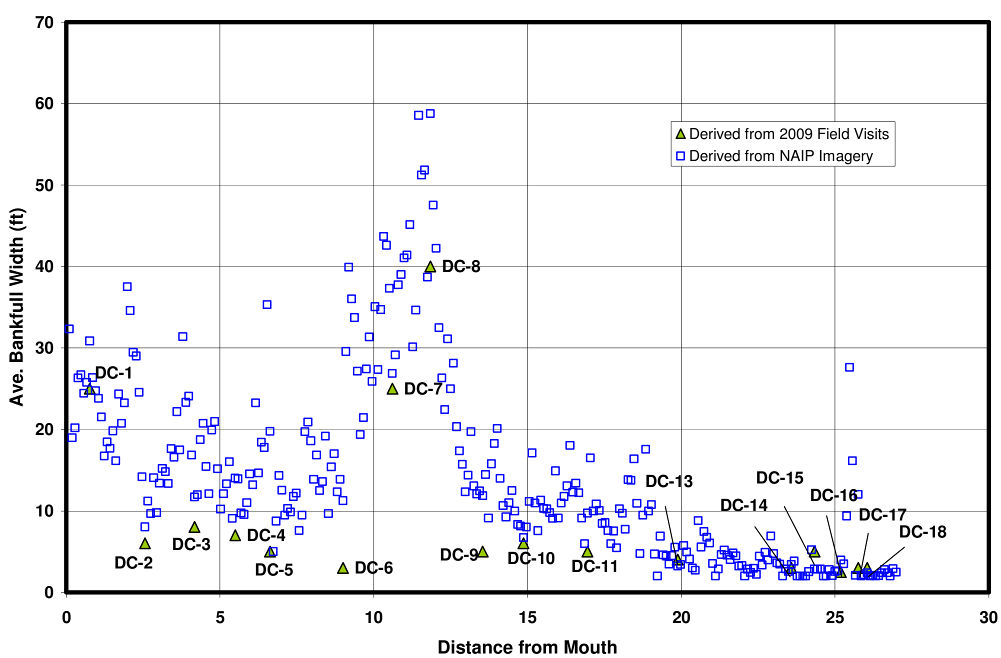


Figure 24. Dixie Creek Existing Bankfull Widths

3.1.3 Flow and Water Use

Runoff from snowmelt from the Pinyon Range, along with springs, accounts for most of the flow in the watershed (DCNR and USDA, 1963). However, little flow and water use information are available for the Dixie Creek system. The U.S. Geological Survey operated a gaging station on the lower Dixie Creek, but for only a brief period of time (1990 through 1996) (Figure 25). For 1990-96, the average annual flow was about 4,400 acre-feet, with flows varying from 0 to 232 cfs, and an average daily flow of about 6 cfs. However, flows below average were common with over 80% of the days experiencing flows below 6 cfs (Figure 26). Based upon field visits over the last few years, flows have been found to vary significantly throughout Dixie Creek with dry conditions occurring in the lower and middle reach in the late summer. Only the upper half appears to have year round flows (Figure 27). The extent of dry sections observed in 2009 were similar to those shown in August 7, 2006 NAIP

There are approximately 750 acres of irrigation rights under the Bartlett and Edwards decrees, however most of these lands are not irrigated due to the washing out of diversion structures. There is a small amount of irrigation in the upper Dixie, but is thought to have little effect on the stream flow (K. Owsley, 2010).

3.1.4 Occurrence of Lahontan Cutthroat Trout (LCT)

The upper Dixie Creek is one of the few streams in the South Fork Humboldt drainage that supports a small population of LCT. According to the Nevada Department of Wildlife (Elliot and Layton, 2004), the LCT population in Hanks Creek has been estimated at 100 – 500. With the LCT being federally designated as threatened, Dixie Creek temperatures (and other measures of stream health) are of concern to the land and water quality managers.

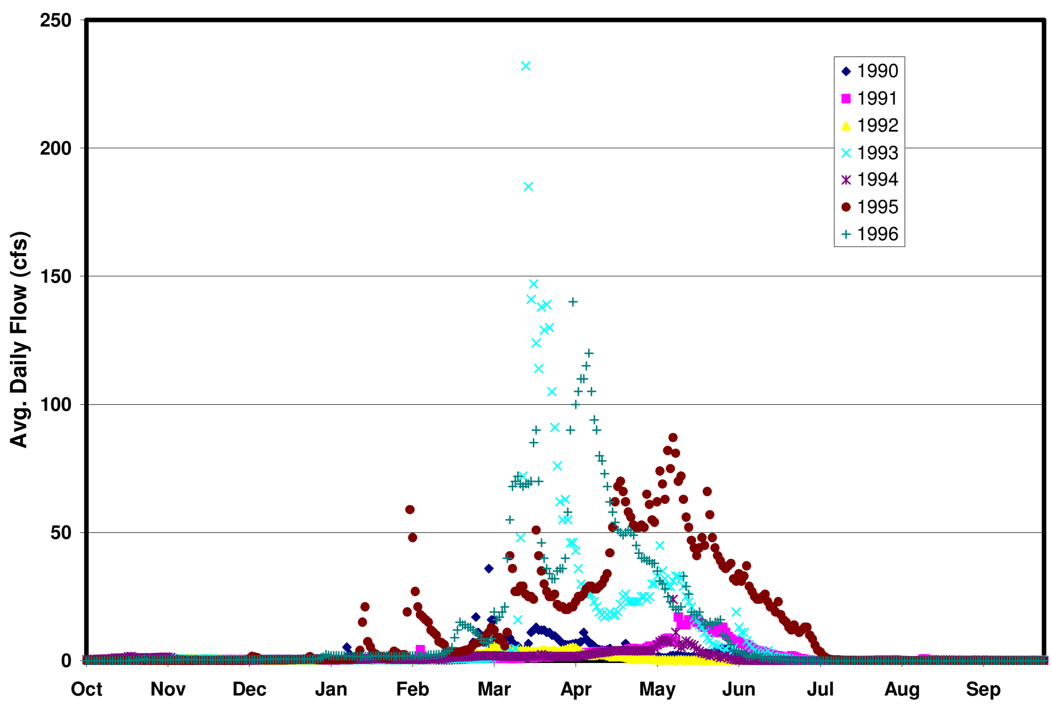


Figure 25. Average Daily Flows at 10320100 – Dixie Creek above South Fork Humboldt River near Elko, NV.

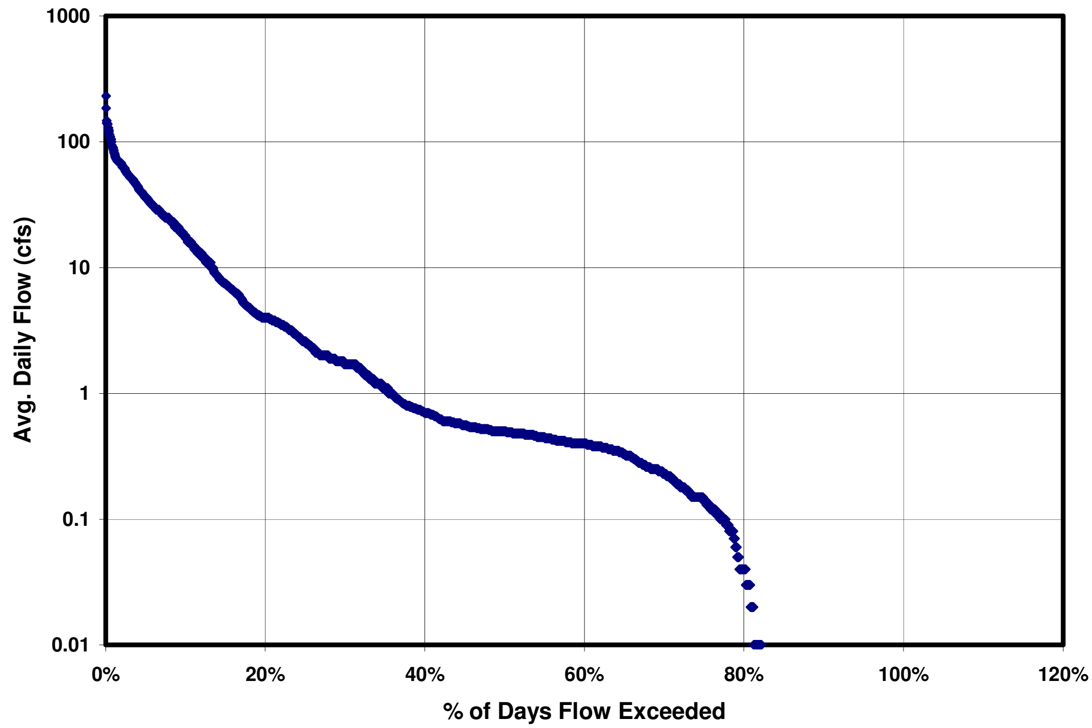


Figure 26. Flow Duration Curve for 10320100 – Dixie Creek above South Fork Humboldt River near Elko, NV.

4.0 Problem Statement

Dixie Creek (Waterbody ID NV04-SF-62_00) was first placed on Nevada's 303(d) List in 2006 for temperature impairment of aquatic life beneficial uses. It is important to note that site specific water quality standards (beneficial uses and numeric criteria) have not been set for Dixie Creek. However under the tributary rule (NAC 445A.145), the standards for the South Fork Humboldt River are applicability to Dixie Creek. Currently, the South Fork Humboldt River temperature standards are set at ≤20° C (NAC 445A.125). NDEP is intending to set site specific standards for Dixie Creek in the coming years.

In addition to aquatic life, other beneficial uses applicable to Dixie Creek under the tributary rule include contact recreation, non-contact recreation, propagation of wildlife, municipal and domestic drinking water, irrigation, stock watering, industrial uses. However regarding the temperature standard, the aquatic life use is deemed to be the most restrictive. The 2006 Listing was based upon spot temperature readings taken by BLM at four locations (Figure 28) and NDEP at 3 locations. Temperatures ranged from 6.7 to 25.2° C, with 6 of the 34 readings exceeding the water quality standard of ≤20° C. Additional temperature data collected by Schroeter (2001) supports the listing. In 1999 and 2000, Schroeter collected continuous temperature data at 10 locations in the upper reaches between Mile 22 and Mile 26, in the vicinity of NDEP-HS31. Data from 10 thermologgers indicated maximum water temperatures ranged from about 22 to about 27° C during 1999 (pre-Sadler Complex wildfire) and from about 25 to 31° C during 2000 (post-Sadler Complex wildfire). For this same stretch, average weekly maximum temperatures ranged from about 20 to 25° C in 1999 and from about 22 to 28° C in 2000.

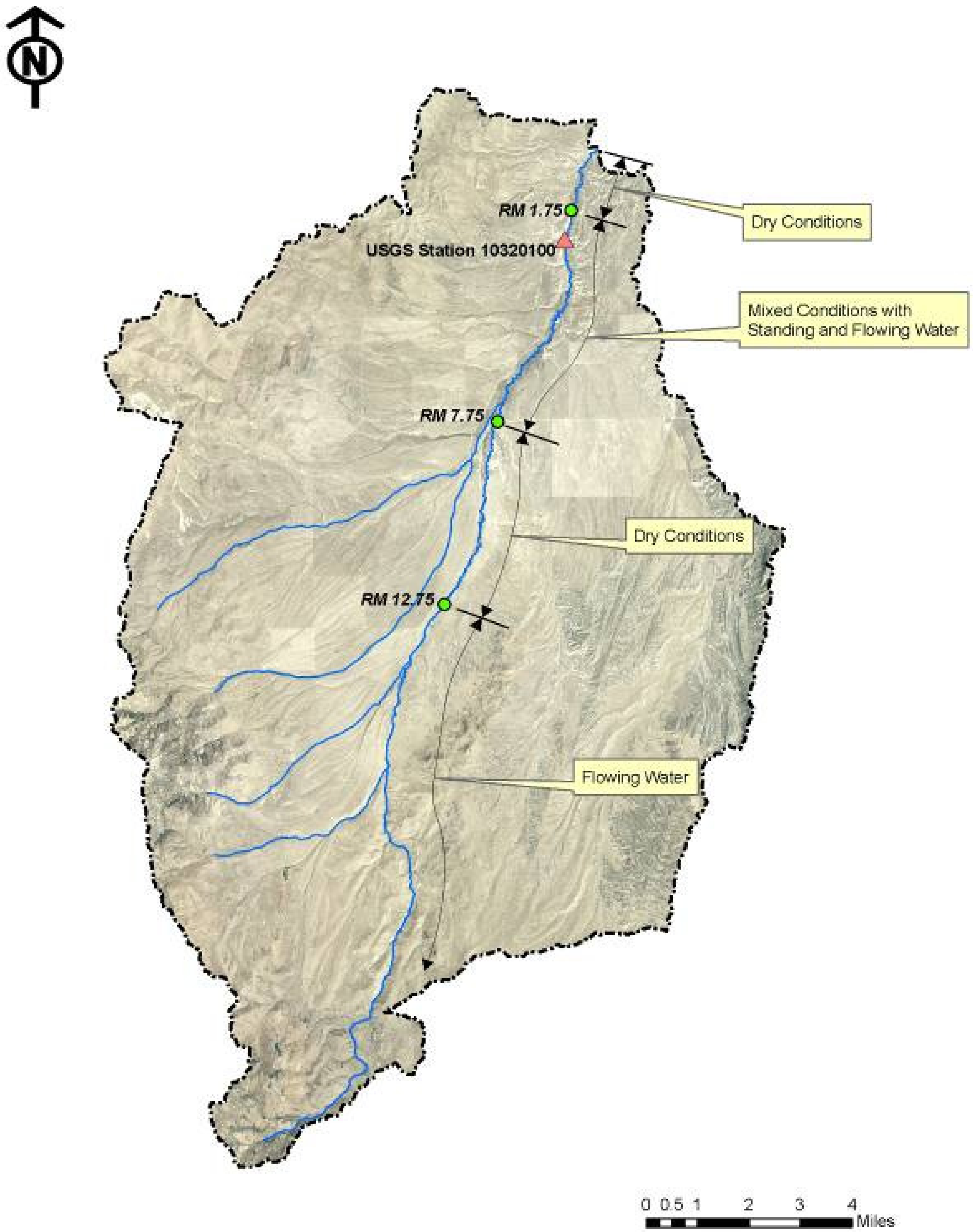


Figure 27. Dixie Creek Flow Conditions on September 1-2, 2009

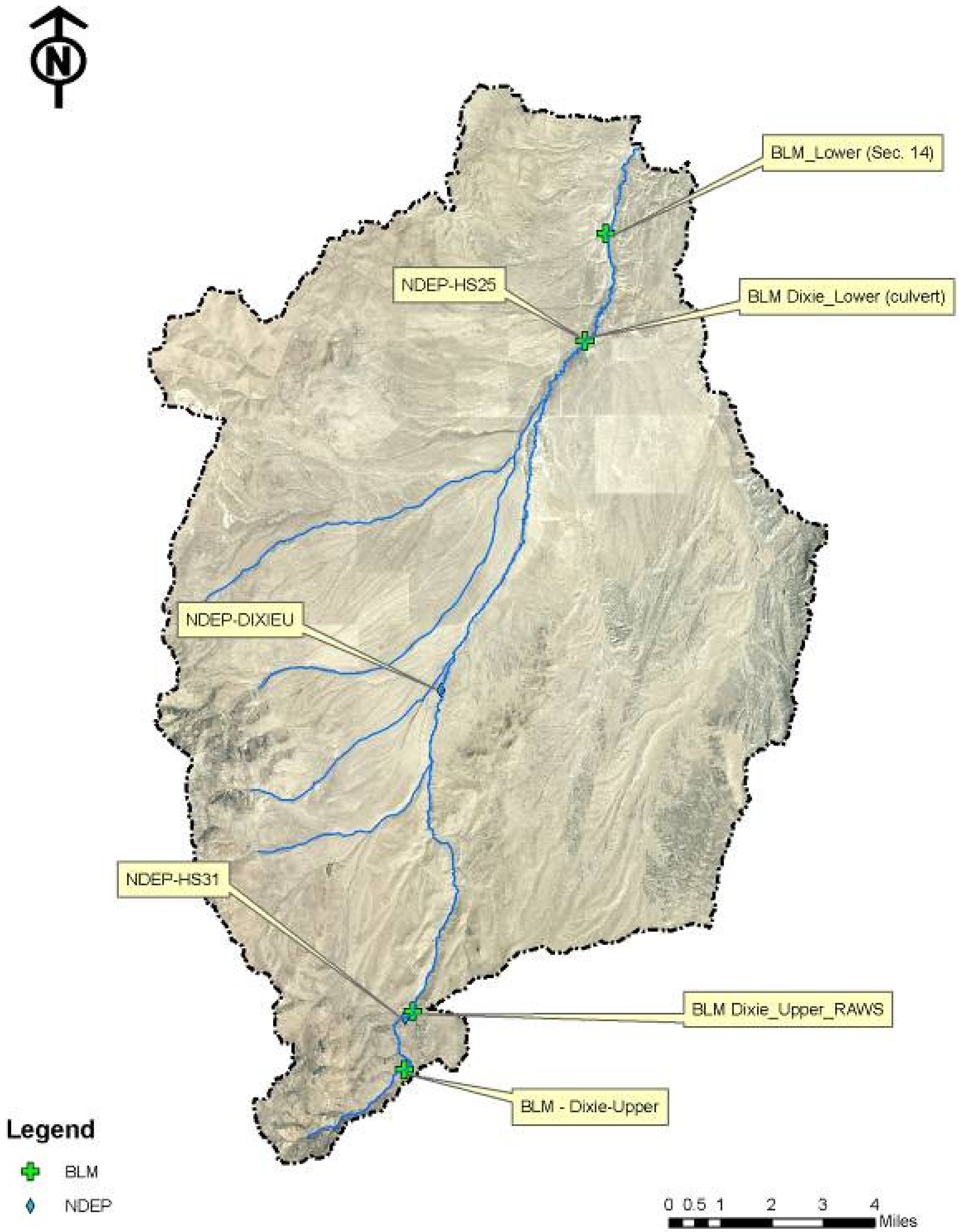


Figure 28. Dixie Creek Temperature Monitoring Sites

4.0 Source Analysis (Existing Conditions)

Areas with limited riparian vegetation are believed to be a significant factor leading to elevated temperature levels in Dixie Creek. As described earlier, solar radiation is a key thermal load source to stream. Control of this nonpoint thermal source can be achieved through vegetative shading. At this time, no point sources contribute any thermal loads to the stream.

While vegetation conditions are believed to be a major factor contributing to elevated temperatures, little quantitative information actually exists to describe the current riparian vegetation conditions. In 2008, the BLM performed stream assessments (including bank cover ratings) at five locations in the upper watershed (See Table 5). To supplement this information, NDEP staff rated the bank cover at 16 sites throughout the stream (Figure 29). To further characterize bank cover conditions, the following equation was used along with information extracted from the NAIP imagery:

Bank Cover = (0.478 x % Woody Vegetation in Buffer) + (0.264 x % Riparian Vegetation in Buffer) + 25

Figure 30 shows a good correlation between the bank cover ratings estimated from the NAIP imagery and those from field visits. A variety of factors are believed to contribute to areas of reduced riparian vegetation health depending upon the reach in question. The lowest bank cover ratings, occurring in 2 reaches (0 – 2.5 miles; 9.0 – 13.5 miles), are believed to be the result of little to no flow in the late summer within these areas. The available information suggests that these low flows are naturally occurring as there are limited irrigation diversions upstream.

For the reach from Mile 11.4 to origin, Dixie Creek fell within the limits of the 1999 Sadler Fire (Figure 30). As a result, several important riparian areas were burned or experienced delayed mortality. This no doubt affected the conditions depicted on the 2006 imagery and observed during the 2009 field work. However, Nevada Department of Wildlife reports indicated that the condition of the riparian vegetation was already in poor to fair conditions prior to the 1999 fire (Schroeter, 2001). It is uncertain what factors led to these poor/fair conditions observed by NDOW. Grazing does occur in parts of this reach, however the impacts to the riparian vegetation are uncertain. Other factors such as beaver activity, channel conditions and soils may play a role in shaping the extent of the riparian conditions.

Between River Mile 13.0 and 18.0, the 2006 NAIP imagery showed poor riparian vegetation conditions with bank cover ratings around 30. Field visits in 2009 indicate that conditions in this reach have improved since 2006. This reach was within the limits of the 1999 Sadler and conditions have appeared to improve.

Table 5. Summary of Dixie Creek Bank Cover Conditions based upon Field Visits

Site ID	Bank Cover Rating by NDEP (2009)	Bank Cover Rating by BLM (2008)
DC-1	25	na
DC-2	50	
DC-3	50	
DC-4	50	
DC-5	95	
DC-6	48	
DC-7	25	
DC-8	25	
DC-9	40	
DC-10	63	
DC-11	48	
DC-12	75	
DC-13	75	
DC-14 (BLM Site S-6)	58	60
DC-15 (BLM Site S-7)	58	58
DC-16 (BLM Site S-8)	58	50
DC-17 (BLM Site S-8A)	88	88
DC-18 (BLM Site S-9)	88	85

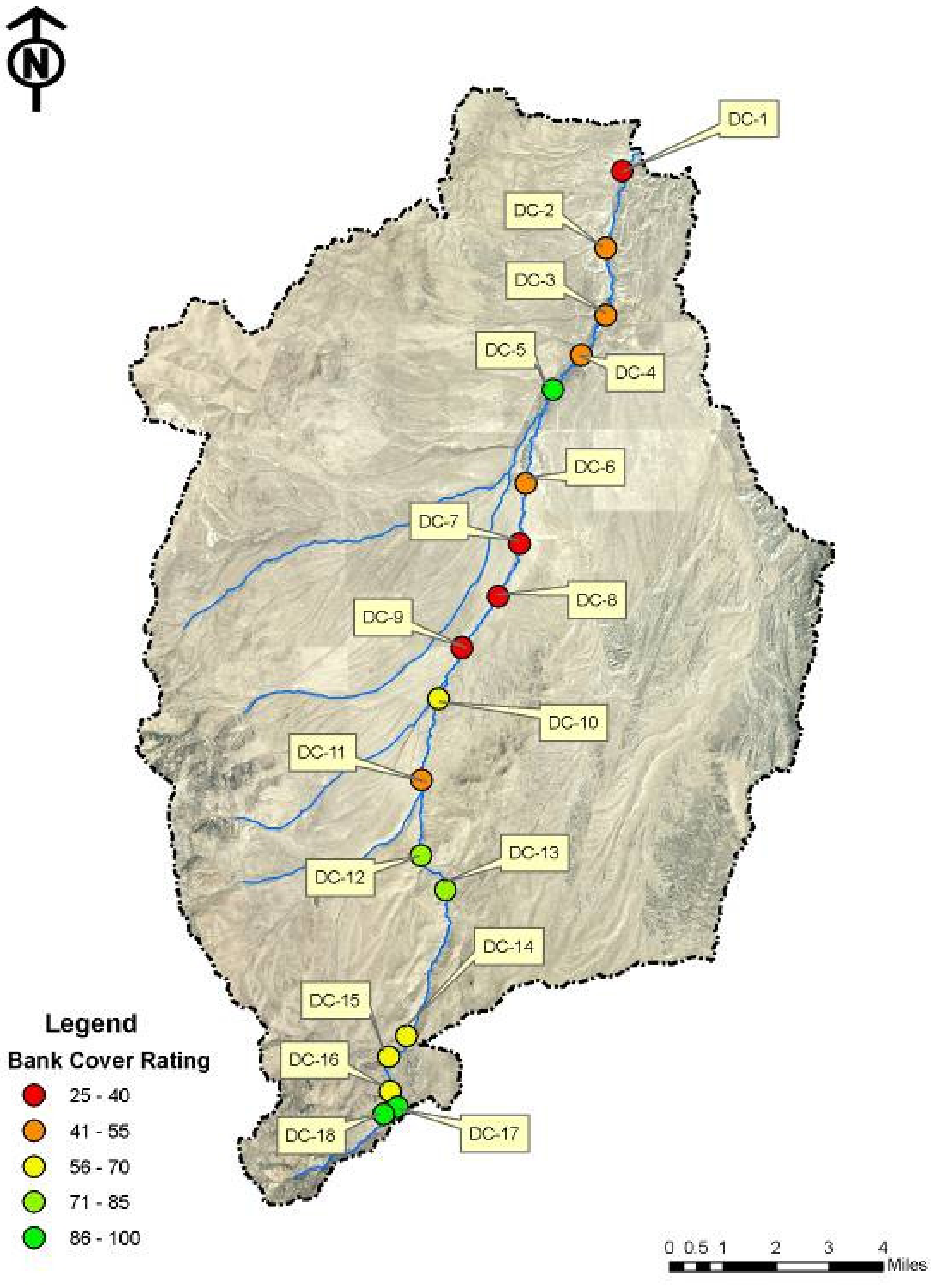


Figure 29. Dixie Creek – 2009 Field Estimates of Bank Cover Conditions

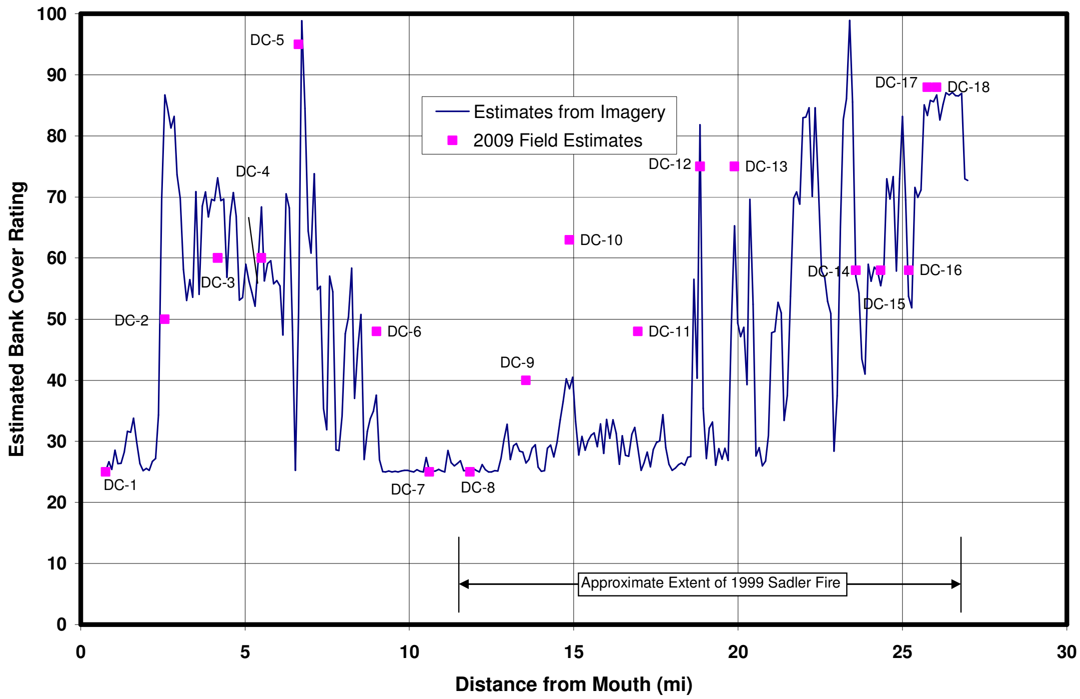


Figure 30. Dixie Creek – Existing Bank Cover Rating

3.4 Target Analysis

As previously discussed, the TMDL targets are to be defined in terms of riparian vegetation conditions (using BLM's riparian condition rating system) rather than stream temperature. Conditions within the lower Hanks Creek have been selected as representative of achievable "natural" conditions for much of Dixie Creek. However, two reaches (0 – 2.5 miles; 9.0 – 13.5 miles) naturally go dry beginning sometime during the summer. For the perennial flow areas, the assigned target bank cover conditions are an average of 80 with a minimum of 50 (Table 6). No targets have been set for the intermittent reaches. The potential to establish health riparian vegetation in these 2 sections is uncertain given these dry conditions. However, there is a possibility that riparian vegetation may be able to extend into these areas. Over time, other stretches of Dixie Creek have experienced improved base flows and the expansion of the riparian buffer into areas that had previously been dry.

Table 6. Bank Cover Targets for Dixie Creek

Reach (miles from mouth)	Bank Cover Target
0 – 2.5	Intermittent reach – potential unknown
2.5 – 9.0	Average = 80, Minimum = 50
9.0 – 13.5	Intermittent reach – potential unknown
Above 13.5	Average = 80, Minimum = 50

Figure 31 presents bank cover conditions as estimated using the 2006 NAIP imagery and bank cover targets for Dixie Creek. Of the approximately 20 miles with assigned targets, only about 14% of Dixie Creek exceeds the mean bank cover target of 80, with about 54% exceeding the minimum bank cover target of 50, The actual percentages are expected to be some what higher as conditions between DC-9 and DC-12 have improved since the 2006 NAIP imagery was collected.

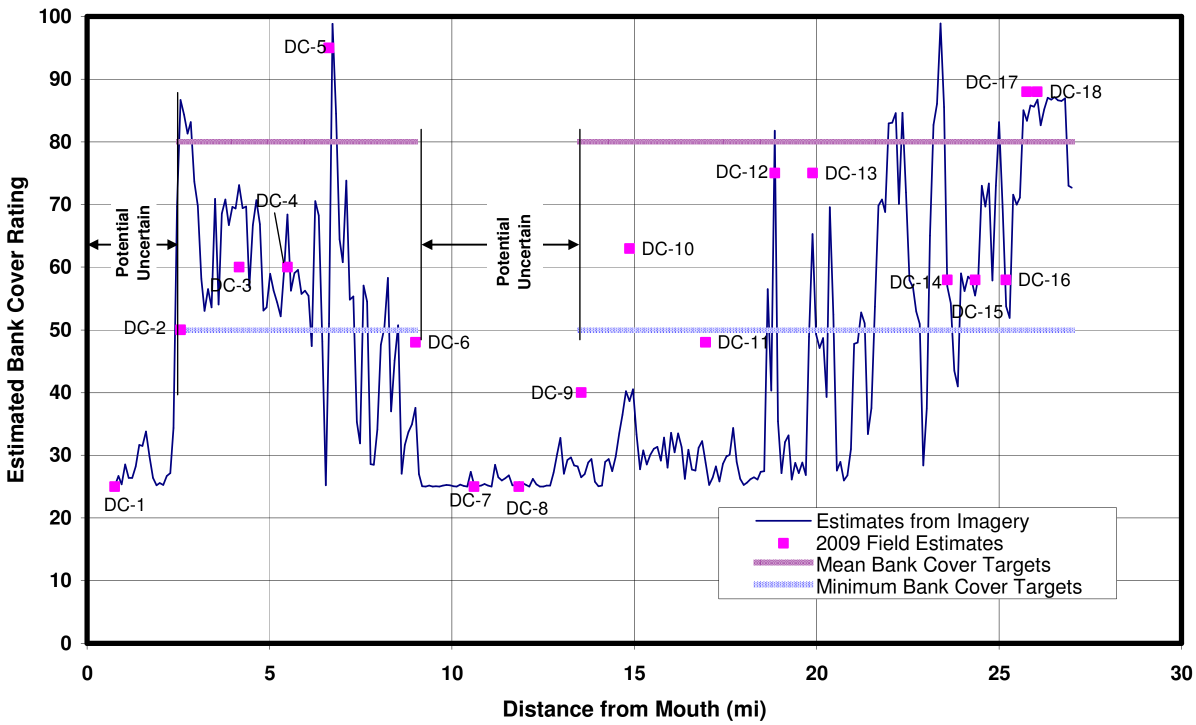


Figure 31. Dixie Creek – Existing and Target Bank Cover Rating

3.5 Pollutant Load Capacity and Reductions

Existing Loads: Computer model predictions of shade and the associated solar radiation loads were developed using the State of Oregon's Heat Source Model (Boyd and Kasper, 2003). The following inputs for the Heat Source model for Dixie Creek were as follow in estimating existing shade and radiation loads:

- Width: Estimated from the bankfull limits digitized from the NAIP imagery (Figure 24).
- Vegetation offset: Insufficient information available. Assumed = 0.
- Vegetation height: For the upper reach (above approximately Mile 15.0), Booth's Willow are thought to be the dominant woody vegetation. According to Hoag (2005), Booth's Willow generally reach 6 to 10 feet in height. For this TMDL, a height of 10 feet was assumed. In the lower reach below Mile 10.0, Coyote Willow dominates. This species normally grows 1.5 to 9 feet tall (Hoag, 2005). A height of 9 feet was assumed for this TMDL.

- Vegetation density: Set at 0%, 25%, 50%, 75% or 100% based upon visual estimates from the NAIP imagery.
- Reach orientation: Derived from NAIP imagery.

For this TMDL, June 21 was selected as the reference date for which to base estimates of existing shade/solar radiation load. While the warmest stream temperatures in this area typically occur in July and August, June 21 was selected as this is the time of highest solar radiation.

In addition to the computer model estimates, NDEP performed some field work to estimate shade at a few sites. During the summer of 2009, NDEP staff used a Solar Pathfinder™ to measure shade at some sites on Dixie and Hanks creeks. The Solar Pathfinder™ is a device that allows one to capture an outline of the shade producing objects and readily convert the information to percent shade (percent of solar radiation that is blocked). However resources did not allow for extensive shade measurements.

Target Loads: Target loads were calculated using the same model inputs as the existing loads, except for stream width and vegetation density. The target bankfull widths were assigned based upon the widths for the healthier locations within Dixie Creek. Using data for selected 2009 field survey sites with bank cover conditions near or above the bank cover targets, a relationship between bankfull widths and drainage area was developed and was used to develop target bankfull widths (Figure 32).

Vegetation densities for each of the model segments were set at 72% or at the existing levels estimated in Step 1, whichever is higher. As discussed in Section 2.0 – Methodology, vegetation densities of about 72% seemed to correlate well with mean bank cover ratings of 80.

Allocations and Load Reductions: The existing and target shade and solar radiation loads as estimated using the Heat Source Model are shown in Figures 33 and 34. Shade estimates from the Solar Pathfinder were close to those estimated using the Heat Source Model, with the exception of DC-10 which has experienced improved riparian conditions since the 2006 NAIP imagery was generated.

Load allocations for Dixie Creek are represented by Figure 34 (target conditions), and are assigned to nonpoint source activities that have or may affect riparian vegetation. Solar radiation reductions associated with the vegetation target conditions and the load allocations are presented in Figure 35. The overall average solar radiation reduction is estimated at about 37% (Table 7). A detailed breakdown for the existing and target conditions for each 500-foot subreach of Dixie Creek is provided in Table 8.

Table 7. Summary of Solar Load Allocations and Reductions for Dixie Creek (Waterbody ID NV04-SF-62_00)

	Average Percent Shading	Average Solar Loading (Langleys/day)
Existing	14.1%	643
Target Allocations	46.1%	403
Load Reduction	na	-240
% Change	na	-37%

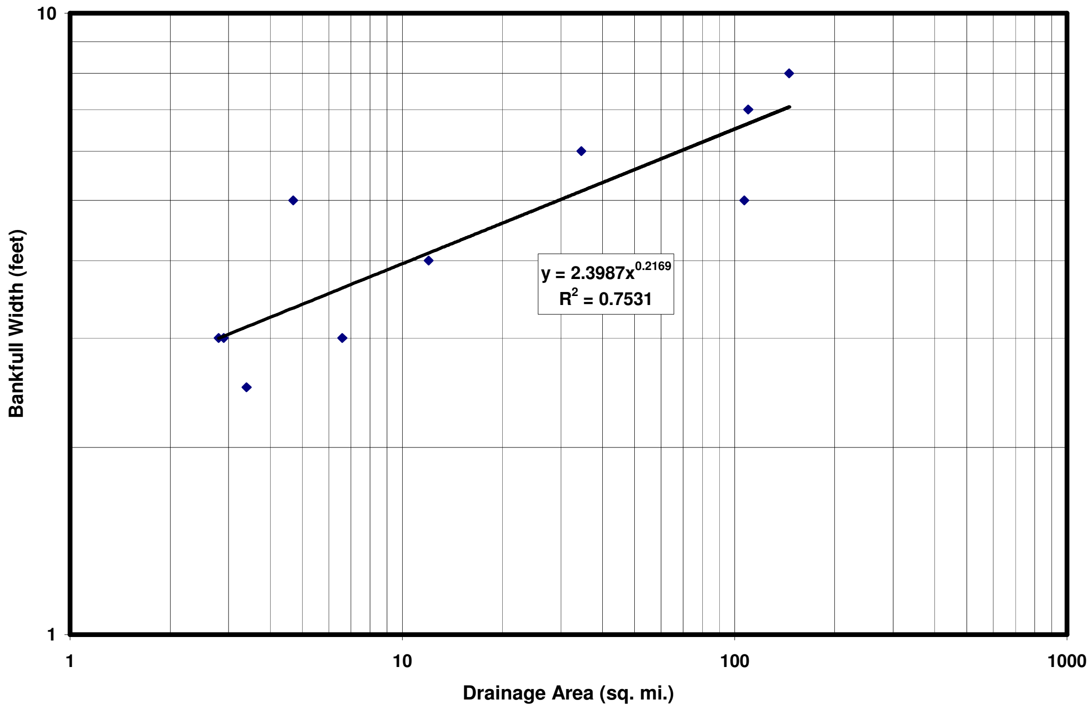


Figure 32. Drainage Area vs. Bankfull Width – Dixie Creek Stations Near or exceeding Bankfull Targets

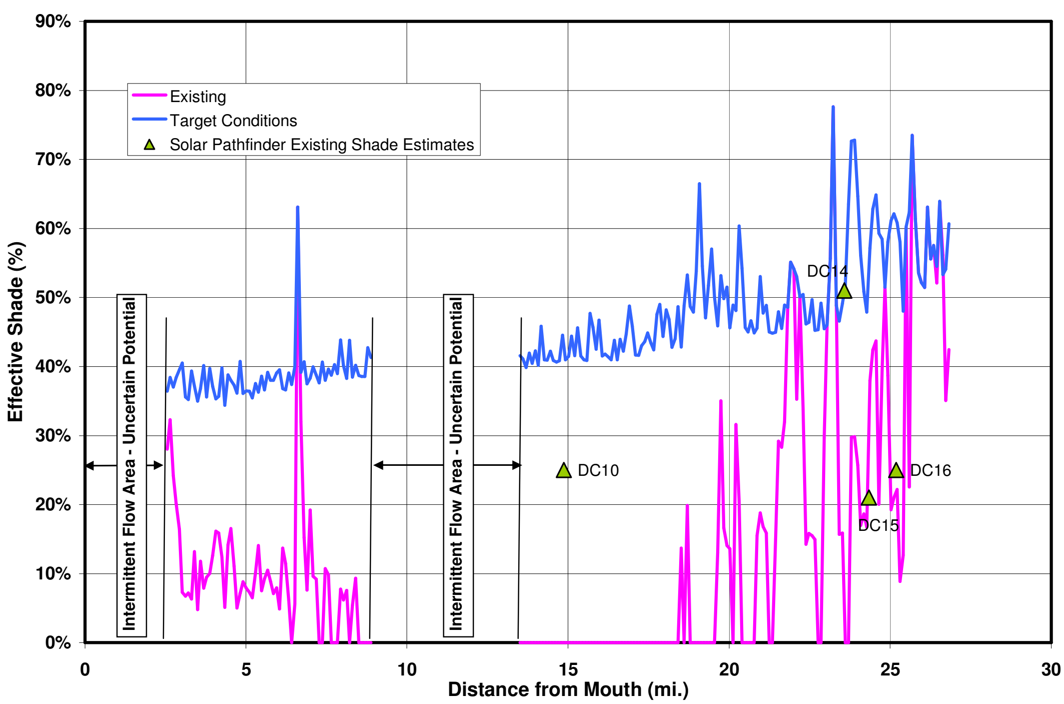


Figure 33. Dixie Creek – Effective Shade – Existing and Target Conditions

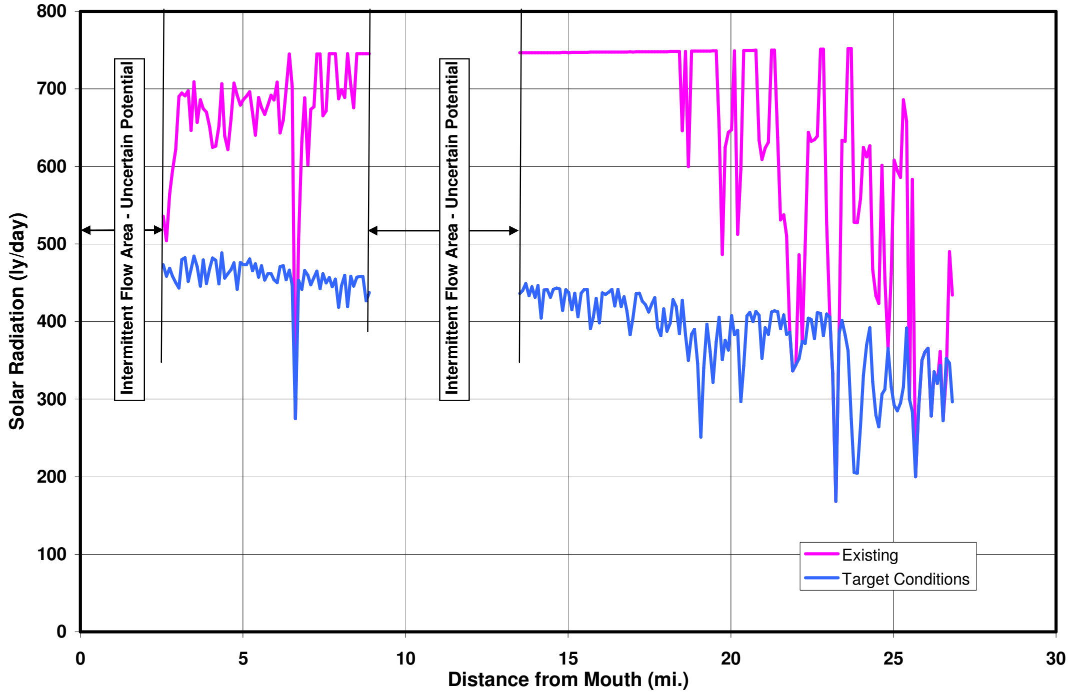


Figure 34. Dixie Creek – Solar Radiation – Existing and Target Conditions

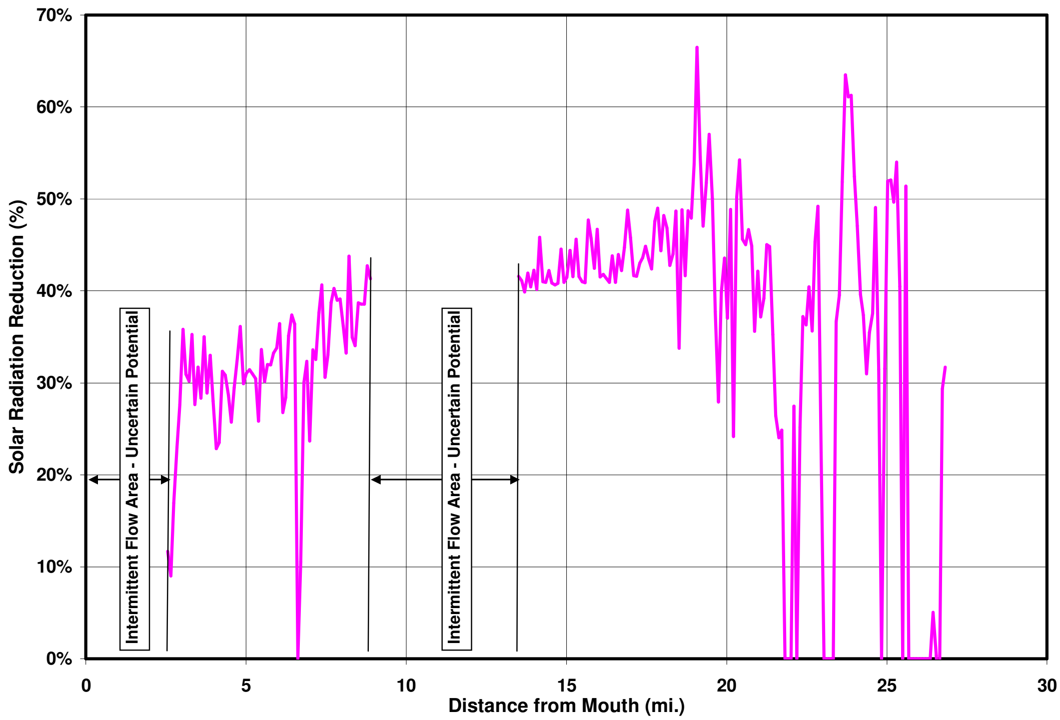


Figure 35. Dixie Creek – Solar Radiation Reductions Associated With Target Conditions

Table 8. Existing and Targeted Solar Loads and Reductions for Dixie Creek (cont'd)

Segment No.	Distance from Mouth (mi)	Existing Solar Load (ly/day)	Existing Shade	Target Solar Load (ly/day)	Target Shade	Load Reduction	Segment No.	Distance from Mouth (mi)	Existing Solar Load (ly/day)	Existing Shade	Target Solar Load (ly/day)	Target Shade	Load Reduction
1	0.00						76	7.09	674	9.6%	447	40.0%	
2	0.10						77	7.18	677	9.2%	457	38.7%	
3	0.19						78	7.27	745	0.0%	465	37.6%	37.6%
4	0.29						79	7.37	745	0.0%	442	40.6%	40.6%
5	0.38						80	7.46	666	10.7%	462	38.0%	30.6%
6	0.48						81	7.56	672	9.8%	450	39.6%	33.0%
7	0.57						82	7.65	745	0.0%	457	38.7%	38.7%
8	0.66						83	7.75	745	0.0%	445	40.3%	40.3%
9	0.76						84	7.84	745	0.0%	455	39.0%	39.0%
10	0.85						85	7.94	688	7.7%	419	43.8%	39.1%
11	0.95						86	8.03	699	6.2%	446	40.1%	36.2%
12	1.04						87	8.12	689	7.5%	460	38.3%	33.3%
13	1.14	Naturally intermittent region -					88	8.22	745	0.0%	419	43.8%	43.8%
14	1.23	No Load Allocations Established					89	8.31	705	5.4%	459	38.5%	35.0%
15	1.33						90	8.41	676	9.3%	446	40.2%	34.0%
16	1.42						91	8.50	745	0.0%	457	38.7%	38.7%
17	1.51						92	8.60	745	0.0%	458	38.6%	38.6%
18	1.61						93	8.69	745	0.0%	458	38.6%	38.6%
19	1.70						94	8.78	745	0.0%	427	42.7%	42.7%
20	1.80						95	8.88	745	0.0%	438	41.3%	41.3%
21	1.89						96	8.97					
22	1.99						97	9.07					
23	2.08						98	9.16					
24	2.18						99	9.26					
25	2.27						100	9.35					
26	2.36						101	9.45					
27	2.46						102	9.54					
28	2.55	536	28.0%	473	36.4%	11.7%	103	9.63					
29	2.65	504	32.3%	459	38.4%	9.0%	104	9.73					
30	2.74	565	24.2%	469	37.0%	16.9%	105	9.82					
31	2.84	595	20.1%	459	38.4%	22.9%	106	9.92					
32	2.93	622	16.4%	450	39.5%	27.7%	107	10.01					
33	3.03	690	7.3%	443	40.5%	35.8%	108	10.11					
34	3.12	695	6.7%	480	35.6%	30.9%	109	10.20					
35	3.21	691	7.2%	483	35.2%	30.2%	110	10.30					
36	3.31	698	6.3%	452	39.3%	35.2%	111	10.39					
37	3.40	647	13.2%	468	37.2%	27.6%	112	10.48					
38	3.50	709	4.8%	484	35.0%	31.7%	113	10.58					
39	3.59	657	11.8%	471	36.8%	28.4%	114	10.67					
40	3.69	686	7.9%	446	40.1%	35.0%	115	10.77					
41	3.78	674	9.4%	480	35.6%	28.9%	116	10.86					
42	3.87	670	10.0%	449	39.7%	33.0%	117	10.96					
43	3.97	651	12.6%	468	37.1%	28.0%	118	11.05					
44	4.06	625	16.1%	482	35.3%	22.9%	119	11.15	Naturally intermittent region -				
45	4.16	626	15.9%	479	35.7%	23.5%	120	11.24	No Load Allocations established				
46	4.25	652	12.4%	448	39.8%	31.3%	121	11.33					
47	4.35	707	5.1%	489	34.4%	30.8%	122	11.43					
48	4.44	639	14.2%	456	38.8%	28.7%	123	11.52					
49	4.54	622	16.5%	462	38.0%	25.7%	124	11.62					
50	4.63	662	11.1%	467	37.3%	29.5%	125	11.71					
51	4.72	708	5.0%	476	36.1%	32.8%	126	11.81					
52	4.82	692	7.2%	442	40.7%	36.1%	127	11.90					
53	4.91	679	8.8%	476	36.1%	29.9%	128	12.00					
54	5.01	686	7.9%	473	36.5%	31.0%	129	12.09					
55	5.10	691	7.3%	474	36.4%	31.4%	130	12.18					
56	5.20	696	6.5%	481	35.5%	31.0%	131	12.28					
57	5.29	669	10.1%	465	37.5%	30.5%	132	12.37					
58	5.39	640	14.1%	475	36.3%	25.8%	133	12.47					
59	5.48	689	7.5%	457	38.6%	33.6%	134	12.56					
60	5.57	676	9.2%	472	36.6%	30.2%	135	12.66					
61	5.67	667	10.5%	453	39.1%	32.0%	136	12.75					
62	5.76	679	8.9%	462	38.0%	32.0%	137	12.85					
63	5.86	692	7.1%	462	38.0%	33.3%	138	12.94					
64	5.95	686	8.0%	454	39.1%	33.8%	139	13.03					
65	6.05	709	4.9%	450	39.5%	36.5%	140	13.13					
66	6.14	643	13.7%	471	36.8%	26.8%	141	13.22					
67	6.24	659	11.5%	472	36.6%	28.4%	142	13.32					
68	6.33	700	6.1%	454	39.1%	35.1%	143	13.41					
69	6.42	745	0.0%	467	37.4%	37.4%	144	13.51	747	0.0%	436	41.6%	41.6%
70	6.52	703	5.6%	447	40.0%	36.4%	145	13.60	747	0.0%	440	41.1%	41.1%
71	6.61	275	63.1%	275	63.1%	0.0%	146	13.70	747	0.0%	449	39.9%	39.9%
72	6.71	507	32.0%	453	39.2%	10.5%	147	13.79	747	0.0%	434	41.9%	41.9%
73	6.80	632	15.2%	442	40.7%	30.1%	148	13.88	747	0.0%	445	40.4%	40.4%
74	6.90	688	7.6%	466	37.5%	32.3%	149	13.98	747	0.0%	431	42.2%	42.2%
75	6.99	602	19.2%	460	38.3%	23.7%	150	14.07	747	0.0%	447	40.2%	40.2%

Table 8. Existing and Targeted Solar Loads and Reductions for Dixie Creek

Segment No.	Distance from Mouth (mi)	Existing Solar Load (ly/day)	Existing Shade	Target Solar Load (ly/day)	Target Shade	Load Reduction	Segment No.	Distance from Mouth (mi)	Existing Solar Load (ly/day)	Existing Shade	Target Solar Load (ly/day)	Target Shade	Load Reduction
151	14.17	747	0.0%	404	45.9%	45.9%	226	21.25	750	0.0%	412	45.0%	45.0%
152	14.26	747	0.0%	441	41.0%	41.0%	227	21.34	750	0.0%	414	44.8%	44.8%
153	14.36	747	0.0%	441	40.9%	40.9%	228	21.44	638	15.0%	413	45.0%	35.3%
154	14.45	747	0.0%	432	42.2%	42.2%	229	21.53	531	29.2%	391	47.9%	26.5%
155	14.54	747	0.0%	442	40.9%	40.9%	230	21.63	538	28.3%	409	45.5%	24.0%
156	14.64	747	0.0%	443	40.7%	40.7%	231	21.72	511	32.0%	383	48.9%	24.9%
157	14.73	747	0.0%	442	40.8%	40.8%	232	21.82	386	48.6%	386	48.6%	0.0%
158	14.83	747	0.0%	414	44.5%	44.5%	233	21.91	337	55.1%	337	55.1%	0.0%
159	14.92	747	0.0%	441	41.0%	41.0%	234	22.00	344	54.1%	344	54.1%	0.0%
160	15.02	747	0.0%	437	41.5%	41.5%	235	22.10	486	35.3%	352	53.1%	27.5%
161	15.11	747	0.0%	415	44.4%	44.4%	236	22.19	375	50.1%	375	50.1%	0.0%
162	15.21	747	0.0%	437	41.6%	41.6%	237	22.29	498	33.7%	372	50.4%	25.2%
163	15.30	747	0.0%	406	45.6%	45.6%	238	22.38	644	14.2%	404	46.1%	37.2%
164	15.39	747	0.0%	437	41.5%	41.5%	239	22.48	632	15.8%	403	46.4%	36.3%
165	15.49	747	0.0%	441	41.0%	41.0%	240	22.57	635	15.5%	378	49.7%	40.4%
166	15.58	747	0.0%	442	40.9%	40.9%	241	22.67	639	14.9%	412	45.2%	35.6%
167	15.68	747	0.0%	391	47.7%	47.7%	242	22.76	751	0.0%	411	45.3%	45.3%
168	15.77	747	0.0%	406	45.7%	45.7%	243	22.85	751	0.0%	382	49.2%	49.2%
169	15.87	747	0.0%	430	42.5%	42.5%	244	22.95	528	29.7%	410	45.5%	22.4%
170	15.96	747	0.0%	398	46.7%	46.7%	245	23.04	406	46.0%	406	46.0%	0.0%
171	16.06	747	0.0%	437	41.5%	41.5%	246	23.14	333	55.7%	333	55.7%	0.0%
172	16.15	747	0.0%	435	41.8%	41.8%	247	23.23	168	77.6%	168	77.6%	0.0%
173	16.24	747	0.0%	438	41.4%	41.4%	248	23.33	385	48.9%	385	48.9%	0.0%
174	16.34	748	0.0%	442	40.9%	40.9%	249	23.42	634	15.7%	402	46.6%	36.7%
175	16.43	748	0.0%	420	43.8%	43.8%	250	23.52	632	15.9%	383	49.1%	39.5%
176	16.53	748	0.0%	442	40.9%	40.9%	251	23.61	752	0.0%	362	51.8%	51.8%
177	16.62	748	0.0%	419	43.9%	43.9%	252	23.70	752	0.0%	274	63.5%	63.5%
178	16.72	748	0.0%	432	42.2%	42.2%	253	23.80	528	29.8%	205	72.7%	61.1%
179	16.81	748	0.0%	413	44.7%	44.7%	254	23.89	528	29.8%	205	72.8%	61.2%
180	16.91	748	0.0%	383	48.8%	48.8%	255	23.99	559	25.7%	266	64.6%	52.4%
181	17.00	748	0.0%	405	45.8%	45.8%	256	24.08	625	17.0%	331	56.1%	47.1%
182	17.09	748	0.0%	436	41.7%	41.7%	257	24.18	612	18.6%	370	50.9%	39.6%
183	17.19	748	0.0%	437	41.6%	41.6%	258	24.27	626	16.7%	392	47.9%	37.4%
184	17.28	748	0.0%	426	43.0%	43.0%	259	24.36	467	38.0%	322	57.2%	31.0%
185	17.38	748	0.0%	422	43.6%	43.6%	260	24.46	433	42.4%	280	62.8%	35.5%
186	17.47	748	0.0%	412	44.9%	44.9%	261	24.55	424	43.7%	264	64.9%	37.6%
187	17.57	748	0.0%	423	43.5%	43.5%	262	24.65	602	20.1%	306	59.3%	49.1%
188	17.66	748	0.0%	431	42.4%	42.4%	263	24.74	456	39.4%	313	58.5%	31.5%
189	17.76	748	0.0%	392	47.6%	47.6%	264	24.84	365	51.5%	365	51.5%	0.0%
190	17.85	748	0.0%	382	49.0%	49.0%	265	24.93	462	38.7%	316	58.0%	31.5%
191	17.94	748	0.0%	416	44.4%	44.4%	266	25.03	608	19.2%	292	61.2%	51.9%
192	18.04	748	0.0%	388	48.2%	48.2%	267	25.12	595	21.0%	285	62.1%	52.1%
193	18.13	748	0.0%	398	46.8%	46.8%	268	25.21	586	22.2%	295	60.8%	49.6%
194	18.23	748	0.0%	428	42.8%	42.8%	269	25.31	686	8.9%	316	58.1%	54.0%
195	18.32	748	0.0%	419	44.0%	44.0%	270	25.40	658	12.7%	392	48.0%	40.5%
196	18.42	748	0.0%	384	48.7%	48.7%	271	25.50	299	60.2%	299	60.2%	0.0%
197	18.51	646	13.7%	428	42.8%	33.8%	272	25.59	583	22.6%	284	62.4%	51.4%
198	18.61	749	0.0%	383	48.8%	48.8%	273	25.69	200	73.5%	200	73.5%	0.0%
199	18.70	600	19.8%	350	53.2%	41.7%	274	25.78	291	61.4%	291	61.4%	0.0%
200	18.79	749	0.0%	384	48.7%	48.7%	275	25.88	350	53.6%	350	53.6%	0.0%
201	18.89	749	0.0%	390	47.9%	47.9%	276	25.97	361	52.1%	361	52.1%	0.0%
202	18.98	749	0.0%	346	53.8%	53.8%	277	26.06	366	51.5%	366	51.5%	0.0%
203	19.08	749	0.0%	251	66.5%	66.5%	278	26.16	278	63.1%	278	63.1%	0.0%
204	19.17	749	0.0%	340	54.6%	54.6%	279	26.25	335	55.6%	335	55.6%	0.0%
205	19.27	749	0.0%	397	47.0%	47.0%	280	26.35	320	57.6%	320	57.6%	0.0%
206	19.36	749	0.0%	361	51.7%	51.7%	281	26.44	361	52.1%	343	54.5%	5.0%
207	19.45	749	0.0%	322	57.0%	57.0%	282	26.54	273	63.8%	272	63.9%	0.3%
208	19.55	749	0.0%	374	50.1%	50.1%	283	26.63	331	56.2%	352	53.3%	0.0%
209	19.64	651	13.1%	405	45.9%	37.7%	284	26.73	490	35.1%	346	54.1%	29.3%
210	19.74	487	35.0%	351	53.2%	27.9%	285	26.82	434	42.5%	297	60.7%	31.7%
211	19.83	625	16.6%	376	49.8%	39.9%							
212	19.93	644	14.1%	363	51.5%	43.6%							
213	20.02	647	13.6%	408	45.6%	37.0%							
214	20.12	749	0.0%	383	48.9%	48.9%							
215	20.21	513	31.6%	389	48.1%	24.1%							
216	20.30	596	20.5%	297	60.4%	50.2%							
217	20.40	750	0.0%	343	54.2%	54.2%							
218	20.49	750	0.0%	407	45.6%	45.6%							
219	20.59	750	0.0%	412	45.0%	45.0%							
220	20.68	750	0.0%	400	46.6%	46.6%							
221	20.78	750	0.0%	413	44.9%	44.9%							
222	20.87	634	15.5%	408	45.6%	35.6%							
223	20.97	609	18.8%	352	53.0%	42.1%							
224	21.06	624	16.8%	392	47.7%	37.2%							
225	21.15	631	15.9%	384	48.8%	39.2%							

Margin of Safety: TMDLs are required to include a margin of safety to account for uncertainties in the analysis. There are a variety of sources for uncertainty in the existing and targeted solar load analyses:

> **Bank Cover Targets:** Bank cover targets were based upon existing conditions in lower Hanks Creek as estimated from the NAIP imagery. As shown in Figure 15, there is considerable uncertainty in any individual estimate at a given location. However, it is thought that some estimates will be above the mean and others will be below with the fluctuations balancing out.
>
> **Stream width:** Existing widths were derived from NAIP imagery. The 1-meter resolution of the NAIP made it difficult to exactly identify streambanks and the widths. It is believed that the process results in overestimating and underestimating stream widths with the errors balancing out.
>
> **Vegetation offset:** For purposes of this TMDL, the distance that riparian vegetation is offset from the edge of the stream was assumed to be zero. Field observations and the NAIP imagery show great variability in the offset, with some areas having vegetation overhanging the stream edge (a negative offset) and other areas set back anywhere from 0 to >10 feet. However under this methodology, woody vegetation farther than 10 feet from the stream edge would not be included in the % woody vegetation estimates. The assumption of zero is deemed to be an appropriate approximation of overall conditions.
>
> **Percent woody vegetation:** The target conditions are set at an average bank cover rating of 80 with acceptable values ranging from 50 to 100. Under average target conditions (Bank Cover = 80), it is estimated that corresponding percent woody vegetation amounts could vary from about 60 to 72% within the riparian buffer (Figure17). Under minimum acceptable target conditions (Bank Cover = 50), it is estimated that the corresponding percent woody vegetation amounts would be about 16 to 30%. At the maximum Bank Cover condition (100), 100% woody vegetation coverage is most likely. Based on this information, a stream meeting the Bank Cover targets could have percent woody vegetation coverage ranging from 16% to 100%. For the target loads, the high end of the range (72%) for average Bank Cover conditions (80) was assumed to be the desired condition. Overall, this is likely on the high side and believed to have led to conservatively lower target solar load needs.

The margin of safety with the temperature TMDLs is considered implicit in the methodology, specifically through the use of conservative assumptions in the percent woody vegetation values used in the solar shading modeling.

Seasonal Variation: Federal regulations require that TMDLs account for seasonal variations. From a solar radiation perspective, peak solar radiation levels occur on the summer solstice (June 21) and lowest levels on the winter solstice (December 21). For this TMDL, loads allocations were calculated for the peak solar radiation period (June 21). As such, compliance with these allocations would assure compliance with any allocations needed for less intense solar radiation periods.

4.0 Hanks Creek Temperature TMDL

4.1 Study Area Background

Located in the upper Humboldt River basin, Hanks Creek flows into Marys River and drains a watershed of approximately 72 square miles in size. Watershed elevations range from about 8100 feet in the mountains on the west boundary of the watershed to about 5700 feet at the outlet. Hanks Creek and the South Fork Hanks Creek are the main streams in the watershed with a number of other tributaries that may contribute flows during spring runoff or rainfall events.

4.1.1 Land Cover, Ownership and Use

Under the USGS National Gap Analysis Program (2004), 1999-2001 Landsat imagery has been used to develop landcover information for the southwestern United States. These data show the Hanks Creek watershed to be dominated by sagebrush-type ecological systems (Table 9, Figure 36).

Table 9. Land Cover for Hanks Creek Watershed

Category	Area (sq. mi.)
Intermountain Basins Montane Sagebrush Steppe	51.4
Intermountain Basins Big Sagebrush Shrubland	8.8
Great Basin Xeric Mixed Sagebrush Shrubland	5.0
Great Basin Pinyon-Juniper Woodland	4.1
Other	1.6
Intermountain Basins Semi-Desert Grassland	1.3

All of the watershed is public land administered by the BLM under 3 grazing allotments (Figure 37). There are a number of grazing systems and exclosures on some of the riparian areas.

The watershed has experienced a number of wildfires over the last few years with the most recent occurring in 2006 after the collection of the NAIP imagery (Figure 38). During the 2006 Charleston Complex fire, about 50% of the riparian community along Hanks Creek experienced moderate to heavy fire intensity. However, the BLM surveyed the burned reaches of Hanks Creek by helicopter in 2007 and 2008 and found willow regrowth to be good to excellent in most areas.

4.1.2 Channel Characteristics

Hanks Creek and its main tributary, SF Hanks Creek, are small streams with widths typically less than 6 to 8 feet as derived from field visits and the 2006 NAIP imagery (Figure 39). Slopes are not as variable as in Dixie Creek, with gradients ranging from about 2% in upper Hanks Creek to 0.5% in lower Hanks Creek (Figure 40).

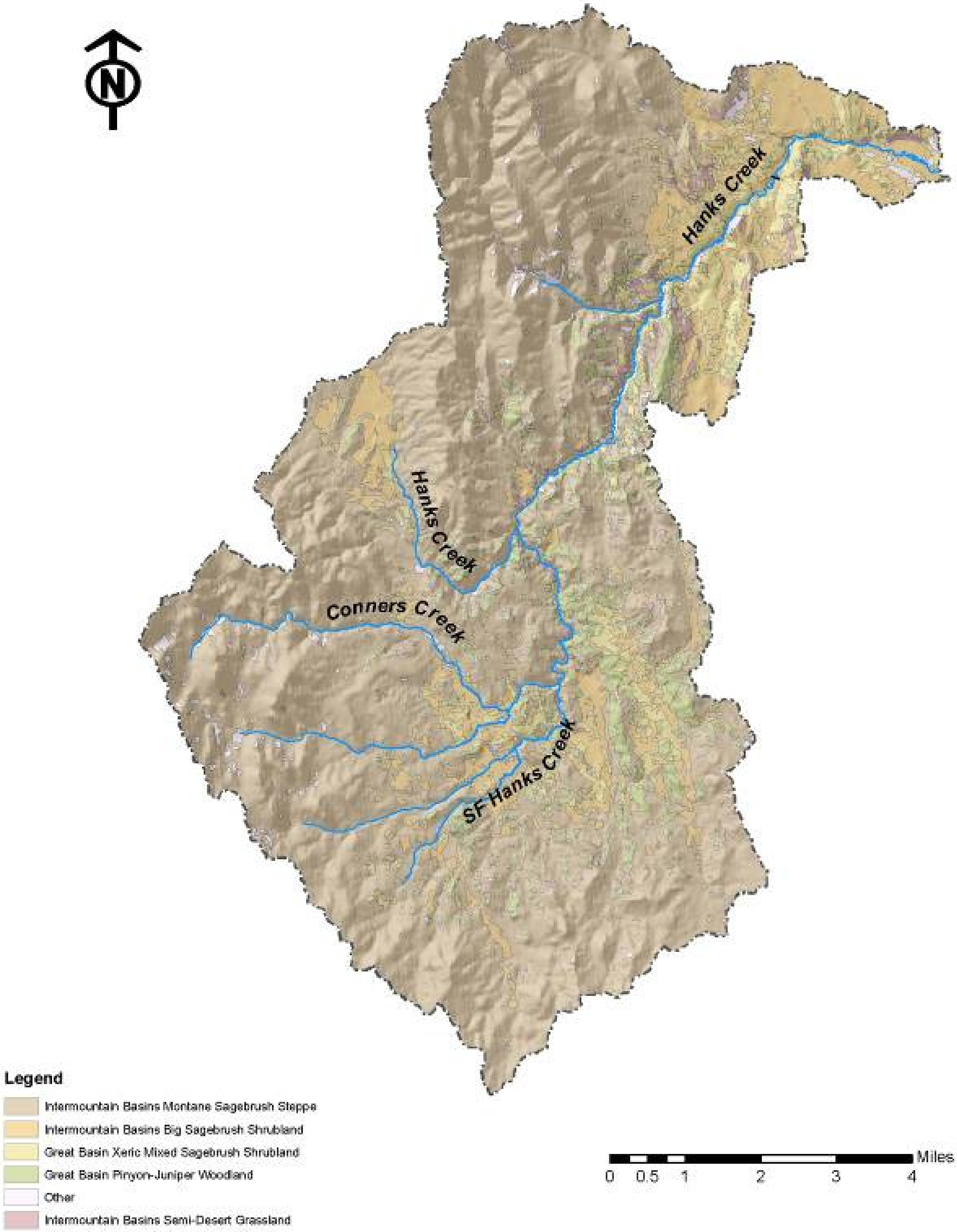


Figure 36. Hanks Creek Watershed Land Cover (USGS, 2004)

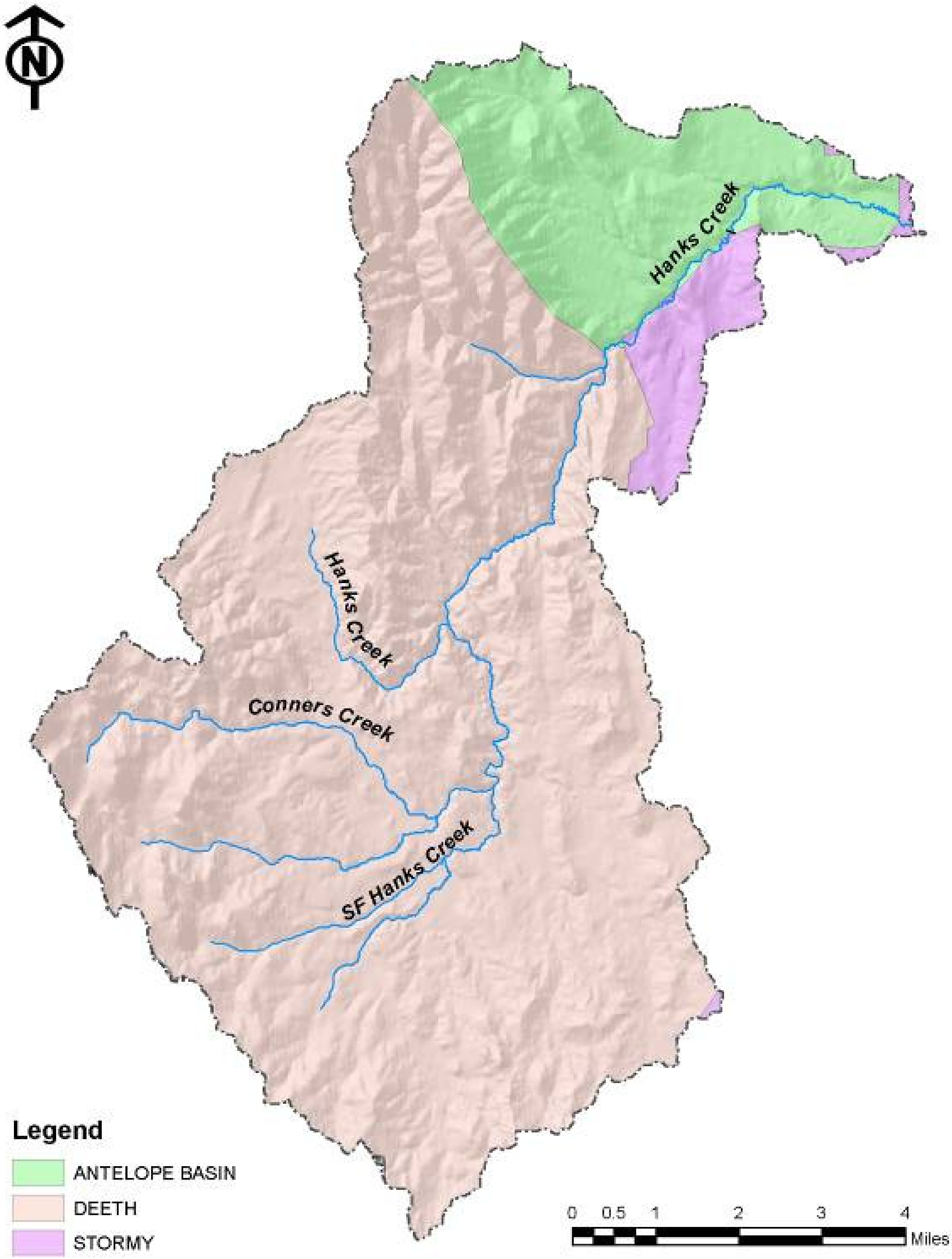


Figure 37. Hanks Creek Watershed BLM Allotments

Figure 38. Recent Wildfires in Hanks Creek Watershed

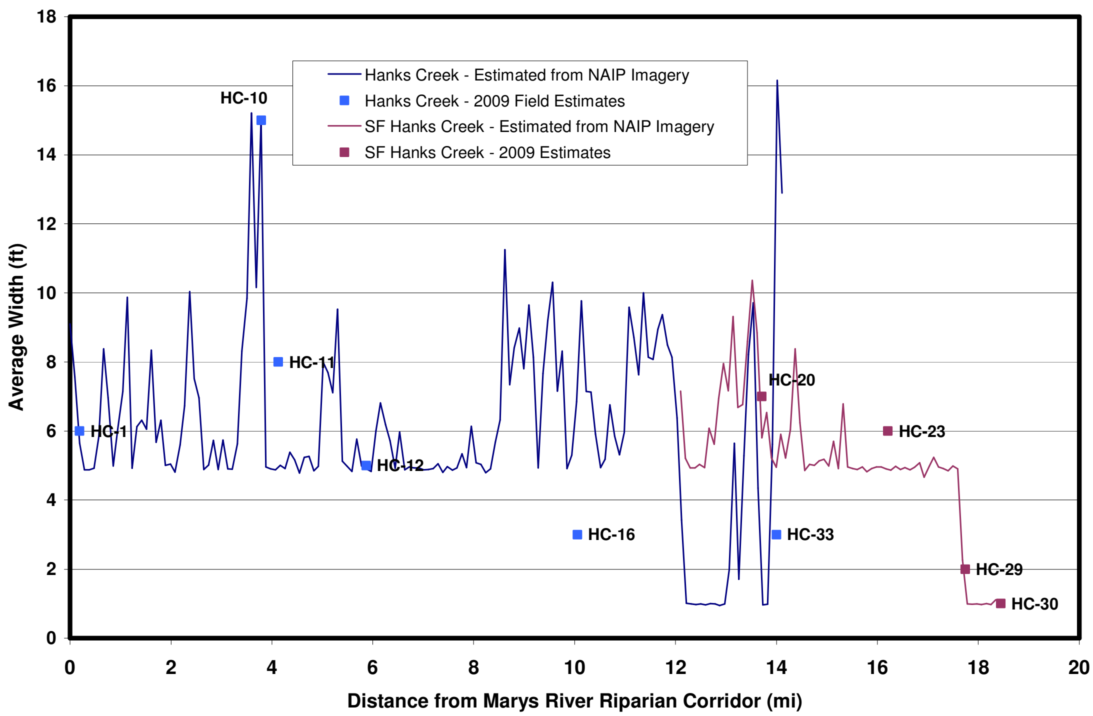


Figure 39. Hanks Creek and SF Hanks Creek – Existing Bankfull Widths

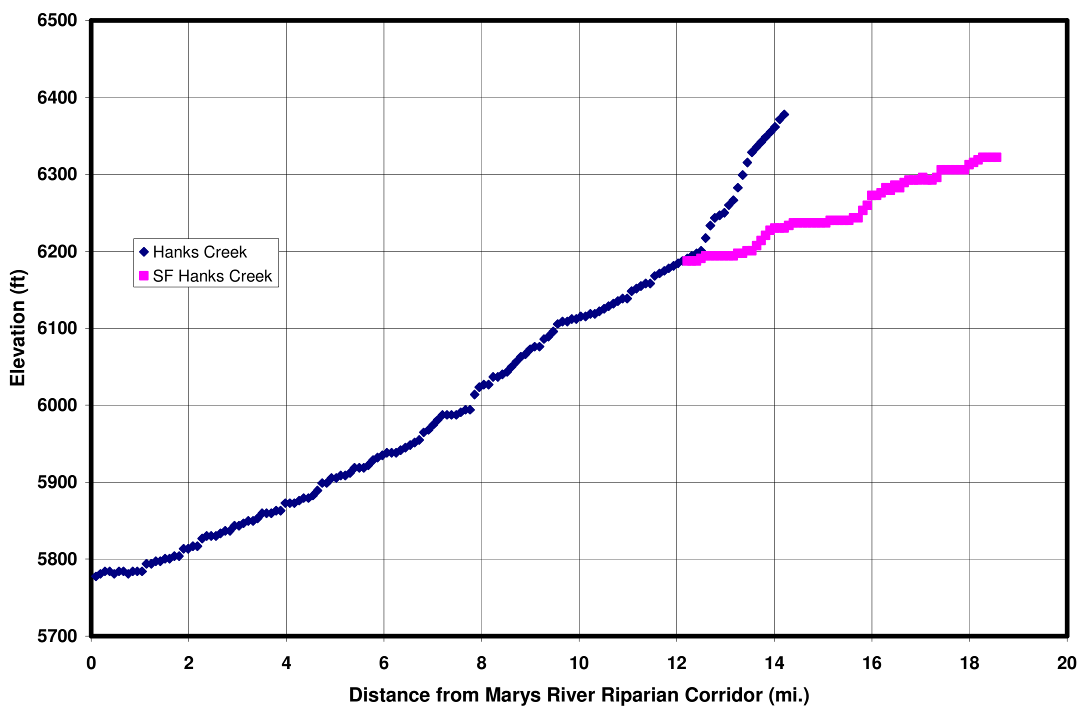


Figure 40. Hanks Creek and SF Hanks Creek Stream Profiles

4.1.3 Flow and Water Use

No flow gaging station data exists for Hanks Creek and it main tributaries so little is know about the flow characteristics of Hanks Creek. However it can be deduced from the field investigations and aerial imagery that summer flows in lower Hanks Creek area maintained primarily by inflows from SF Hanks Creek. It appears that upper Hanks Creek (above SF Hanks Creek) is kept wet in the upper portion by spring sources. However, the 2006 NAIP imagery suggests the stretches immediately above SF Hanks Creek are often dry in the late summer. According to the K. Owsley, Nevada Division of Water Resources), there are no irrigation rights from Hanks Creek. However, there is stock watering in many areas (Owsley, 2010).

4.1.4 Occurrence of Lahontan Cutthroat Trout (LCT)

According to the Nevada Department of Wildlife (Elliot and Layton, 2004), the LCT population in Hanks Creek has been estimated at 100 – 500. Additionally, Hanks Creek basin has been identified as a priority metapopulation recovery area for the LCT (Elliot and Layton, 2004). With the LCT being federally designated as threatened, Hanks Creek temperature (and other measures of stream health) are of concern to the land and water quality managers.

4.2 Problem Statement

Hanks Creek (Waterbody ID NV04-MR-98_00) was first placed on Nevada's 303(d) List in 2006 for temperature impairment of aquatic life beneficial uses. The SF Hanks Creek has not been categorized as impaired, but this is due solely to the lack of temperature data. Elevated stream temperatures are believed to occur in the SF Hanks Creek as the result of limited riparian shading. Also, these elevated temperatures in the SF Hanks Creek contribute to elevated temperatures downstream in Hanks Creek.

As with Dixie Creek, site specific water quality standards have not been set for Hanks Creek and SF Hanks Creek. However under the tributary rule (NAC 445A.145), the standards for Marys River are applicable to Hanks Creek and its tributaries. Marys River temperature standards at the confluence with Hanks Creek are set at $\leq$20° C (NAC 445A.125). NDEP is considering setting site specific standards for Hanks Creek in coming years.

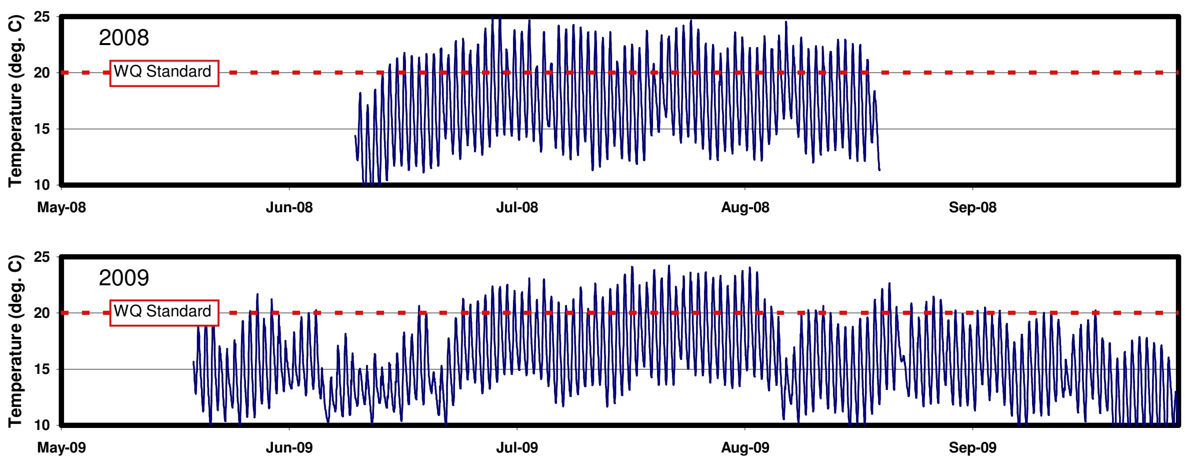
In addition to aquatic life, other beneficial uses applicable to Hanks Creek under the tributary rule include contact recreation, non-contact recreation, propagation of wildlife, municipal and domestic drinking water, irrigation, stock watering, industrial uses. However regarding the temperature standard, the aquatic life use is deemed to be the most restrictive.

The 2006 Listing was based upon continuous temperature monitoring performed by BLM for the lower Hanks Creek for the period 2002-2006. Since that time, additional data has been collected for both the upper and lower Hanks Creek (Table 10; Figures 41 through 43). It is interesting to note that the 2009 temperature at the lower Hanks Creek site were lower than at the upper monitoring site. This could be due to more shading in the lower reaches of the creek, or other factors such as cooler groundwater inflow.

Table 10. Summary of Temperature Standard Exceedances

Parameter	2002	2003	2004	2005	2006	2008	2009	Total
Upper Hanks Creek								
No. of Days Sampled	---	---	---	---	---	71	140	211
No. of Standard Exceedances	---	---	---	---	---	66	70	136
% of Sampled Days with Exceedances	---	---	---	---	---	93%	50%	64%
% of Year with Exceedances	---	---	---	---	---	18%	19%	19%
Lower Hanks Creek								
No. of Days Sampled	145	162	139	66	105	---	140	757
No. of Standard Exceedances	54	74	37	22	35	---	22	244
% of Sampled Days with Exceedances	37%	46%	27%	33%	33%	---	16%	32%
% of Year with Exceedances	15%	20%	10%	6%	10%	---	6%	11%

Figure 41. Temperature Data for Upper Hanks Creek



4.3 Source Analysis (Existing Conditions)

Areas with limited riparian vegetation are believed to be a significant factor leading to elevated temperature levels in Dixie Creek. As described earlier, solar radiation is a key thermal load source to stream. Control of this nonpoint thermal source can be achieved through vegetative shading. At this time, no point sources contribute any thermal loads to the stream.

While vegetation conditions are believed to be a major factor contributing to elevated temperatures, little quantitative information actually exists to describe the current riparian vegetation conditions. In 2004, the BLM performed stream assessments (including bank cover ratings) at three locations in the lower watershed (See Table 11; Figure 44). To supplement this information, NDEP staff rated the bank cover at 10 sites throughout the streams. To further characterize bank cover conditions, the following equation was used along with information extracted from the NAIP imagery:

Bank Cover = (0.478 x % Woody Vegetation in Buffer) + (0.264 x % Riparian Vegetation in Buffer) + 25

Table 11. Summary of Hanks Creek Bank Cover Ratings based upon NDEP Field Visits

Site ID	Bank Cover Rating by NDEP (2009)	Bank Cover Rating by BLM (2004)
HC-1	73	
S-02	na	88
S-03		70
S-04		73
HC-10	30	na
HC-11	80	
HC-12	73	
HC-16	63	
HC-20	43	
HC-23	50	
HC-29	50	
HC-30	50	
HC-33	50	

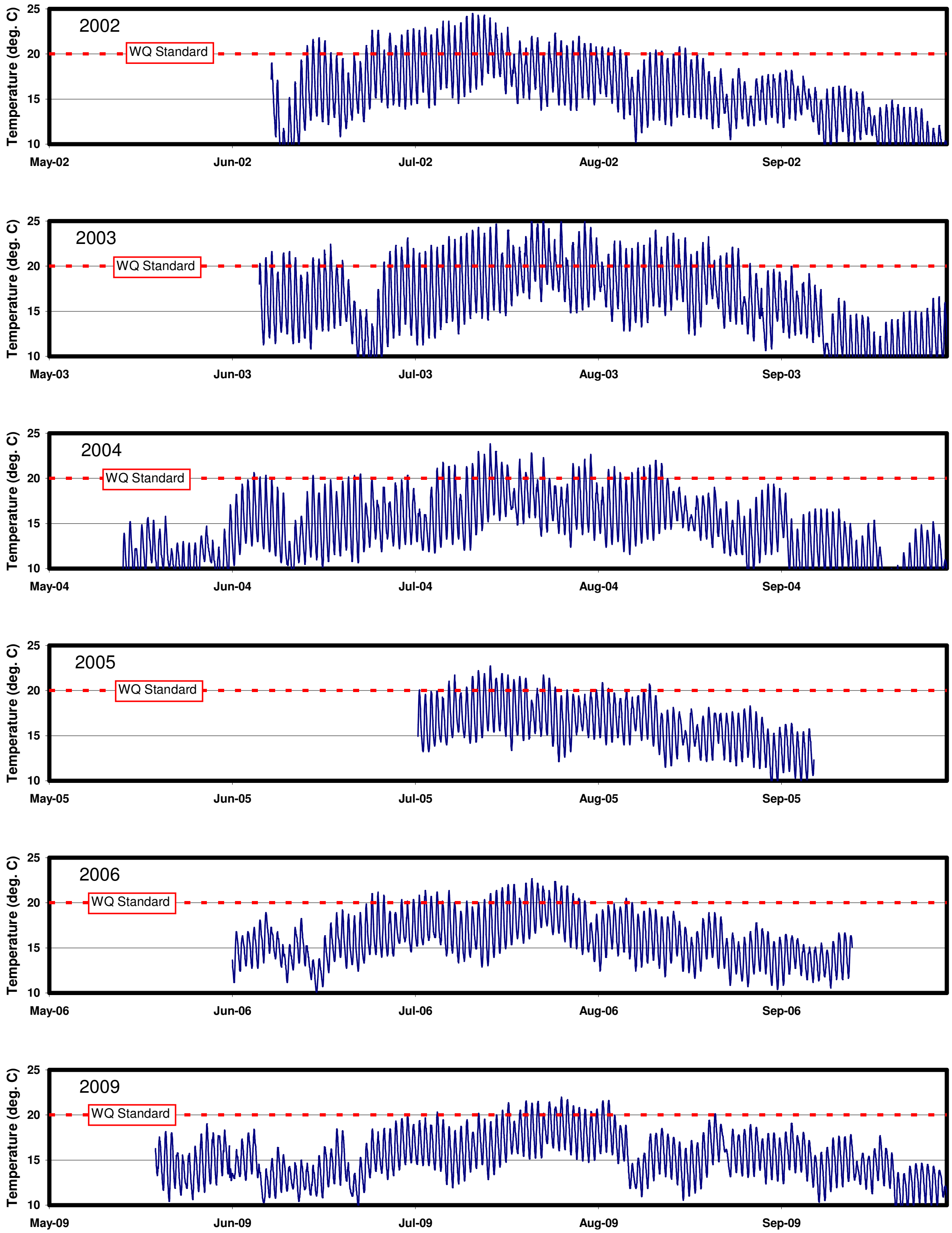


Figure 42. Temperature Data for Lower Hanks Creek

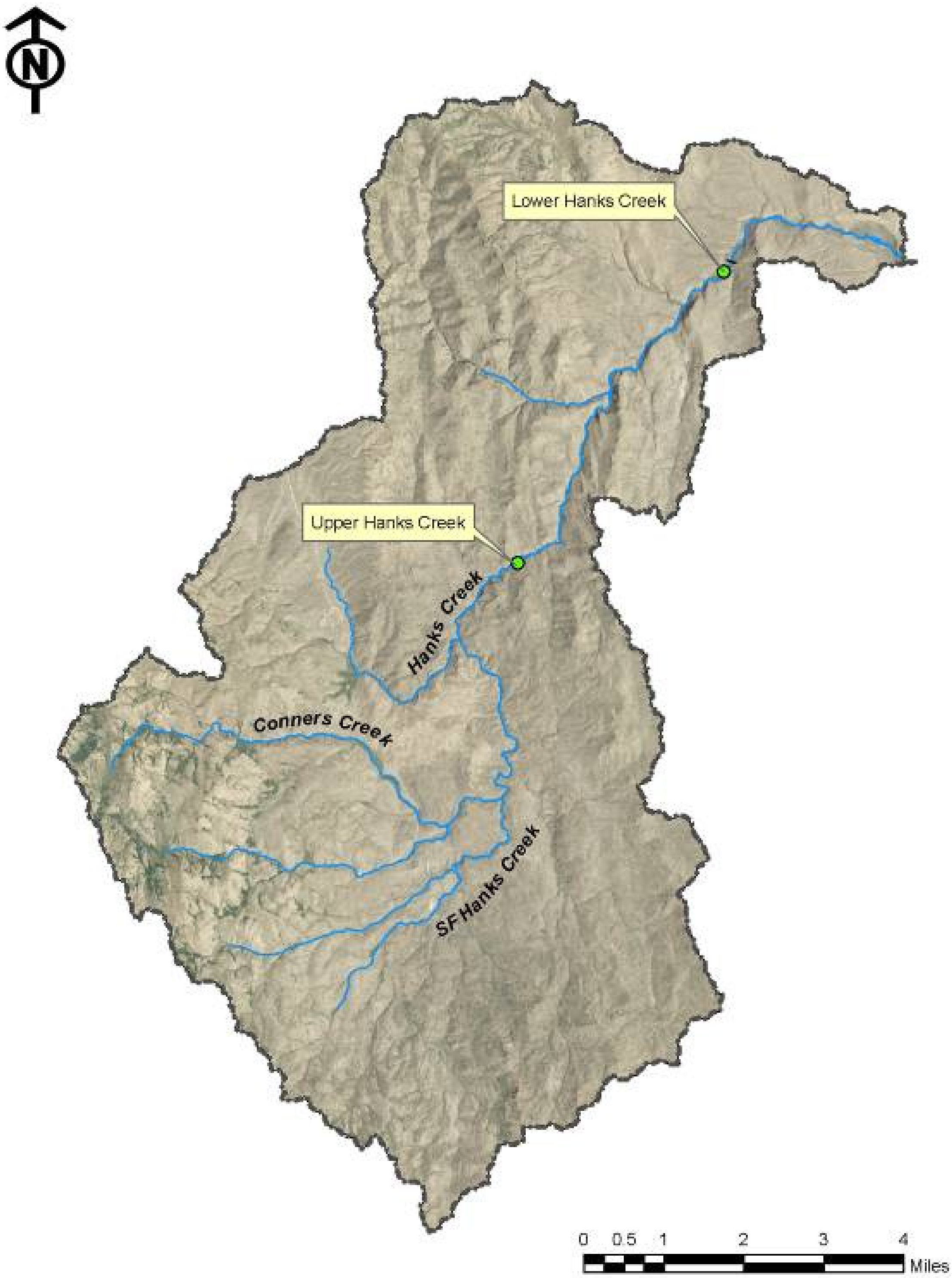


Figure 43. Hanks Creek Temperature Monitoring Sites

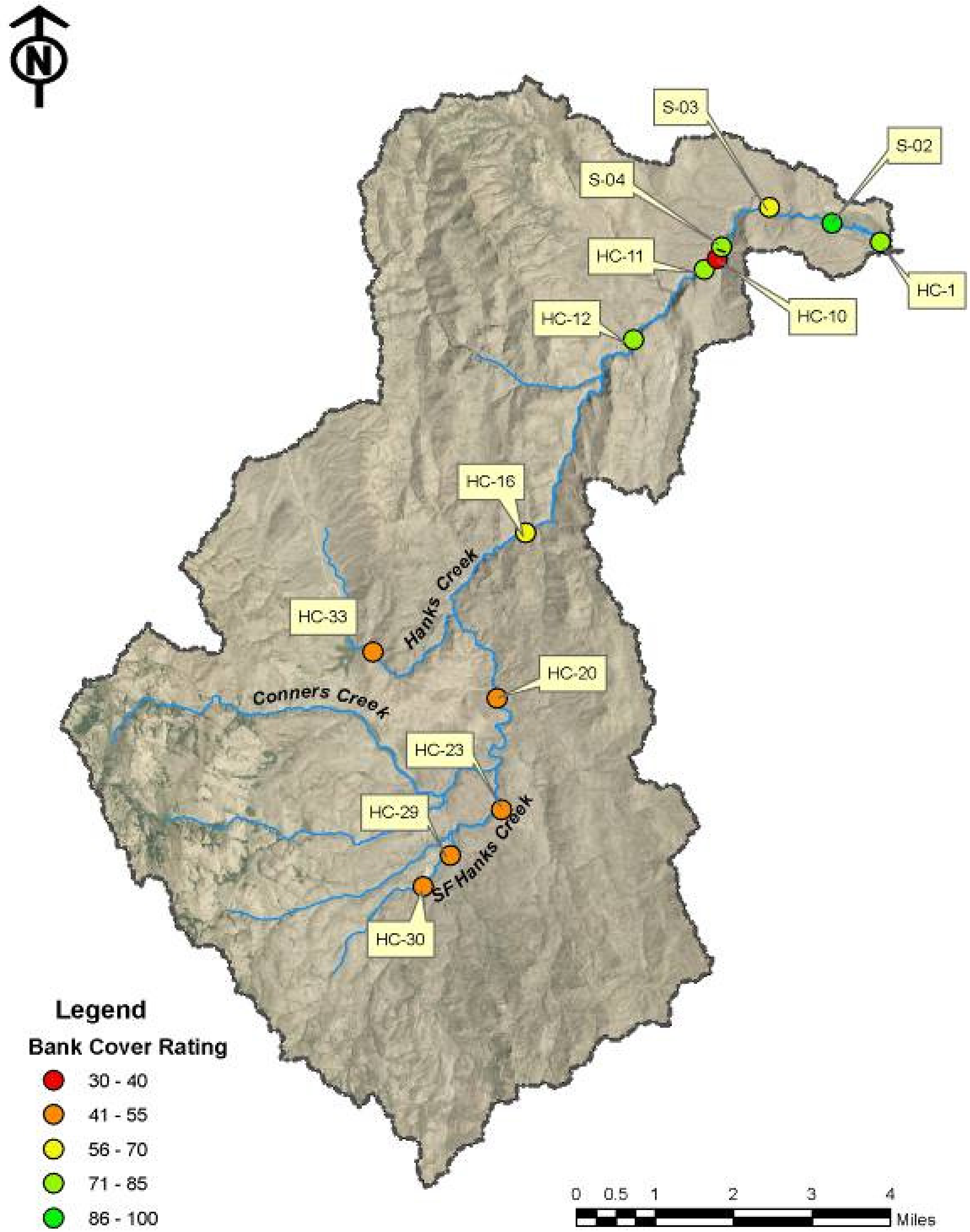


Figure 44. Bank Cover Rating Estimates for Hanks Creek and SF Hanks Creek

Figure 45 shows a good correlation between the bank cover ratings estimated from the NAIP imagery and those from field visits. The best conditions exist in lower Hanks Creek with many of the bank cover ratings exceeding 70. As discussed earlier, the 2006 NAIP conditions for the lower 9.5 miles of Hanks Creek are being used to represent target conditions for other reaches. According to BLM records, this section had not experienced any significant fires for several decades[3]. Also, grazing had not occurred in this reach for about 20 years. However near Mile 4.0, a water gap exists providing watering access for livestock and, not surprisingly, the bank cover at this location is much lower than the surrounding areas.

In the upper Hanks Creek, bank cover ratings are significantly less than those in the lower reach. This is especially true above Mile 12 at the confluence with SF Hanks Creek. Above this point, Hanks Creek is naturally ephemeral to intermittent limiting the ability for riparian vegetation to establish. Again, it must be noted that these bank cover estimates were derived from NAIP imagery that was collected just prior to the 2006 Charleston fire. Prior to that time, this section had not experienced any significant fires for several decades.

Based upon the 2006 NAIP imagery, SF Hanks Creek has bank cover ratings ranging from 25 to around 60. The source of the inadequate riparian vegetation along SF Hanks Creek is uncertain. BLM records show no evidence of any fires in this reach for the last several decades. The available information suggests that flows are not a limiting factor. Possible causes for the reduced riparian vegetation could be grazing and/or natural conditions such as channel conditions, soils, etc. Nevertheless, BLM staff believe the bank cover targets are achievable in this reach.

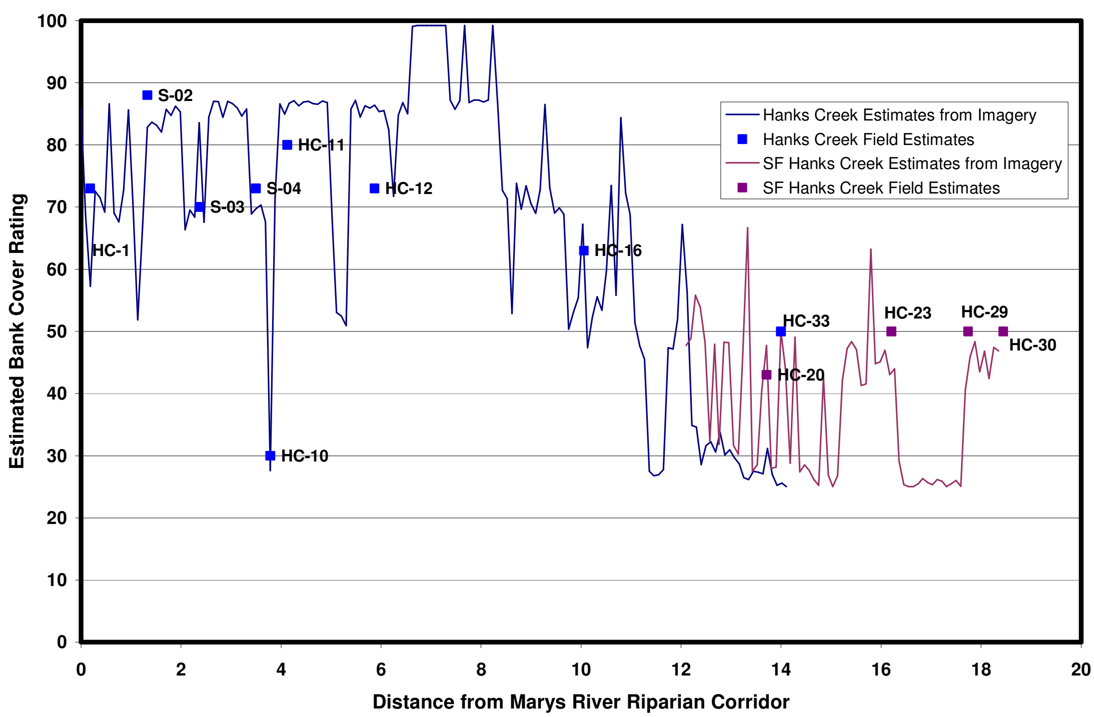


Figure 45. Hanks Creek and SF Hanks Creek – Existing Bank Cover Rating

[3] The 2006 NAIP imagery was acquired prior to the 2006 Charleston Fire.

4.4 Target Analysis

As previously discussed, the TMDL targets are to be defined in terms of riparian vegetation conditions (using BLM's riparian condition rating system) rather than stream temperature. Conditions within the lower Hanks Creek have been selected as representative of achievable "natural" conditions for much of the remaining Hanks Creek and SF Hanks Creek. Bank cover targets for these stretches have been set at an average of 80 with a minimum of 50 (Figure 46). However, no targets have been set for the naturally-intermittent stretch of Hanks Creek above the confluence with SF Hanks Creek. The potential to establish health riparian vegetation in this section is uncertain given the dry conditions.

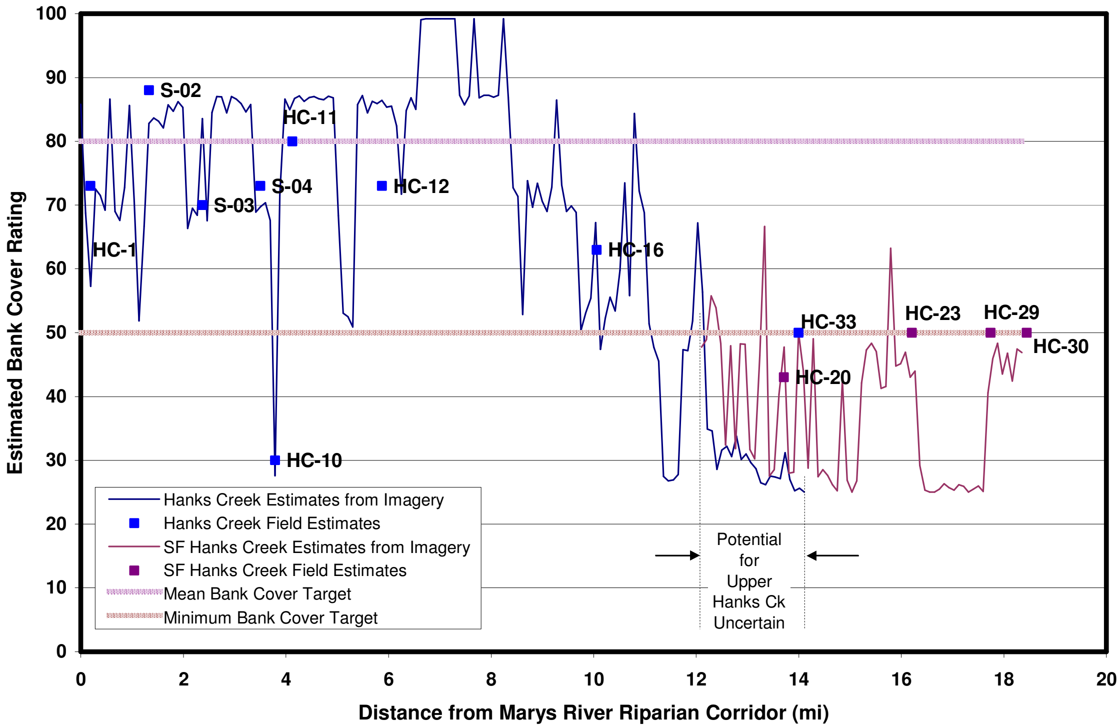


Figure 46. Hanks Creek and SF Hanks Creek – Existing and Target Bank Cover Ratings

4.5 Pollutant Load Capacity and Allocation

Existing Loads: Computer model predictions of shade and the associated solar radiation loads were developed using the State of Oregon's Heat Source Model (Boyd and Kasper, 2003). The following inputs for the Heat Source model for Hanks Creek and SF Hanks Creek were as follows in estimating existing shade and radiation loads:

- Width: Estimated from the bankfull limits digitized from the NAIP imagery (Figure 39).
- Vegetation offset: Insufficient information available. Assumed = 0.
- Vegetation height: Booth's Willow are thought to be the dominant woody vegetation. According to Hoag (2005), Booth's Willow generally reach 6 to 10 feet in height. For this TMDL, a height of 10 feet was assumed.
- Vegetation density: Set at 0%, 25%, 50%, 75% or 100% based upon visual estimates from the NAIP imagery.
- Reach orientation: Derived from NAIP imagery.

For this TMDL, June 21 was selected as the reference date for which to base estimates of existing shade/solar radiation load. While the warmest stream temperatures in this area typically occur in July and August, June 21 was selected as this is the time of highest solar radiation.

In addition to the computer model estimates, NDEP performed some field work to estimate shade at a few sites. During the summer of 2009, NDEP staff used a Solar Pathfinder™ to measure shade at some sites on Dixie and Hanks creeks. The Solar Pathfinder™ is a device that allows one to capture an outline of the shade producing objects and readily convert the information to percent shade (percent of solar radiation that is blocked). However resources did not allow for extensive shade measurements.

Target Loads: Target loads were calculated using the same model inputs as the existing loads, except for stream width and vegetation density. The target bankfull widths were assigned based upon the widths for the healthier locations within Hanks Creek. Using data for the 2009 field survey sites with bank cover conditions equal or greater than the minimum target of 50, a relationship between bankfull widths and drainage area was developed and was used to develop target bankfull widths (Figure 47).

Vegetation densities for each of the model segments were set at 72% or at the existing levels estimated in Step 1, whichever is higher. As discussed in Section 2.0 – Methodology, vegetation densities of about 72% seemed to correlate well with mean bank cover ratings of 80.

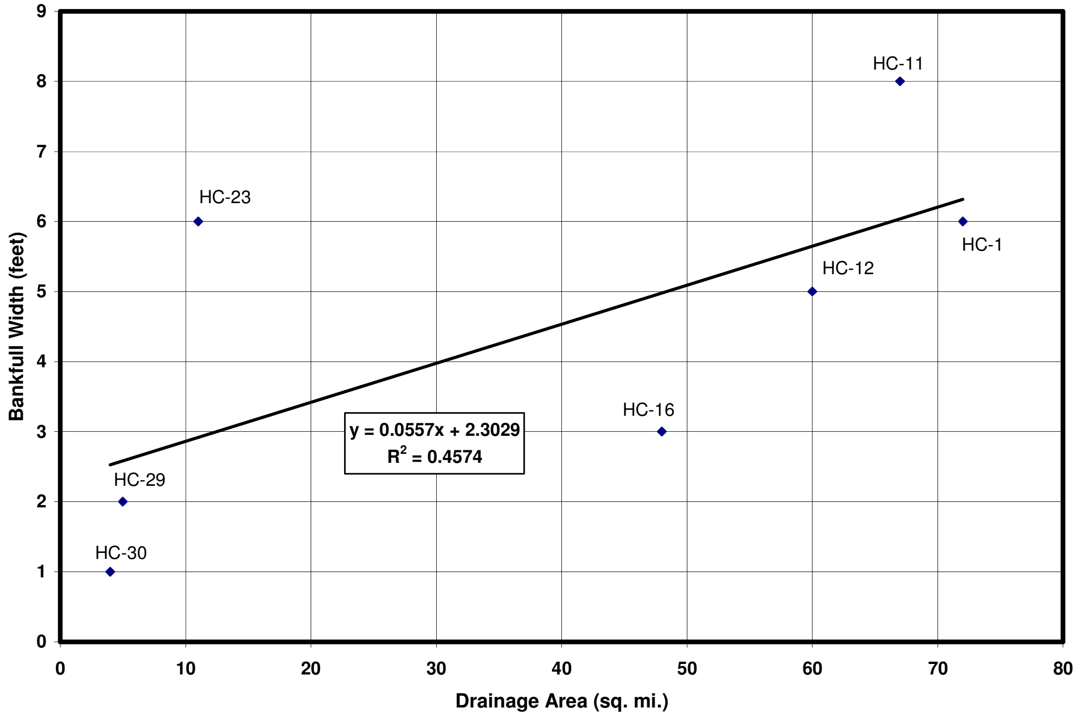


Figure 47. Drainage Area vs. Bankfull Width – Selected Hanks Creek Stations

Allocations and Load Reductions: The existing and target shade and solar radiation loads as estimated using the Heat Source Model are shown in Figures 48 through 51. Shade estimates from the Solar Pathfinder were close to those estimated using the Heat Source Model.

Load allocations for the Hanks Creek and SF Hanks Creek are represented by Figures 49 and 51, and are assigned to nonpoint sources activities that have or may affect riparian vegetation. Solar radiation reductions associated with the vegetation target conditions and the load allocations are presented in Figures 52 and 53. The overall average solar radiation reduction is estimated at about 19% and 57% for Hanks Creek and SF Hanks Creek, respectively (Table 12). A detailed breakdown for the existing and target conditions for each 500-foot subreach of Hanks and SF Hanks creeks are provided in Tables 13 and 14.

Table 12. Summary of Solar Load Allocations and Reductions for Hanks Creek and SF Hanks Creek

	Hanks Creek (Waterbody ID NV04-MR-98_00)		SF Hanks Creek (no Waterbody ID assigned as yet)	
	Average Percent Shading	Average Solar Loading (Langleys/day)	Average Percent Shading	Average Solar Loading (Langleys/day)
Existing	32.7%	502	6.3%	702
Target Allocations	45.6%	406	54.6%	340
Load Reduction	na	-96	na	-362
% Change	na	-19%	na	-57%

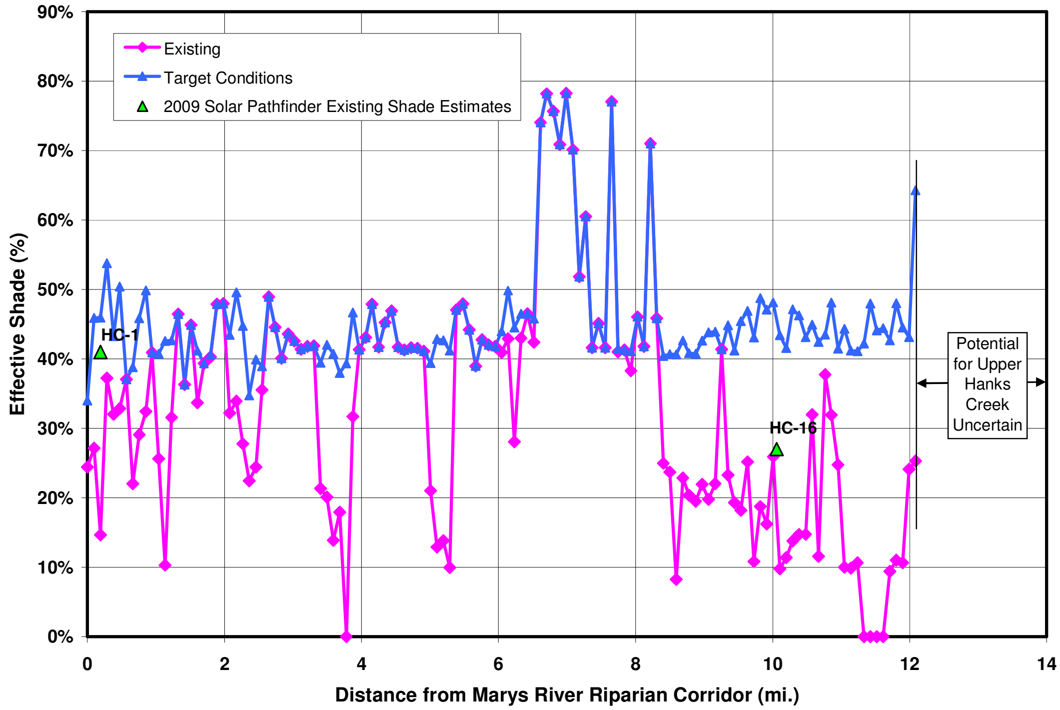


Figure 48. Hanks Creek – Effective Shade – Existing and Target Conditions

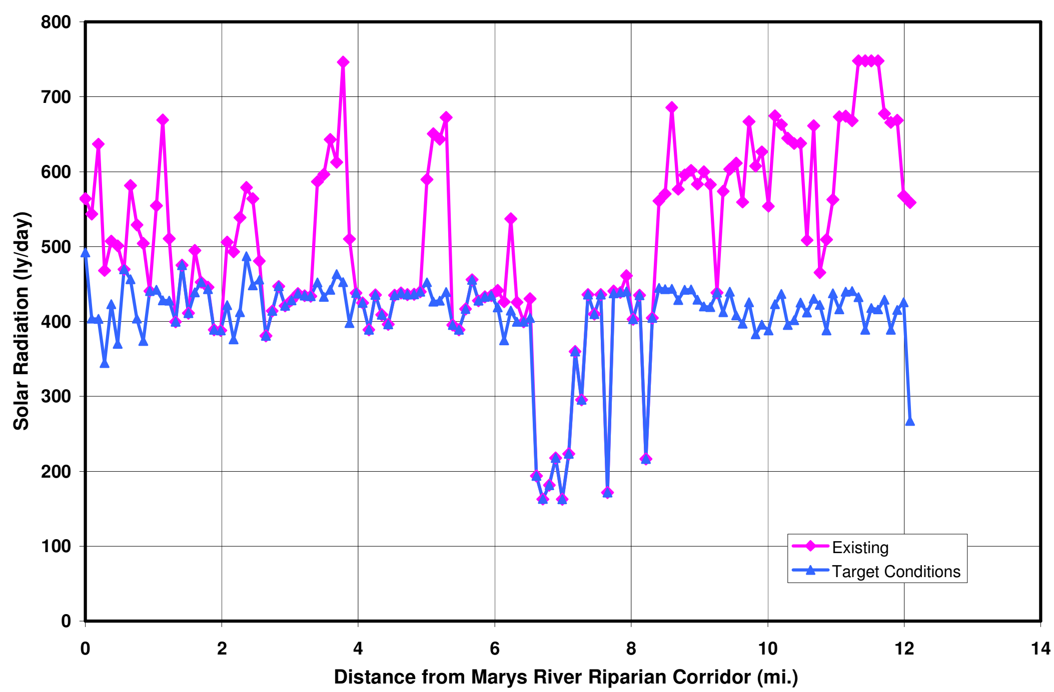


Figure 49. Hanks Creek – Solar Radiation – Existing and Target Conditions

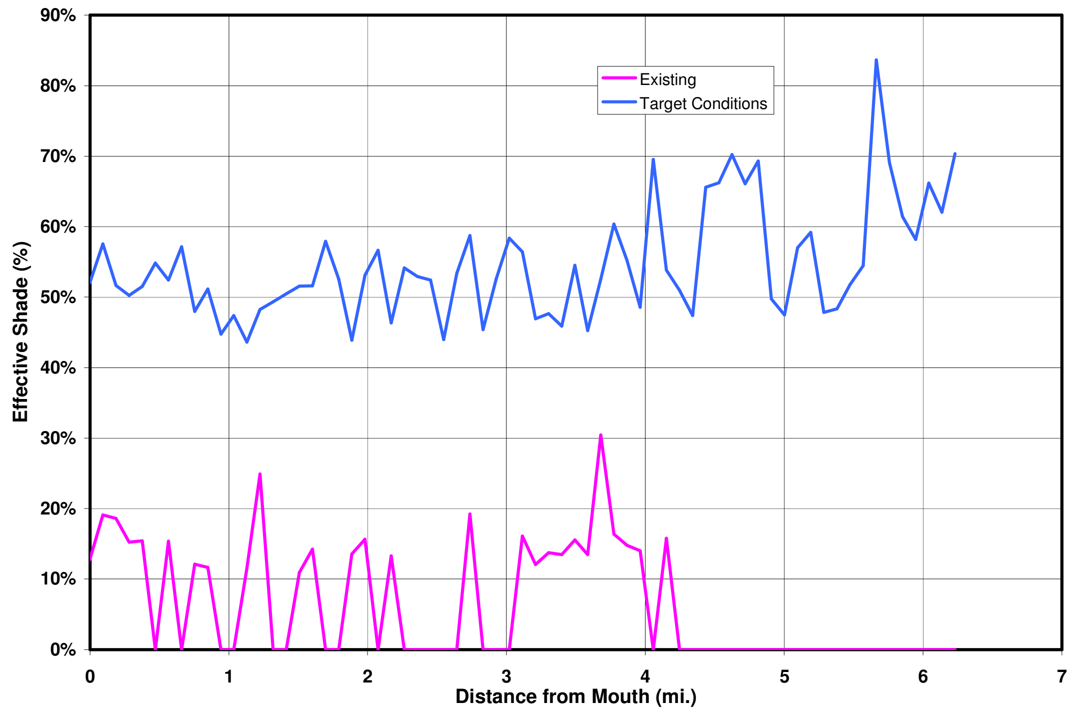


Figure 50. SF Hanks Creek – Effective Shade – Existing and Target Conditions

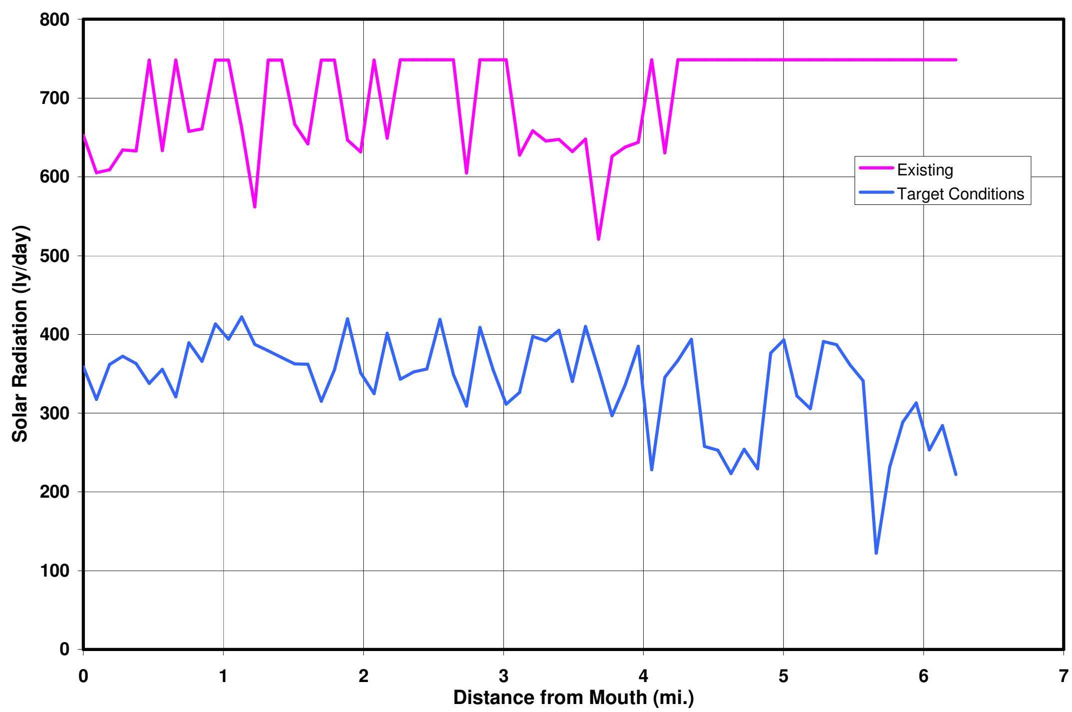


Figure 51. SF Hanks Creek – Solar Radiation – Existing and Target Conditions

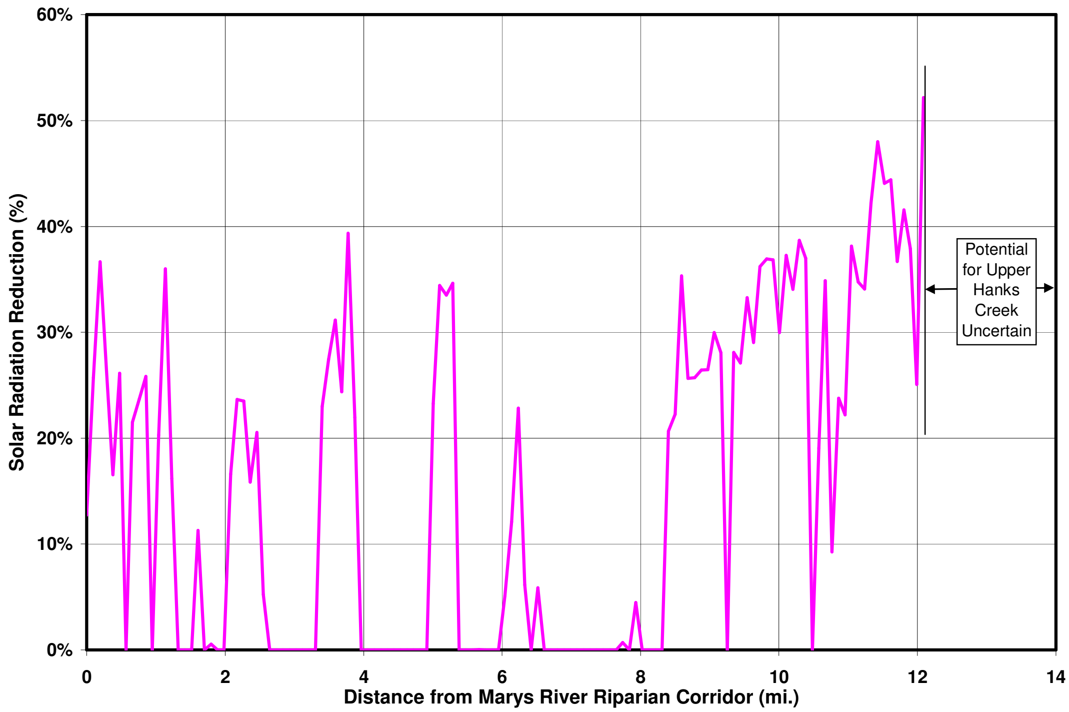


Figure 52. Hanks Creek – Solar Radiation Reductions Associated with Target Conditions

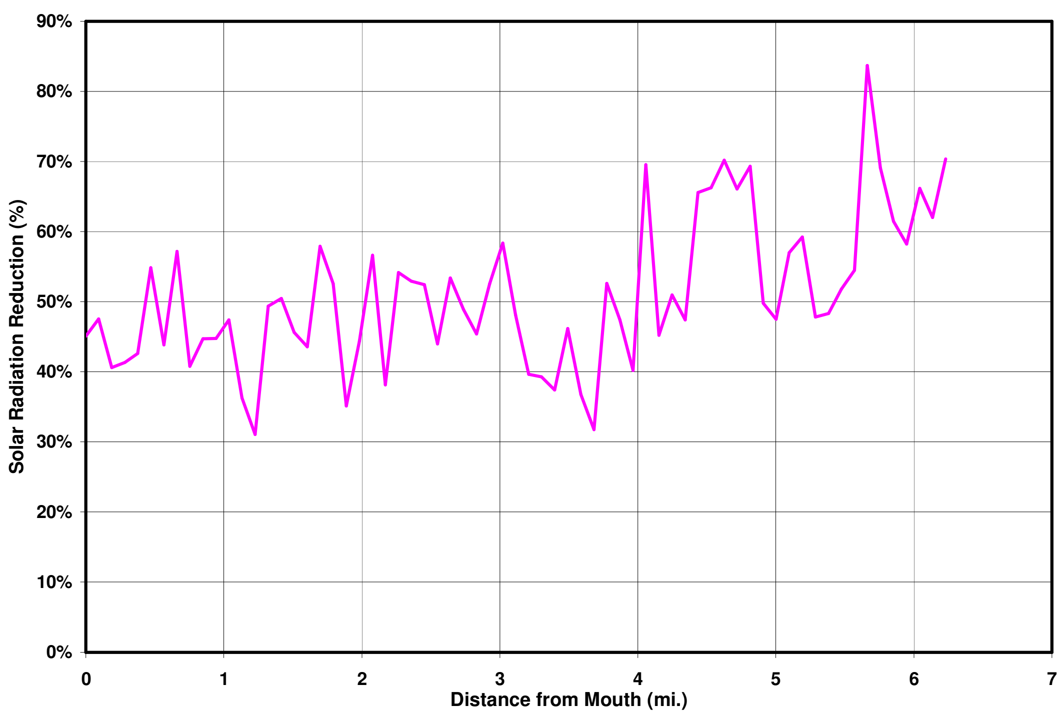


Figure 53. SF Hanks Creek – Solar Radiation Reductions Associated with Target Conditions

Table 13. Existing and Targeted Solar Loads and Reductions for Hanks Creek

Segment No.	Distance from Marys Corridor (mi)	Existing Solar Load (ly/day)	Existing Shade	Target Solar Load (ly/day)	Target Shade	Load Reduction	Segment No.	Distance from Marys Corridor (mi)	Existing Solar Load (ly/day)	Existing Shade	Target Solar Load (ly/day)	Target Shade	Load Reduction
1	0.00	564	24.4%	492	34.0%	12.7%	76	7.08	223	70.1%	223	70%	0.0%
2	0.10	543	27.1%	404	45.9%	25.7%	77	7.18	360	51.8%	360	52%	0.0%
3	0.19	637	14.6%	403	45.9%	36.7%	78	7.27	295	60.5%	295	60%	0.0%
4	0.28	468	37.2%	345	53.8%	26.4%	79	7.37	436	41.6%	436	42%	0.0%
5	0.38	507	32.0%	423	43.3%	16.6%	80	7.46	410	45.1%	410	45%	0.0%
6	0.47	501	32.8%	370	50.4%	26.1%	81	7.55	436	41.6%	436	42%	0.0%
7	0.57	469	37.1%	469	37.1%	0.0%	82	7.65	171	77.0%	171	77%	0.0%
8	0.66	582	22.0%	457	38.8%	21.5%	83	7.74	441	41.0%	438	41%	0.7%
9	0.76	529	29.1%	404	45.9%	23.7%	84	7.84	439	41.3%	439	41%	0.0%
10	0.85	504	32.4%	374	49.9%	25.8%	85	7.93	461	38.3%	440	41%	4.5%
11	0.95	441	40.9%	441	40.9%	0.0%	86	8.03	403	46.1%	403	46%	0.0%
12	1.04	555	25.6%	442	40.7%	20.3%	87	8.12	435	41.8%	435	42%	0.0%
13	1.13	669	10.3%	428	42.6%	36.0%	88	8.22	217	71.0%	217	71%	0.0%
14	1.23	510	31.6%	428	42.6%	16.2%	89	8.31	405	45.8%	405	46%	0.0%
15	1.32	399	46.5%	399	46.5%	0.0%	90	8.40	561	24.9%	445	40%	20.6%
16	1.42	475	36.3%	475	36.3%	0.0%	91	8.50	570	23.7%	443	41%	22.3%
17	1.51	411	44.9%	411	44.9%	0.0%	92	8.59	686	8.2%	443	41%	35.3%
18	1.61	495	33.7%	439	41.2%	11.3%	93	8.69	577	22.8%	429	43%	25.7%
19	1.70	452	39.4%	452	39.4%	0.0%	94	8.78	595	20.3%	442	41%	25.7%
20	1.79	446	40.3%	443	40.6%	0.6%	95	8.88	602	19.5%	443	41%	26.4%
21	1.89	389	47.9%	389	47.9%	0.0%	96	8.97	583	21.9%	429	43%	26.5%
22	1.98	388	48.0%	388	48.0%	0.0%	97	9.07	600	19.7%	420	44%	30.0%
23	2.08	506	32.2%	422	43.5%	16.6%	98	9.16	583	22.0%	419	44%	28.1%
24	2.17	493	33.9%	376	49.6%	23.7%	99	9.25	438	41.4%	438	41%	0.0%
25	2.27	539	27.8%	412	44.7%	23.5%	100	9.35	574	23.3%	412	45%	28.1%
26	2.36	579	22.4%	487	34.7%	15.9%	101	9.44	603	19.3%	440	41%	27.1%
27	2.46	564	24.4%	448	39.9%	20.5%	102	9.54	612	18.2%	408	45%	33.3%
28	2.55	481	35.5%	456	38.9%	5.2%	103	9.63	560	25.2%	397	47%	29.0%
29	2.64	381	49.0%	381	49.0%	0.0%	104	9.73	667	10.8%	425	43%	36.2%
30	2.74	414	44.5%	414	44.5%	0.0%	105	9.82	608	18.7%	383	49%	36.9%
31	2.83	447	40.1%	447	40.1%	0.0%	106	9.92	627	16.2%	396	47%	36.8%
32	2.93	421	43.6%	421	43.6%	0.0%	107	10.01	554	25.9%	388	48%	30.0%
33	3.02	428	42.6%	428	42.6%	0.0%	108	10.10	675	9.8%	423	43%	37.3%
34	3.12	437	41.4%	437	41.4%	0.0%	109	10.20	663	11.4%	437	42%	34.1%
35	3.21	434	41.8%	434	41.8%	0.0%	110	10.29	645	13.8%	395	47%	38.7%
36	3.31	434	41.9%	434	41.9%	0.0%	111	10.39	638	14.7%	402	46%	37.0%
37	3.40	587	21.3%	452	39.4%	23.0%	112	10.48	638	14.7%	425	43%	33.3%
38	3.49	596	20.1%	433	42.0%	27.4%	113	10.58	509	32.0%	412	45%	19.0%
39	3.59	643	13.9%	442	40.7%	31.2%	114	10.67	661	11.5%	431	42%	34.9%
40	3.68	613	17.9%	463	37.9%	24.4%	115	10.77	466	37.7%	422	44%	9.3%
41	3.78	746	0.0%	453	39.4%	39.4%	116	10.86	509	31.9%	388	48%	23.8%
42	3.87	510	31.7%	398	46.7%	22.0%	117	10.95	563	24.8%	438	41%	22.2%
43	3.97	438	41.3%	438	41.3%	0.0%	118	11.05	673	10.0%	416	44%	38.2%
44	4.06	425	43.1%	425	43.1%	0.0%	119	11.14	674	9.9%	440	41%	34.8%
45	4.16	389	47.9%	389	47.9%	0.0%	120	11.24	668	10.7%	440	41%	34.1%
46	4.25	435	41.7%	435	41.7%	0.0%	121	11.33	748	0.0%	432	42%	42.2%
47	4.34	409	45.2%	409	45.2%	0.0%	122	11.43	748	0.0%	389	48%	48.0%
48	4.44	396	46.9%	396	46.9%	0.0%	123	11.52	748	0.0%	418	44%	44.1%
49	4.53	435	41.7%	435	41.7%	0.0%	124	11.61	748	0.0%	416	44%	44.4%
50	4.63	438	41.3%	438	41.3%	0.0%	125	11.71	678	9.4%	429	43%	36.7%
51	4.72	436	41.6%	436	41.6%	0.0%	126	11.80	666	11.0%	389	48%	41.6%
52	4.82	436	41.5%	436	41.5%	0.0%	127	11.90	669	10.6%	415	44%	37.9%
53	4.91	440	41.1%	440	41.1%	0.0%	128	11.99	568	24.1%	426	43%	25.1%
54	5.01	590	21.0%	452	39.4%	23.3%	129	12.09	559	25.3%	267	64%	52.2%
55	5.10	651	12.9%	427	42.9%	34.4%	130	12.18					
56	5.19	644	13.8%	428	42.7%	33.5%	131	12.28					
57	5.29	672	9.9%	439	41.2%	34.7%	132	12.37					
58	5.38	395	47.0%	395	47.0%	0.0%	133	12.46					
59	5.48	389	47.9%	389	47.9%	0.0%	134	12.56					
60	5.57	417	44.2%	417	44.2%	0.0%	135	12.65					
61	5.67	456	38.9%	456	39.0%	0.1%	136	12.75					
62	5.76	428	42.7%	428	42.7%	0.0%	137	12.84					
63	5.86	433	42.0%	433	42.0%	0.0%	138	12.94					
64	5.95	435	41.8%	435	41.8%	0.0%	139	13.03					
65	6.04	441	40.9%	419	43.9%	5.1%	140	13.13	Naturally intermittent region - No Load Allocations established				
66	6.14	426	42.9%	375	49.8%	12.1%	141	13.22					
67	6.23	537	28.1%	414	44.5%	22.8%	142	13.31					
68	6.33	426	43.0%	400	46.5%	6.2%	143	13.41					
69	6.42	399	46.5%	399	46.5%	0.0%	144	13.50					
70	6.52	430	42.4%	405	45.8%	5.9%	145	13.60					
71	6.61	194	74.0%	194	74.0%	0.0%	146	13.69					
72	6.70	163	78.2%	163	78.2%	0.0%	147	13.79					
73	6.80	182	75.7%	182	75.7%	0.0%	148	13.88					
74	6.89	218	70.8%	218	70.8%	0.0%	149	13.98					
75	6.99	163	78.2%	163	78.2%	0.0%	150	14.07					

Table 14. Existing and Targeted Solar Loads and Reductions for SF Hanks Creek

Segment No.	Distance from Marys Corridor (mi)	Existing Solar Load (ly/day)	Existing Shade	Target Solar Load (ly/day)	Target Shade	Load Reduction
1	0.00	653	12.7%	359	52.0%	45.0%
2	0.09	605	19.1%	318	57.6%	47.5%
3	0.19	609	18.6%	362	51.7%	40.6%
4	0.28	634	15.2%	372	50.3%	41.3%
5	0.38	633	15.4%	363	51.5%	42.6%
6	0.47	748	0.0%	338	54.8%	54.8%
7	0.56	633	15.4%	356	52.5%	43.8%
8	0.66	748	0.0%	321	57.1%	57.1%
9	0.75	657	12.1%	389	47.9%	40.8%
10	0.85	661	11.6%	366	51.1%	44.7%
11	0.94	748	0.0%	413	44.7%	44.7%
12	1.04	748	0.0%	393	47.4%	47.4%
13	1.13	662	11.5%	422	43.6%	36.3%
14	1.23	562	24.9%	387	48.2%	31.0%
15	1.32	748	0.0%	379	49.3%	49.3%
16	1.41	748	0.0%	371	50.5%	50.5%
17	1.51	667	10.9%	362	51.6%	45.6%
18	1.60	642	14.2%	362	51.6%	43.6%
19	1.70	748	0.0%	315	57.9%	57.9%
20	1.79	748	0.0%	355	52.6%	52.6%
21	1.89	647	13.5%	420	43.9%	35.1%
22	1.98	631	15.6%	351	53.1%	44.4%
23	2.08	748	0.0%	325	56.6%	56.6%
24	2.17	649	13.3%	402	46.3%	38.1%
25	2.26	748	0.0%	343	54.2%	54.2%
26	2.36	748	0.0%	352	52.9%	52.9%
27	2.45	748	0.0%	356	52.4%	52.4%
28	2.55	748	0.0%	419	44.0%	44.0%
29	2.64	748	0.0%	349	53.4%	53.4%
30	2.74	605	19.2%	309	58.7%	48.9%
31	2.83	748	0.0%	409	45.4%	45.4%
32	2.93	748	0.0%	355	52.6%	52.6%
33	3.02	748	0.0%	312	58.4%	58.4%
34	3.11	628	16.1%	326	56.4%	48.1%
35	3.21	658	12.0%	397	46.9%	39.6%
36	3.30	645	13.8%	392	47.6%	39.3%
37	3.40	647	13.5%	405	45.9%	37.4%
38	3.49	632	15.5%	340	54.5%	46.2%
39	3.59	648	13.4%	410	45.2%	36.7%
40	3.68	521	30.4%	355	52.5%	31.8%
41	3.77	626	16.4%	297	60.4%	52.6%
42	3.87	638	14.8%	335	55.2%	47.4%
43	3.96	644	14.0%	385	48.6%	40.2%
44	4.06	749	0.0%	228	69.5%	69.5%
45	4.15	631	15.8%	346	53.8%	45.2%
46	4.25	749	0.0%	367	51.0%	51.0%
47	4.34	749	0.0%	394	47.4%	47.4%
48	4.44	749	0.0%	258	65.6%	65.6%
49	4.53	749	0.0%	253	66.2%	66.2%
50	4.62	749	0.0%	223	70.2%	70.2%
51	4.72	749	0.0%	254	66.1%	66.1%
52	4.81	749	0.0%	230	69.3%	69.3%
53	4.91	749	0.0%	376	49.8%	49.8%
54	5.00	749	0.0%	393	47.5%	47.5%
55	5.10	749	0.0%	322	57.0%	57.0%
56	5.19	749	0.0%	305	59.2%	59.2%
57	5.29	749	0.0%	391	47.8%	47.8%
58	5.38	749	0.0%	387	48.3%	48.3%
59	5.47	749	0.0%	361	51.8%	51.8%
60	5.57	749	0.0%	341	54.5%	54.5%
61	5.66	749	0.0%	122	83.7%	83.7%
62	5.76	749	0.0%	231	69.1%	69.1%
63	5.85	749	0.0%	289	61.4%	61.4%
64	5.95	749	0.0%	313	58.2%	58.2%
65	6.04	749	0.0%	253	66.2%	66.2%
66	6.14	749	0.0%	284	62.0%	62.0%
67	6.23	749	0.0%	222	70.4%	70.4%

Margin of Safety: TMDLs are required to include a margin of safety to account for uncertainties in the analysis. There are a variety of sources for uncertainty in the existing and targeted solar load analyses:

Bank Cover Targets: Bank cover targets were based upon existing conditions in lower Hanks Creek as estimated from the NAIP imagery. As shown in Figure 15, there is considerable uncertainty in any individual estimate at a given location. However, it is thought that some estimates will be above the mean and others will be below with the fluctuations balancing out.

Stream width: Existing widths were derived from NAIP imagery. The 1-meter resolution of the NAIP made it difficult to exactly identify streambanks and the widths. It is believed that the process results in overestimating and underestimating stream widths with the errors balancing out.

Vegetation offset: For purposes of this TMDL, the distance that riparian vegetation is offset from the edge of the stream was assumed to be zero. Field observations and the NAIP imagery show great variability in the offset, with some areas having vegetation overhanging the stream edge (a negative offset) and other areas set back anywhere from 0 to >10 feet. However under this methodology, woody vegetation farther than 10 feet from the stream edge would not be included in the % woody vegetation estimates. The assumption of zero is deemed to be an appropriate approximation of overall conditions.

Percent woody vegetation: The target conditions are set at an average bank cover rating of 80 with acceptable values ranging from 50 to 100. Under average target conditions (Bank Cover = 80), it is estimated that corresponding percent woody vegetation amounts could vary from about 60 to 72% within the riparian buffer (Figure 17). Under minimum acceptable target conditions (Bank Cover = 50), it is estimated that the corresponding percent woody vegetation amounts would be about 16 to 30%. At the maximum Bank Cover condition (100), 100% woody vegetation coverage is most likely. Based on this information, a stream meeting the Bank Cover targets could have percent woody vegetation coverage ranging from 16% to 100%. For the target loads, the high end of the range (72%) for average Bank Cover conditions (80) was assumed to be the desired condition. Overall, this is likely on the high side and believed to have led to conservatively lower target solar load needs.

The margin of safety with the temperature TMDLs is considered implicit in the methodology, specifically through the use of conservative assumptions in the percent woody vegetation values used in the solar shading modeling.

Seasonal Variation: Federal regulations require that TMDLs account for seasonal variations. From a solar radiation perspective, peak solar radiation levels occur on the summer solstice (June 21) and lowest levels on the winter solstice (December 21). For this TMDL, loads allocations were calculated for the peak solar radiation period (June 21). As such, compliance with these allocations would assure compliance with any allocations needed for less intense solar radiation periods.

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Appendix A

Part B

Aquatic Habitat Inventory and Monitoring Level III Survey Procedures – Transect Method (BLM, 2002)

Aquatic Habitat Inventory and Monitoring
Level III Survey Procedures - Transect Method
Elko Revised Handbook 6720-1

Elko Field Office of the Bureau of Land Managment, Elko. Nevada

Release 1, 2002

24. Embeddedness

Enter rating code for the embeddedness of channel materials (i.e. gravel, rubble, and boulder). This rates the degree that larger particles are surrounded by fine sediment.

Code	Description
1	Gravel, rubble, and boulder particles having over 75% of their surface covered by fine sediment.
2	Gravel, rubble, and boulder particles having 50% to 75% of their surface covered by fine sediment.
3	Gravel, rubble, and boulder particles having 25% to 50% of their surface covered by fine sediment.
4	Gravel, rubble, and boulder particles having 5% to 25% of their surface covered by fine sediment.
5	Gravel, rubble, and boulder particles having less than 5% of their surface covered by fine sediment.

25. Riparian Width

Enter the width of the riparian vegetation to the nearest 0.5 ft. for the right and left banks at the transect into one of the following categories:

A. Canopy cover of shrubs, trees and basal cover of herbaceous vegetation is less than 50%.

- OR -

B. Canopy cover of shrubs, trees and basal cover of herbaceous vegetation is greater than 50%.

Note: Both cover types can occur within the same riparian zone width.

Only riparian vegetation is recorded. Vegetation to be considered should be limited to that which occurs adjacent to and is being maintained by the active stream channel. The beginning of the riparian zone is defined where the riparian vegetation is within half of its average un-grazed height to the water's edge. Where riparian plant species become gradually but increasingly scattered, the zone will be defined as ending where the average distance between riparian plant species is greater than the average un-grazed height of those plants.

If the transect (perpendicular to flow) is on a "hairpin" meander that would result in the riparian zone measurement going over a point bar and paralleling the stream corridor, measure what makes sense. That is, measure a representative riparian width for the transect and comment on the remarks line or on the stream survey notes form.

26. Bank Cover (From: Nevada BLM Stream Survey Manual 6671)

Bank cover is living riparian vegetation occurring within the active floodplain. Vegetative cover along streams provides shade for water temperature control, hiding cover for fish, bank stability through root systems, and a place for insects to live and breed which indirectly provides a source of fish food as these insects fall into the stream.

To be effective for shade and water temperature control, the trees and shrubs must be twice as high as the distance to the water's edge. For example, a willow 16 ft. tall must be within 8 ft. or less of the water's edges to be effective as a streamside shade cover plant.

The class of streamside vegetation which influences the transect will be recorded for both the right and left banks based on the vegetative characteristics extending 50 ft. above and below the end of each transect. Four classes of streambank vegetation is recognized. Each vegetative type is given a numerical rating that will be used in the final analysis to determine overall condition of the stream. The numerical rating should be entered in this column on the data form. The vegetative classes and numerical ratings are as follows:

Rating	Type	Description
2.0	Forested	If bank is medium to heavily covered with trees and/or tall (>7') shrubs. (Banks with no more than one continuous 10-foot opening are considered medium dense. In addition to one 10-foot opening, there may be several smaller openings less than 10 ft. in length.)
1.5	Brush	If banks have scattered trees and/or tall (>7') shrubs. (A scattered density is considered to have 2 or more 10-foot openings.) A few trees or tall (>7') shrubs scattered along the streambank does not warrant a rating of 1.5.
1.0	Grass	If bank is medium to heavily covered with low to medium shrubs, forbs, or grasses, or a combination of these plants.
0.5	Exposed	If bank is covered with scattered low to medium shrubs, forbs, or grasses, or is exposed.

Notes: *Do not include upland vegetation in the measurement of bank cover.*
The difference between scattered and medium cover will be determined on the basis of plant spacing. Where the average distance between plants is greater than the average ungrazed height of those plants, cover will be considered scattered. Where plants are closer together than their average height, the cover will be determined as medium (or higher). Refer to the following photographs for examples of cover ratings.

Streambank Cover Rating Examples:

2.0 Cover

Height, density and proximity of the willow/dogwood riparian community give this site a rating of 2.0.

2.0 Cover

Height and spacing of aspen saplings form the basis of this 2.0 cover rating. Openings between aspen do not exceed ten feet.

2.0 Cover

Although low flow conditions contribute to some exposure of the channel, willow height and proximity of willows to the baseflow stream channel easily allow for a rating of 2.0 for this site.

Streambank Cover Rating Examples:

1.5 Cover

Although a small grassy floodplain exists between the willow corridor and the base-flow stream channel, the willows are within half their height of the water's edge and are therefore included in the evaluation of streambank cover. The height of the willows, as well as the presence of two or more ten-foot openings, gives this site a rating of 1.5. This example represents the upper end of the 1.5 cover category.

1.5 Cover

Willow height and density are the basis for a rating of 1.5 at this site. Willows here are more scattered than in the previous example, but they are sufficiently dense to warrant a rating of 1.5.

1.5 Cover

Although willow height varies at this site, a sufficient number of tall willows are present to warrant a 1.5 rating.

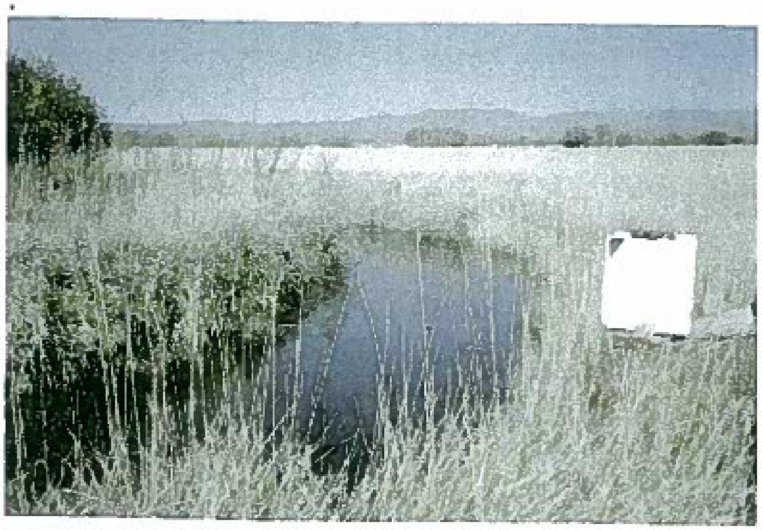
Streambank Cover Rating Examples:

1.0 Cover

Although grazed, herbaceous riparian cover remains medium to heavy, resulting in a rating of 1.0.

1.0 Cover

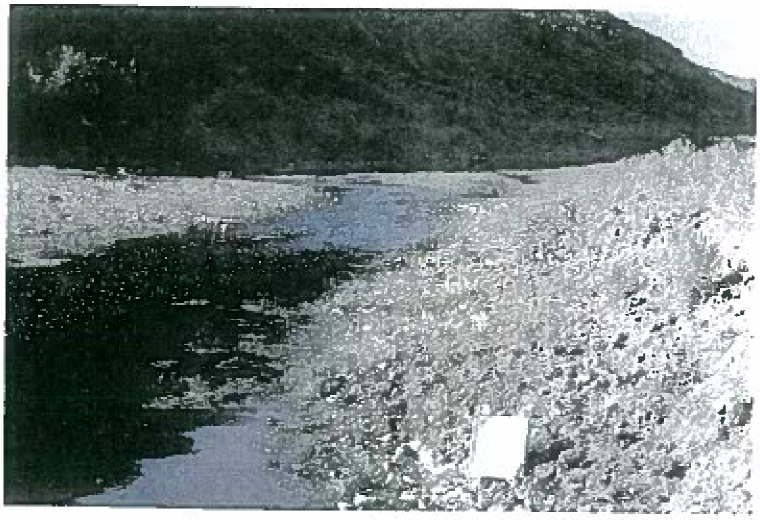
At this site, both streambanks support combinations of medium to heavy cover of low to medium shrubs (in this case, willows), riparian grasses, and forbs. This example represents the upper end of the 1.0 cover class.



1.0 Cover

Streambanks are heavily covered with a combination of riparian forbs, grasses and grass-like species. Although not specifically identified in the cover description, it is important to include riparian grass-like species such as sedges and rushes in the assessment of stream-bank cover.

Streambank Cover Rating Examples:



0.5 Cover

This example represents the lower end of the cover class description. The few riparian forbs and grass species are present are widely scattered and the streambanks are exposed.

0.5 Cover

Although there are riparian grasses and forbs present, the amount of bare ground precludes the site from being characterized as supporting medium to heavy cover. Note that the presence of a few large trees does not change the overall cover rating of 0.5.

0.5 Cover

Kentucky bluegrass, a shallow rooted riparian species, provides limited cover for these streambanks and the associated floodplain. This site clearly warrants a rating of 0.5.

27. Bank Stability (From: Nevada BLM Stream Survey Manual 6671)

Few streams exist which do not have some degree of streambank erosion. Stable banks are generally associated with those covered by dense vegetation, or characterized by large or solid rock. Unstable banks are usually associated with sparse vegetative cover, stream-bank/channel alteration or other factors. Banks in a vertical profile may be highly unstable when composed of fine materials and with very little vegetative root systems to bind the soils together. However, vertical and in some cases, undercut banks located in meadows are frequently very stable. Therefore, investigators must view streambank stability from the standpoint of whether they are eroding at a slow and normal rate, or whether erosion is accelerated and is contributing excessive amounts of sediments. Undercut or overhanging banks could be present as part of a totally stable bank system.

Investigators should not confuse the active stream channel with streambanks. Streambanks are part of the active floodplain and form the edge of the bankfull channel.

Bank stability is evaluated by observing the right and left streambank, a distance of 50 ft. above and below each end of each transect. Thus, as with bank cover, investigators will not evaluate banks along channel separations unless they extend a full 50 ft. in each direction from the transect line. Each bank stability class is assigned a numerical rating that should be entered in column #27 on the field form.

The bank stability classes and their numerical ratings are:

Rate	Description
2.0	If bank is totally stable. Minimal evidence of bank erosion at any flow condition.
1.5	If 50 % or more of bank is stable, but not totally stable. Some erosion present but usually associated with high flows. Banks are recovering naturally.
1.0	If less than 50 % percent stable, but not totally unstable. Moderate to heavy erosion and bank sloughing taking place during high and low flows.
0.5	If totally unstable. Heavy erosion and bank sloughing occurring on most of the streambank length. Erosion constant.

Note: *Streambank trampling and shearing can be considered as contributing to streambank instability. Refer to the following photographs for examples of stability ratings.*

Streambank Stability Rating Examples:

2.0 Stability

Near complete cover of herbaceous and woody riparian species and their associated root masses make these streambanks very stable. The occasional downstream point bars are within the bankfull channel and should not be evaluated in the context of streambank stability.

2.0 Stability

A combination of boulders and vigorous willow growth make these streambanks extremely stable.

2.0 Stability

Dense herbaceous riparian vegetation and aspen suckers make these streambanks stable. Areas of exposed streambank are not evident.

Streambank Stability Rating examples:

1.5 Stability

Although the streambanks are quite stable, the 1.5 rating is based on the limited presence of exposed or sloughing banks.

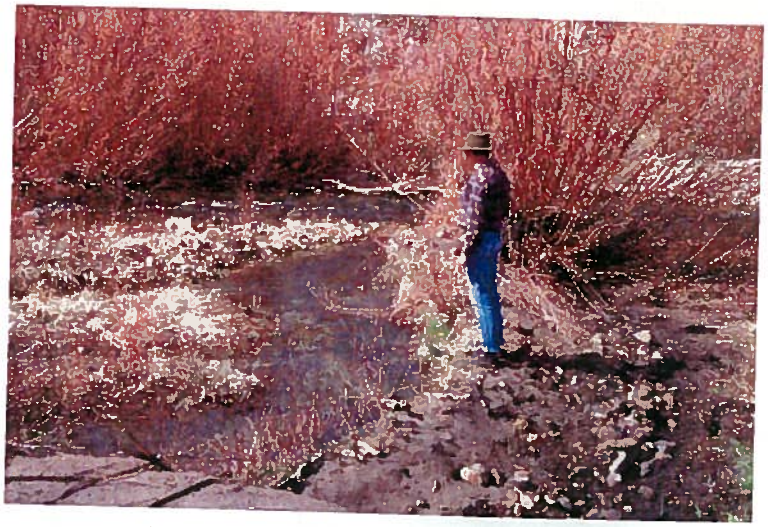
1.5 Stability

Streambanks exhibit stability where the stream is functioning within a floodplain; however, sloughing is still occurring where the stream is cutting into a terrace. Minor amounts of streambank erosion are also evident within the floodplain.

1.5 Stability

Although the herbaceous cover is scattered, the bank's moderate to high rock content provides for additional streambank stability resulting in a rating of 1.5.

Streambank Stability Rating Examples:



1.0 Stability

Although excessive deposition in the form of mid-channel bars and levees is indicative of considerable instability at this site, mature willows with their associated strong root masses provide resistance to the energies of flowing water.

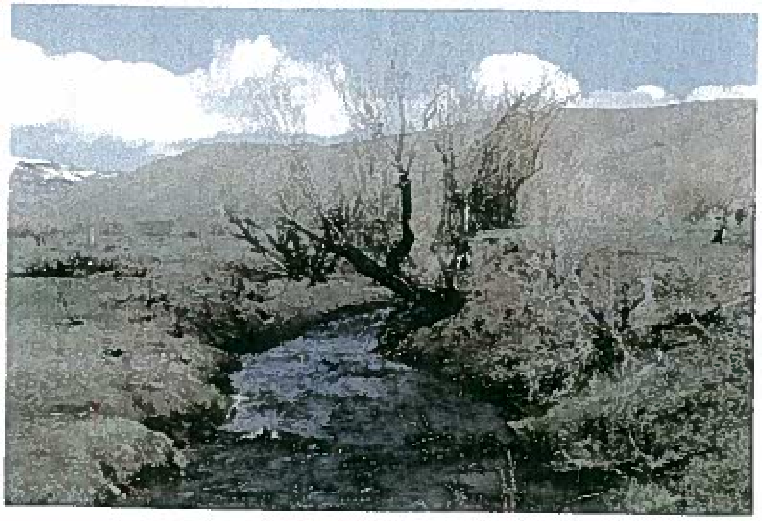
1.0 Stability

The roots associated with these young willows will provide some anchoring for the unconsolidated alluvial material comprising this streambank. Normally, unconsolidated alluvium, particularly if composed of fine materials, would be considered unstable.

1.0 Stability

Though rock and herbaceous cover provide some stability, the high level of bank shearing and trampling, as well as a lack of deep rooted riparian species, makes these banks vulnerable to erosion. This example represents the upper end of the 1.0 stability rating.

Streambank Stability Rating Examples:



0.5 Stability

The minimal herbaceous riparian cover present is insufficient to provide any stability to these incised streambanks. Although some willow cover is present, it does not appear to have survived severe scorching by wildfire.

0.5 Stability

This channel is deeply incised and totally unstable, representing the lower end of the 0.5 stability rating.

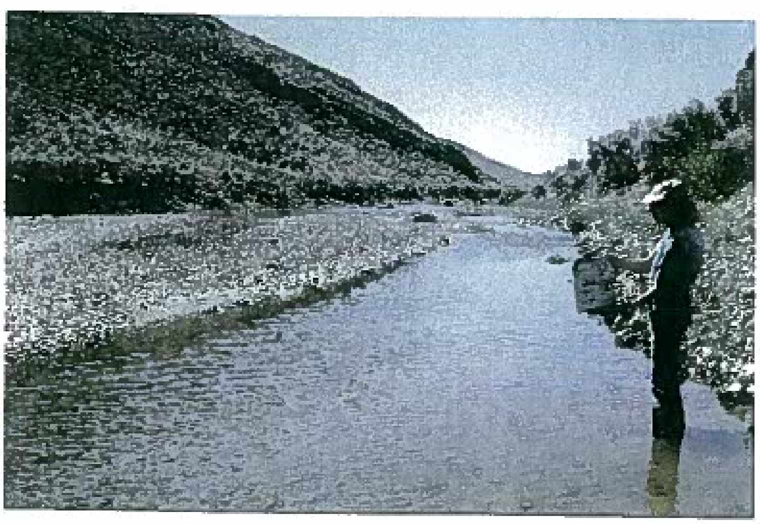
0.5 Stability

Although these streambanks have some willow cover, they are almost entirely comprised of fine erosive materials and are therefore essentially unstable.

Special Considerations:

Stability: Special Considerations

It could be argued that the streambanks immediately upstream from the lower head-cut should receive a stability rating of 1.0. However, a rating of 0.5 is probably more accurate given the evidence of active and progressive channel down-cutting. Note the second head-cut forming in the upper part of the photo.



Stability: Special Considerations

This gravel bar, which is located within the active bankfull channel, should not be evaluated for streambank stability. Instead, it is the steep, exposed streambanks located beyond the bankfull channel that should be rated 0.5 for stability.