NOWOOD RIVER STORAGE, LEVEL II STUDY
PHASE I SUMMARY REPORT
WYOMING WATER DEVELOPMENT COMMISSION
CHEYENNE, WYOMING

December 6, 2013
Project #: 06N-002-001

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List of Acronyms

ac-ft – acre-feet
ACE – Anderson Consulting Engineers, Inc.
ACOE – United States Army Corps of Engineers
ARPA – Archeological Resources Protection Act
BGEPA – Bald and Golden Eagle Protection Act
BLM – Bureau of Land Management
CCC – Civilian Conservation Corps
cfs – cubic feet per second
CIR – crop irrigation requirement
Core Area – Sage-Grouse Core Area
cy – cubic yard
DDCT – Disturbance Density Calculation Tool
DEM – digital elevation model
EA – Environmental Assessment
EIS – Environmental Impact Statement
EOM – end of month
EPA – Environmental Protection Agency
ft-amsl – feet above mean sea level
FONSI – Finding of no Significant Impact
FWS – United States Fish and Wildlife Service
GIS – Geographic Information System
HAI – Hollingsworth Associates, Inc.
List of Acronyms (cont.)

HUC – Hydrologic Unit Code
IDF – Intensity-Duration-Frequency
Level I Matrix – Level I Study Reservoir Evaluation Matrix
Level I Study – Nowood River Storage/Watershed Level I Study
LTA – LTA, Inc.
ma – million years old
Matrix – Level II Reservoir Evaluation Matrix
MBTA – Migratory Bird Treaty Act
Spreadsheet Model – Wind/Bighorn River Spreadsheet Model
NAIP – National Agriculture Imagery Program
National Register – National Register of Historic Places
NED – National Elevation Dataset
NEPA – National Environmental Policy Act
NHPA – National Historic Preservation Act
NOI – Notice of Intent
NPDES – National Pollution Discharge Elimination System
NWI – National Wetlands Inventory
O&M – Operations and Maintenance
ORV – off road vehicle
ParsonsWater – ParsonsWater Consulting LLC
PMF – Probable Maximum Flood
Project – Nowood River Storage, Level II Study
RCC – roller compacted concrete
List of Acronyms (cont.)

RMEF – Rocky Mountain Elk Foundation

ROD – Record of Decision

ROW – right-of-way

sage-grouse – Greater Sage-Grouse

SBOC – State Board of Control

SGCN – Species of Greatest Conservation Need

SHPO – State Historic Preservation Office

SLIB – State Lands and Investment Board

SWAP – State Wildlife Action Plan

SWPPP – Stormwater Pollution Prevention Plan

Trihydro – Trihydro Corporation

USDA – United States Department of Agriculture

USFS – United States Forest Service

USDOC – United States Department of Commerce

USGS – United States Geological Survey

Watershed – Nowood River Watershed

WCCD – Washakie County Conservation District

WDEQ – Wyoming Department of Environmental Quality

WGFD – Wyoming Game and Fish Department

WPDES – Wyoming Pollution Discharge Elimination System

WQD – Water Quality Division

WSE – water surface elevation

WSEO – Wyoming State Engineer’s Office
List of Acronyms (cont.)

WWDC – Wyoming Water Development Commission

WWDO – Wyoming Water Development Office

WWPP – Wyoming Water Planning Program

WyGISC – Wyoming Geographic Information Science Center
1.0 INTRODUCTION

The Wyoming Water Development Commission (WWDC) contracted Trihydro Corporation (Trihydro) on June 3, 2010, to provide professional services for the Nowood River Storage, Level II Study (Project). The purpose of the Project is to explore opportunities to develop water storage within the Nowood River Watershed (Watershed) that will benefit Wyoming and its residents by addressing late-season water supply shortages evidenced within the Watershed. Trihydro, in association with Anderson Consulting Engineers, Inc. (ACE), ParsonsWater Consulting LLC (ParsonsWater), and Hollingsworth Associates, Inc. (HAI), modeled surface water shortage and availability, identified potential storage sites, and evaluated potential storage site characteristics to determine the most viable storage sites in the Watershed. The work was completed under the direction, and with the assistance of the Wyoming Water Development Office (WWDO). This report includes descriptions of the tasks completed during the Project and presentation of the results of hydrologic modeling and storage site evaluations.

1.1 PROJECT SETTING

A detailed description of the Nowood River Watershed is provided in Section 3 of the Nowood River Storage/Watershed Level I Study (Level I Study) Final Report, dated March 9, 2010. The Watershed covers approximately 2,012 square miles in north central Wyoming. The Watershed is located in parts of six counties (Washakie, Big Horn, Johnson, Natrona, Hot Springs, and Fremont), although the main portion of the watershed is located in Washakie (59%) and Big Horn (34%) counties (Figure 1-1). This area includes the eastern edge of the Big Horn Basin and the western slope of the Big Horn Mountains. Elevations across the Watershed range from around 4,000 feet at the Nowood River’s confluence with the Big Horn River at Manderson to approximately 13,000 feet in the Big Horn Mountains. The western and eastern sides of the Watershed differ significantly due to the influence of the Big Horn Mountains on the eastern side. These differences are evident in the precipitation ranges; 11 to 15 inches per year for the west side and 15 to 25 inches per year for the east side (Figure 1-2) (ACE 2010).

Lands within the Watershed are comprised of Bureau of Land Management (BLM) administered lands (49%), United States Forest Service (USFS) (16%), private lands (27%), and State of Wyoming lands (7%) (Figure 1-3). The remaining lands are owned or administered by the Nature Conservancy and the Wyoming Game and Fish Department (WGFD) (ACE 2010). Two towns, Ten Sleep and Hyattville, and a portion of a third, Manderson, are located within the Watershed. The Watershed lands are used primarily for agriculture, including irrigated crops and livestock grazing. Recreation, consisting of hunting, fishing, hiking, off road vehicle (ORV) use, and camping is also prevalent across the Watershed.
The Watershed experiences substantial spring runoff; however, these flows are not captured and water shortages occur during low-flow periods common in late summer and fall. There is a significant amount of irrigated area within the watershed, and the water shortages observed during the late season irrigation period result in fields that cannot be irrigated (ACE 2010).

1.2 PROJECT OVERVIEW

Concerns with late season water shortages and negative impacts to the Watershed were raised by a group of concerned, local landowners in 2007. These landowners formed the Proponents of Nowood Drainage Storage and requested funding for a watershed investigation. This group submitted an application for funding assistance to the WWDC in fall 2007. Their application was successful and the 2008 Wyoming Legislature awarded funding for the Level I Study. The Proponents of Nowood Drainage Storage formed a Steering Committee in January 2008 that also serves as the Project Sponsor.

In June 2008, the WWDC contracted ACE to complete the Level I Study. The purpose of the Level I Study was to evaluate and describe the Watershed and to develop a watershed management plan. The three primary issues evaluated as part of Level I Study, consistent with other WWDC watershed studies, were: 1) opportunities for surface water storage; 2) the state of, and possible improvements to irrigation infrastructure; and 3) opportunities to enhance upland water resources. Through the course of the Level I Study, ACE and the WWDC developed recommendations for irrigation system conservation and rehabilitation, livestock and/or wildlife upland watering opportunities, grazing management opportunities, other upland management opportunities, and stream rehabilitation. ACE also concluded that, due to the timing of flows in the watershed, late-season water shortages exist, but that water is available for storage during high, spring flows. ACE identified 35 sites that potentially could be developed as storage reservoirs to store available water during the spring and release flows later in the water year (ACE 2010).

Based on the initial findings of the Level I Study relative to potential late-season shortages and early-season water availability, the Project Sponsors (Steering Committee) completed an application for a Level II, Phase I feasibility study. This application was also successful and funding was approved by the 2010 Wyoming Legislature for the Nowood River Storage, Level II Study. The scope of this Project is focused on estimating potential water shortages, estimating flows available for storage, investigating and evaluating potential storage locations, and assessing the capability of the highest-ranked locations to meet water shortages and provide other Watershed benefits (e.g., reducing flooding potential or magnitude, reducing stream erosion, increasing late-season stream flows, enhancing habitat, and providing recreational opportunities, among others). Specific Project scope items include:
• Compile and review existing literature and hydrologic modeling results applicable to the study area, including the Level I Study and the Wind/Bighorn River Basin Plan.

• Develop, execute, and optimize a StateMOD hydrologic model, incorporating available water rights information on file with the Wyoming State Engineer’s Office (WSEO), to estimate stream flows and identify timing/locations of available water and timing/locations of shortages.

• Continue and expand on temporary stream gaging efforts undertaken in the Level I Study to support development and ground-truthing of the StateMOD model.

• Review the Watershed to identify additional potential storage locations not identified during the Level I Study.

• Evaluate the characteristics, potential impacts, and potential benefits associated with identified storage locations to rank the locations and identify locations warranting further investigation.

• Assess the geotechnical/geological conditions at select potential storage locations to support an alternatives analysis.

• Investigate documented or potential cultural/archaeological sites and their potential impact on the top-ranked storage sites.

• Compile a list of permits that could potentially be required for each of the top-ranked storage alternatives, identify possible environmental mitigation measures, and review threatened or endangered species potentially affected by the alternative sites.

• Develop information to form the basis of a Purpose and Need statement that will be used during future National Environmental Policy Act (NEPA) review activities.

• Prepare conceptual level designs and cost estimates for the top-ranked storage alternatives, including embankments, spillways, outlet works, other appurtenances, and diversion/delivery infrastructure.

• Complete a benefit-cost analysis for the top-ranked storage alternatives to assist in identifying preferred site alternatives.

1.3 PROJECT RESPONSIBILITY AND ACKNOWLEDGEMENTS

Jason Mead, P.E., served as the WWDO’s Project Manager and participated in all phases of the Project. Mike Besson, P.E., Deputy Director of the WWDO Dams and Reservoirs Division assisted with the Project and provided technical and procedural guidance throughout. Consulting work conducted for the Project was supervised by Trihydro’s Project Director, Joel Farber, P.E., P.G. Mr. Farber is also the Geologist of Record for this Project. The Project was managed by Trihydro’s Project Manager, Mark Donner, P.E., who served as the point-of-contact for the WWDO, and as the
Engineer of Record for this Project. Mr. Jay Schug of ACE assisted with project management, coordination with the WWDO, Project Sponsor, and landowners, and served as the liaison to work conducted during the Level I Study. Harold Hollingsworth, P.E. of HAI served as the Project’s geotechnical engineer, leading the geotechnical investigation tasks. Rick Parsons, P.E. of ParsonsWater served as the senior water resources engineer and led modeling of water shortages and availability. David Ward, P.E. formerly with Trihydro, Derrick Thompson, P.E. with Trihydro, and Travis Rounsaville, P.E. with ACE provided additional Project support and design services.

Members of the Steering Committee, who each donated personal time to advance the Project, include: Nancy Joyce, Martin Mercer, Terril Mills, Cecil Mullins, April Nelson, Terri O’Donnell, and Shane Starbuck. The Steering Committee provided input, background, coordination with local stakeholders, and support throughout the Project.

Others who provided valuable input to the Project include Dave Deutz with the WSEO Worland office, Craig Cooper with Cooper Consulting, Linda Hamilton with the South Big Horn Conservation District, Tori Dietz with the Washakie County Conservation District (WCCD), staff at the Worland BLM office, staff from the WGFD Cheyenne and Cody offices, staff from the United States Fish and Wildlife Service (FWS) Cody office, staff from the United States Army Corps of Engineers (ACOE) Cheyenne office, and Project stakeholders or landowners that attended Project meetings or completed Project surveys.
2.0 SUMMARY OF LEVEL I STUDY FINDINGS AND CONCLUSIONS

In March 2010, the Level I Study was completed on behalf of the WWDO by ACE with the assistance of Trihydro. The Level I Study consisted of a comprehensive, multi-disciplinary evaluation of existing Watershed conditions. Specific tasks in this effort included:

- Facilitate consensus building among the Steering Committee, landowners, and the WWDC.
- Facilitate public participation.
- Evaluate and describe the Watershed, including quantity and quality of surface water resources, and riparian/upland conditions.
- Evaluate the potential for storage to mitigate late season irrigation shortages and flooding during spring runoff.
- Conduct a geomorphic investigation of the primary channels within the Watershed and identify potential mitigation measures to improve impaired channel reaches.
- Inventory irrigation systems and develop a rehabilitation plan for those ditches interested in participating.
- Evaluate water storage needs and opportunities to augment water available for livestock and wildlife.
- Develop a watershed management plan that identifies problem areas within the Watershed and proposes practical economic solutions.
- Identify permits, easements, and clearances necessary to implement the watershed management plan.
- Develop cost estimates for improvements.
- Complete an economic analysis and evaluate alternative funding sources.

Landowners and stakeholders within the study area face several key issues related to water within the basin. The Nowood River generates a significant amount of runoff during the spring; however, shortages occur during late season, low-flow periods. There is a significant amount of irrigated area within the watershed, and the water shortages observed during the late season irrigation period result in non-irrigated fields. In addition, many irrigation ditches in the study area are in need of improvement. Grazing of livestock is also a primary land use within the study area, and often occurs on lands that also support riparian vegetation (ACE 2010).

Of specific interest to this Project are the results of the storage investigation completed during the Level I Study, which involved evaluating the potential for development of water storage opportunities to mitigate late season irrigation...
shortages. The objectives of that portion of the Level I Study were to: 1) evaluate the water storage needs and availability; and 2) identify and prioritize potential storage locations.

2.1 WATER STORAGE NEEDS AND AVAILABILITY

The Level I Study relied upon results of the Wind/Bighorn River Spreadsheet Model (Spreadsheet Model) developed as part of the Wind/Bighorn River Basin Plan (BRS 2003) for evaluation of water shortages and availability in the Watershed. The Wind/Bighorn Basin Plan and Spreadsheet Model were updated (2010 Wind/Bighorn Update) shortly following completion of the Level I Study (MWH 2010). A spreadsheet simulation model approach works well when constraints can be simplified and when a general understanding of water availability based on the physical amount of stream flow is required. The Spreadsheet Model was developed to be a planning tool for the Wind/Bighorn River Basin water users and the State of Wyoming. The Spreadsheet Model works well for planning; however, several limitations and their implications should be considered when using the Spreadsheet Model. The Spreadsheet Model approach does not explicitly account for legal and administrative constraints such as water rights, reservoir operations, river compact allocations, or the management of the basin’s water supply per these constraints. Often times the surface water systems or water rights are too complicated to be easily represented using a spreadsheet model. To gain a better understanding of local hydrology and its beneficiaries, a water right’s allocation model such as the State of Colorado’s StateMOD model should be used. StateMOD has the ability to not only quantify water shortages, but to also identify where in the watershed shortages occur and to what extent of time during the irrigation season.

To estimate the quantity of the physical water supply that might be available for storage at a given Spreadsheet Model node (Figure 2-1), available water was defined as that portion of the physically available stream flow that could be stored without causing a shortage to existing water users in any downstream river reach on the Nowood River or on the Bighorn River. In other words, the water available at a node was determined as the minimum of the physically available flow at that point or the minimum available flow at any node downstream in the system (including the Bighorn River). This evaluation was made on a water budget basis (inherent to the Spreadsheet Model) and did not directly incorporate individual water rights (ACE 2010).

Results of the availability analyses indicated that there likely are flows available for storage without incurring a shortage in downstream reaches, as summarized in Table 2-1 for modeled stream reaches within the Watershed or downstream on the Bighorn River. The total annual available flow for the entire Watershed (represented by Reach No. 800 in Table 2-1) is estimated in the Spreadsheet Model as over 316,000 acre-feet (ac-ft) for a normal (6 out of 10 years) condition and over 248,000 ac-ft for a dry (2 out of 10 years) condition. Review of the Spreadsheet Model
results indicate that the majority of available flows occur in April, May, and June, as would be expected in this hydrologic setting and consistent with the pattern of flows gaged during the Level I Study (ACE 2010).

Shortages estimated by the Spreadsheet Model are presented in Table 2-2. Review of the Spreadsheet Model indicated shortages occur on tributaries to the Nowood River under both the normal and dry year conditions. As estimated through the Spreadsheet Model, and substantiated by area landowners, shortages primarily occur during the late season irrigation months of August and September. Total shortages (demands) were estimated to be approximately 6,500 ac-ft and 10,200 ac-ft for the normal and dry year conditions, respectively (ACE 2010).

2.2 IDENTIFICATION AND EVALUATION OF POTENTIAL RESERVOIR STORAGE LOCATIONS
A total of 35 potential storage sites were identified during the Level I Study (Figure 2-2). These sites were collated from a variety of sources including:

- **Previous investigations**: Five previous investigations pertaining to the Nowood River and Bighorn River basins have been completed; four in the early 1970’s and one in 2007. These investigations included recommendations of potential reservoir locations throughout the Watershed. Many of the recommendations were identified in the early studies and repeated in subsequent studies. Nineteen of the 35 potential storage sites were identified in these studies.

- **Steering Committee and Public Input**: The Steering Committee and the general public directed the Level I Study project team to several potential reservoir locations based on their knowledge of local conditions.

- **Geographic Information System (GIS) Review**: Most of the remaining 16 sites were identified by the project team during the review of Watershed topography and hydrology within the GIS environment.

A wide array of relevant information was compiled for each site within a Level I Study Reservoir Evaluation Matrix (Level I Matrix), provided in Appendix A. The information included environmental characteristics, hydrologic characteristics, engineering characteristics, geologic characteristics, potential benefits, costs, ownership, and others. The Level I Study GIS was used to quantify many of the attributes associated with the sites. For example, quantification of irrigated acres and wetlands affected by each site were calculated in the GIS. Contributing watershed areas were delineated and their characteristics quantified using the GIS in conjunction with a digital elevation model (DEM).

The Level I Matrix was used to assign relative priorities to the sites. The priorities are listed below:
**Priority 1 Sites:** These sites represented the most potentially feasible of the sites evaluated and provided the most benefit at the least cost or environmental impact. These sites were recommended for further evaluation in future investigations. Seven sites were assigned a Priority 1 designation.

**Priority 2 Sites:** These sites, while potentially feasible, contained attributes making them less desirable for further study than the Priority 1 sites. For example, some sites showed potential benefits commensurate with Priority 1 sites but their costs were higher. Designation as a Priority 2 site was not intended to preclude potential sites from being included in future Level II, Phase I studies. Eleven sites were assigned a Priority 2 designation.

**Priority 3 Sites:** These sites contained either fatal flaws that eliminated them from recommendation for further study (e.g., location within the wilderness area), or other attributes causing them to be highly unlikely to be implemented. Seventeen sites were assigned a Priority 3 designation.

The 17 Priority 3 sites were eliminated from further consideration in the Level I Study for reasons as summarized in Table 2-3. Three of the sites were noted as being located within the Cloud Peak Wilderness area. These sites were identified prior to wilderness designation and continue to be mentioned in regional studies. Wilderness areas are protected from construction activities, consequently, permitting and construction of a reservoir in a designated wilderness area would require federal legislative action changing designation. Other sites did not possess the hydrologic conditions necessary to support a reservoir of even moderate size without pumping from alternative sources. Capital cost increases and, more importantly, operation and maintenance expenses associated with pump/storage alternatives often increase financial challenges; therefore, these sites were designated Priority 3. Geologic constraints were generally the reason the remaining Priority 3 sites were designated as such. For these sites, embankments were located on one or more undesirable bedrock formations (ACE 2010).

Designation as a Priority 1 or Priority 2 site during the Level I Study required more detailed comparisons. Several attributes could be quantitatively ranked for comparative purposes (e.g., potential wetland acres impacted, irrigated acres inundated, and costs). Other attributes required a qualitative comparison (e.g., geologic conditions and potential wildlife / fisheries impacts). Color coding in the Level I Matrix reflects the relative feasibility of several attributes. Green shading indicates attributes with favorable or minimal impacts, lower costs, or other beneficial attributes. Red shading indicates negative impacts, high costs, etc. Yellow indicates neutral attributes (ACE 2010).

After populating the Level I Matrix, a work session was conducted with the objective of assigning the relative priorities (Priority 1 or Priority 2) of the sites not screened as Priority 3 sites. The work session was attended by ACE and WWDO representatives. The results of the prioritization effort, listed in Table 2-4, were also presented to the Steering Committee for discussion and review. The seven Priority 1 sites listed in Table 2-4 were recommended for further
study and were evaluated in greater detail during the Level I Study. For each of the Priority 1 sites, conceptual designs and cost estimates were prepared. In addition, discussions of environmental considerations, permitting requirements, and benefits for each site were presented.

The late season shortages identified as part of the Level I Study, coupled with early season available flows, and feasible storage sites led the Project Sponsors and the WWDC to move forward with the Level II, Phase I Study.
3.0 PROJECT MEETINGS AND OUTREACH

The Level I Study indicated a potential need for water storage in the Watershed and identified potential storage sites. Hydrologic modeling completed as part of this Project confirmed the availability of water for storage in the spring and early summer, as well as late-season water shortages in the Watershed. The Project also confirmed the presence of feasible storage sites. While these are important components to the development of storage opportunities in the Watershed, the long-term success of the Project and development of storage will depend on the interest, backing, and support from Watershed stakeholders.

To this end, the Project team coordinated and participated in Steering Committee meetings, public meetings, and open house-style meetings in the Watershed during the course of the Project. The intent of these meetings was to inform stakeholders of the Project, apprise stakeholders of Project status and developments, and solicit input on the need for storage, potential storage sites, and acceptability of feasible storage sites. The Project team also undertook efforts to expand knowledge of the Project and input avenues for the stakeholders through public outreach efforts. These meetings and outreach efforts are discussed in more detail below.

3.1 STEERING COMMITTEE AND WATERSHED MEETINGS

The Project team coordinated and participated in five meetings and one open house (held concurrently in Ten Sleep and Hyattville) during the course of the Project. The public meetings and open houses were advertised in the Northern Wyoming Daily News, on Facebook, and via the Steering Committee. The meetings and specific topics addressed are listed below:

- **June 8, 2010 - Steering Committee Meeting at the Ten Sleep Senior Center:** This meeting was held prior to the public Scoping Meeting and served to introduce the Project team and Steering Committee members to one another. The Project objectives, communication approaches, status of small water projects, and importance of and mechanisms for soliciting public input on the Project were also reviewed during the meeting.

- **June 8, 2010 - Public Scoping Meeting at Ten Sleep Senior Center:** This meeting was conducted following the initial Project Steering Committee Meeting. The focus of the meeting was providing an overview of the WWDC Project process, reviewing the Level I Study, and outlining Project objectives. Specific meeting agenda items included introducing the Steering Committee and Project team members, reviewing the results of the Level I Study, reviewing the small water program, outlining the Project objectives, and emphasizing the need for input.
3.2 PUBLIC OUTREACH

An area of emphasis early in the Project was increasing public awareness of the Project, especially within the Watershed, and providing multiple avenues for interested parties to gain information about the Project and/or to provide input. Public outreach was a central topic during the initial Steering Committee and Scoping meeting. Several approaches were discussed during these meetings and amongst the Project team. Suggested approaches included, among others, increasing advertising prior to Watershed meetings, changing the structure of meetings, sponsoring a
booth at local events, using social media, and various forms of mailings or surveys. A listing of community groups, events, and possible social media options are provided in Appendix B1.

Each of these approaches was used in some fashion to increase public awareness.

- **Project website** - ACE created a Project website (http://www.acewater.com/nowood.htm) during the Level I Study. This website was maintained for the duration of the Project to provide access to the Level I Study and to allow other Project-related information to be posted in a location that was accessible to the general public. This website is no longer active.

- **Project Direct** - Trihydro has developed a proprietary web portal (Project Direct) to allow project information to be shared in a secure manner. A site was added to this web portal for the Project. While this site is secure and not accessible to the general public, it is accessible to the Project team, WWDO, and the Steering Committee. Project-related documents and meeting information were maintained on this site.

- **Facebook** - Based on suggestions during the initial Steering Committee and Scoping meetings, a Project Facebook page was created. The page is accessible by logging into Facebook and searching for the Nowood River Storage, Level II Study Group. This page allowed Project team members and Steering Committee members to post project updates and provide informal information regarding the Project in a format that was widely accessible. Interested parties were also able to post questions, provide input, or upload photos on the page. A Facebook update in 2011 altered the format of the Facebook Groups and required members to re-enroll with the Group. Most members did not re-enroll. Local stakeholders have since created a new Facebook Group – the Nowood Watershed Study, which can be accessed by logging into Facebook and searching for Nowood Watershed Study. A Tech Memo providing additional background on the structure of the Facebook group and outlining other Facebook options considered before establishing the Group is provided in Appendix B2.

- **Project Survey** - A project questionnaire was developed and mailed to landowners and stakeholders in the Watershed during the Level I Study. Unfortunately, response to the questionnaire was limited, with 20 out of the 140 surveys that were sent out being returned with comments (ACE 2010). Despite the low response to the Level I Study questionnaire, a Project Survey was undertaken in an attempt to garner information from stakeholders. Surveys can provide a good route for interested parties to anonymously provide input or for interested parties that have conflicts with public meetings to provide input.

Considering the low response to the Level I Study survey, the Project team attempted to develop the survey in a manner that would increase responses. The survey was targeted at a specific response, questions were multiple choice so that respondents would not be required to write out answers, and the number of questions was limited to reduce the time required to complete the survey. The survey, titled “Stakeholder Survey: Reservoir Storage –
Purpose and Need,” was devised to solicit input that ties directly to the purpose and need for constructing storage in the Watershed. A blank survey form is provided as Appendix B3.

The delivery method for the survey was also changed in an attempt to increase response. Rather than sending out mailings to individual residences, hardcopy surveys were placed, along with drop boxes, in locations around the Watershed. Surveys were placed in the Hyattville Café, the Crazy Women Café in Ten Sleep, at the WCCD, and at the South Big Horn Conservation District. Copies of the survey were also available at the open houses in Hyattville and Ten Sleep on September 14, 2010. In addition to hard copies, the survey was also available on the web via the Survey Monkey site (www.surveymonkey.com). The survey and link to Survey Monkey was also noted on the Project Facebook page.

Unfortunately, even with the efforts described above, responses to the survey were limited. A total of 13 hard copy surveys were placed in drop boxes or completed at the open houses and 2 surveys were completed online. A summary of the survey responses is provided in Table 3-1. Completed surveys are provided in Appendix B4. Names, if provided on the surveys, have been removed for the privacy of the respondents.

- **News Coverage** - Two articles were written by the Northern Wyoming Daily News during the course of the Level II, Phase I Study. The first article provided coverage of the June 2010 Scoping Meeting and was published on June 11, 2013. The second article provided coverage of the November 2012 results meeting and was published on November 3, 2012. These articles can be located by searching the archives portion of the Northern Wyoming Daily News website (www.wyodaily.com). This site can also be used to search for articles covering the Level I Study.

### 3.3 PROGRESS MEETINGS

Progress meetings and conference calls between the Project team and the WWDO were held at regular intervals during the Project. The purpose of these meetings was to review Project status, discuss preliminary findings, outline upcoming Project tasks, and prepare for public or Steering Committee meetings. Meeting topics for formal project status meetings are summarized below.

- **August 16, 2010 - Project Status Meeting:** Discussions during this meeting focused on new potential storage sites identified, reviewing and reducing the long list of potential sites, facilitating public involvement, and which sites would be included in the geotechnical/geologic site visits.

- **May 20, 2011 - Project Status Meeting:** Discussions during this meeting focused on reviewing the status of the StateMOD model and feedback received on the preliminary model results from the Steering Committee during the April 2011 Steering Committee Meeting. The Project Team decided to have Craig Copper of Cooper Consulting perform a preliminary review of the StateMOD model inputs and results. Other items discussed included
alterations to the scope of individual task items, continuing temporary stream gaging for the 2011 water year, and discussions of the ten, top-ranked potential storage sites.

- **June 24, 2011 - Project Status Meeting:** Discussions during this meeting focused on Cooper Consulting’s review of the StateMOD model inputs and preliminary results, and coordinating contacts with landowners associated with top-ranked sites.

- **September 12, 2011 - Project Status Meeting:** Discussions during this meeting focused on the status of the Steering Committee’s Level II, Phase II application and remaining Phase I work. Feedback from landowner contacts were also discussed, as was moving forward with obtaining agency input of the top-ranked sites, and the status of conceptual designs.
4.0 LITERATURE REVIEW AND GIS DEVELOPMENT

4.1 LITERATURE REVIEW

Documents and models pertinent to the Project were reviewed as part of the Level I Study. As the core Project team members remained consistent from the Level I Study through this Project, literature that was reviewed under the Level I Study was not reviewed again. Rather, the Level I Study was reviewed and used as a synopsis of previous literature, investigations, and models pertinent to the Watershed. The Level I Study was also reviewed for investigations, mapping, data, and recommendations developed as part of that study that are directly applicable to the Project.

Specific Project tasks such as development of the StateMOD hydrologic model, assessment of potential Greater Sage-grouse (sage-grouse) disturbance, and evaluation of cultural concerns required review or reference to specific literature, mapping, or models beyond or in more detail than was included in the scope of the Level I Study. These references are cited as appropriate in relevant sections of this Report. A general listing of these documents includes:

- Level I Study Final Report
- 2010 Wind/Big Horn Basin Update and Spreadsheet Model (MWH 2010)
- Tabulation of Adjudicated Surface Water Rights of the State of Wyoming, Water Division Three (WSEO 1999)
- Tensleep Reservoir (Meadowlark Lake) Application for a Permit to Construct, dated November 30, 1938; and accompanying map, dated September 30, 1938
- Tensleep Reservoir (Meadowlark Lake) Order Record 10 of the State Board of Control, dated May 15, 1939; and Certificate of Construction of Reservoir, dated December 19, 1939
- WSEO Contact Report, dated August 19, 1992 summarizing a WSEO inspection of repairs to the Tensleep Reservoir embankment
- WGFD rough bathymetric data and mapping for a May 26, 1991 sounding survey of Meadowlark Lake
- Density and Disturbance Calculation Tool (DDCT) Manual (BLM 2011)
4.2 GIS DEVELOPMENT AND MANAGEMENT

A comprehensive GIS was developed for the Watershed as part of the Level I Study. A GIS is a powerful tool that allows for the compilation and presentation of large amounts of spatial and tabular data. A GIS can also be configured to include additional project information such as photographs and documents. Compilation of this data, coupled with GIS tools, allows users to efficiently evaluate and compare project data. The GIS also allows effective presentation and comparison of results. The background and development of the GIS is discussed in the Level I Study Final Report (ACE 2010).

The GIS developed through the Level I Study continued to be used and expanded during the Project. Statewide data layers were updated, as appropriate, and additional data specific to Level II tasks were obtained or generated during the Project. The GIS serves as the means for housing the majority of the Project data and was used extensively in evaluating potential storage sites and refinement of the evaluation matrix. The Project Team also used the GIS to develop many of the inputs for the StateMOD model. As with the Level I Study, the figures generated for this Report, with the exception of the conceptual design sheets, were prepared using the GIS. The GIS was also used to generate maps and figures to support Project Meetings and requests to agencies for input on the Project.

Data incorporated in the GIS is summarized in Table 4-1. This table includes delineation of data compiled during the Level I Study, data updated during this Project, and data created or added during this Project. As noted in the Level I Study, users of the GIS developed for the Project should understand that much of the data included in the GIS is frequently updated by the agencies that developed the data. These data layers should be updated in the GIS, as appropriate, to allow for the most current data to be used as the Project progresses, or for other projects that build off information gathered during the Level I and Level II studies.
5.0 ACCESS

As described in Section 1.1 and shown on Figure 1-3, a large majority (72%) of lands within the Watershed are managed by federal agencies or the State of Wyoming. Private lands comprise approximately 27% of the Watershed. Landownership layers and landowner names and addresses are included within the GIS. This information was obtained from the BLM Master Title Plats, the Washakie County Assessor’s Office, and the Big Horn County Assessor’s office. This information, especially private landownership, is subject to continuous change and was checked when contacting landowners.

5.1 ACCESS PERMISSION

Private landowners and associations were contacted to obtain permission for access, as appropriate, for field activities during the Project. Field work was not performed on lands for which access permission was not granted.

5.2 INTEREST IN POTENTIAL STORAGE SITES OR APPURTENANCES

Landowners or lessees owning or leasing lands encompassed by the top-ranked potential storage sites’ embankments, reservoir pools, spillways, or proposed feeder canals were contacted to discuss their interest in the potential reservoir sites. Some landowners were contacted or provided input during the Level I Study. For some sites, this input resulted in the site being ranked as a low priority (Priority 3) site in the Level I Study Final Report.

Landowners or lessees for the top-ranked sites were contacted in latter stages of the Project, after the full list of storage alternatives was developed and the Level II Reservoir Evaluation Matrix (Matrix) was updated based on preliminary results from the StateMOD model and revisions to site configurations. This precluded contacting multiple landowners for sites that eventually dropped in priority due to physical, hydrologic, or environmental constraints. However, this approach resulted in several top-ranked sites being dropped from consideration late in the Project.

The landowners or lessees were contacted in order of apparent storage alternative impacts. In other words, landowners with structures that would be impacted were contacted prior to landowners with pasture that would be impacted; or landowners with larger ownership percentages within the footprint of the potential storage site were contacted prior to landowners with smaller ownership percentages. If the primary landowner indicated they were not interested in the potential storage site being located on their lands, then the remaining landowners were not contacted. In some cases, landowners were willing to allow the Project team to perform site investigations or stream gaging, but were opposed to construction of a reservoir or feeder canal across their property. Three of the sites (Cornell Gulch, Lower Brokenback, and West Fork Willow Creek) were removed from consideration late in the Project, but prior to landowners being contacted.
6.0 HYDROLOGIC ANALYSIS

The Level I Study concluded that there likely is flow available for storage within the Watershed without impacting downstream river reaches and that shortages are incurred in the Watershed. As discussed in Section 2.1, available flows appear to occur in the spring and early summer, while shortages typically occur in the latter half of the irrigation season. As previously discussed, available water can be defined as that portion of the physically available stream flow that could be stored without causing a shortage to existing water users in any downstream river reach on the Nowood River or on the Bighorn River. The Level I Study assessment of available flows and shortages were based largely on the results of the 2003 The Wind/Bighorn Basin Plan and Spreadsheet Model and input from local irrigators. The Spreadsheet Model used in the Level I Study does not explicitly account for water rights, reservoir operations, compact allocations, or the management of the basin water supply based on legal constraints (ACE 2010). More comprehensive hydrologic analysis was undertaken during the Project to validate and expand on the Level I Study findings, and to allow for evaluation of potential storage sites under Wyoming Water Law.

The purpose of the hydrologic analysis is to develop a water allocation model capable of reasonably forecasting the water supply physically and legally available for development in the Watershed. Legally available flows are defined as that portion of the physical supply not getting called downstream to a senior water right. The water allocation model is also important for enhancing understanding of the water shortages that may be served by a particular reservoir storage alternative or combination of storage alternatives. An important consideration is the variability of physical and legal supply of water by time, season, and location across the Watershed. The natural water supply in the Watershed is a complex system; the reason why a model is employed to understand the system variability by location within the Watershed and season.

Understanding the water supply hydrology of the Watershed and the water use practices employed by irrigators is fundamentally important to developing an allocation model capable of forecasting opportunities for developing reservoir storage for beneficial use. The model platform selected for application to this Project is StateMOD. StateMOD is an abbreviation that stands for the State of Colorado’s Stream Simulation Model. StateMOD is a generic water allocation and accounting program (i.e., computer program) that is used to simulate the distribution of a natural water supply over space and time. The application of the StateMOD program to model water supplies in Wyoming is appropriate because the program is well suited for simulating the appropriation (i.e., regulation) of water under Wyoming water law.
6.1 WATER ALLOCATION MODELING

A basic appreciation of the underlying modeling concepts and the work flow, or process, followed to develop the StateMOD Model for the Watershed is important to understanding the results of the study. StateMOD is not a physically based hydrologic model. In other words, StateMOD does not generate stream flow data based on the input of precipitation data and information regarding the physical characteristics of the watershed. Rather, StateMOD simulates hydrologic conditions through a specified period based on input of historic records of stream flow, diversions, and storage within a watershed. StateMOD provides generalized computer code that is then tailored to simulate the specific uses of water in a particular hydrologic system. In the case of this Project, records of stream flow, diversions, and reservoir storage available for the period from 1973 through 2008 were used to develop the StateMOD model for the Watershed.

6.1.1 STATEMOD MODEL DEVELOPMENT

The initial structure for the StateMOD model was developed based on the 2010 Wind/Bighorn Update and Spreadsheet Model, as well as data collection and analyses from the Level I Study. Initial development of the StateMOD model included developing the model network, incorporating gage data, diversions, reservoirs, and instream flow reaches, and establishing operating rules. The development process and model components, as well as a discussion of appropriate input data, are discussed in detail in the August 10, 2010 Tech Memo included in Appendix C1.

In order to model Watershed hydrology, the available data on water resources and water use has been compiled within both a GIS database of the Watershed, which is used to create the Watershed figures in this report, and within input files needed to execute the StateMOD model. The information compiled for the Watershed includes the **bolded items** described below. These items and the approach for obtaining the data are described in detail in the April 13, 2011 Tech Memo provided in Appendix C2. Figure 6-1 is a network diagram of the StateMOD model developed for the Watershed. The diagram provides a framework of the input data compiled for the watershed.

- **Gage stream flow** was compiled for seven historical stream gages established by the United States Geological Survey (USGS) at the locations shown in Figure 6-2. The Nowood River near Ten Sleep gage is the only location with gage records during the study period from 1973 to 2008. However, this gage did not include complete records for the entire study period. An extensive hydrologic analysis was performed to understand the correlation of measured flows at this gage with other available hydrologic data in the region. Based on this analysis, missing data for the Nowood River near Ten Sleep gage was developed using correlation with annual precipitation data from the Black Mountain climate station. The Black Mountain climate station is located approximately 30 miles southwest of Ten Sleep in the Kirby Creek drainage, which is adjacent to the Watershed. This station was also used to in fill missing data in the 2010 Wind/Bighorn Update and resulted in the best correlation factors. Monthly stream flows
were estimated from this correlation based on historical pattern of stream flow at the gage for the years when stream flow was recorded. The remaining six stream gages were filled using monthly regressions and associated hydrologic analyses for regional gages or the Nowood River near Ten Sleep gage. Thus, monthly time series of stream flow for the period of study were estimated for each of the seven gage locations in the watershed.

Temporary stream gages have been established at a number of sites (Figure 6-2) across the watershed to gather additional stream flow data on un-gaged streams located in the vicinity of potential reservoir storage locations. The recorded gage data is being used to better constrain hydrologic inputs and regressions in the StateMOD model. A description of the stream gages and the data collected is provided in Section 6.3.

The WSEO installed five, permanent stream gages in the Watershed in 2011. The period of record for these gages is short and does not overlap with the StateMOD model study period. However, they may be used, similar to the temporary stream gages, to constrain hydrologic inputs in future Project phases. These new gages are also shown on Figure 6-2.

- **Stream flow diversions** and associated **water rights** were compiled across the Watershed. A spreadsheet compilation of water rights developed during the Level I Study was initially translated into the GIS database. The water rights were verified using the records of the WSEO, including information compiled during the General Adjudication of the Bighorn River basin. Active points of diversion associated with water rights of record within the Watershed are shown on Figure 6-3. A total of 333 direct flow diversion rights with priorities prior to March 1, 1945 are included in the StateMOD model. Likewise, a total of 39 direct flow diversion rights with a post March 1, 1945 / pre March 1, 1985 priority are input to the model. Two existing storage reservoirs, Meadowlark Lake and Carothers Lake, were also input to the model. The physical capacity of ditches or other facilities used to convey a water right is not presently used to limit diversions simulated by the model. As pertinent information regarding ditch capacity and operational limits becomes available, it may be input to the model to further constrain simulated water delivery to a particular appropriation.

- Monthly estimates of historical diversions input to the model are based on spot data available from WSEO hydrographer’s reports and estimates of water supply-limited historical diversions. The water supply-limited diversions are estimated based on irrigated acreage, calculated crop irrigation requirement (CIR), and estimated system efficiencies.
  - An inventory of irrigated lands and associated crop types within the watershed are identified in the StateMOD model. The irrigated lands are also linked to the water rights tabulated in the GIS, whereby the priority of each diversion in the Watershed is established. Mapped irrigated acreage within the Watershed is shown on Figure 6-3. The irrigated acreage associated with water right permits in the Watershed totals
approximately 27,821 acres. Crop types were established based on satellite imagery, the location of the irrigated parcels within the watershed and communication with project stakeholders.

- Estimates of the CIR for irrigated lands and crop types are based on the modified Blaney-Criddle method and average monthly temperature and precipitation data for the Big Horn basin available from the Western Regional Climate Center (http://www.wrcc.dri.edu/summary/Climsmwy.html). The annual CIR for pasture grass over the study period ranged from 1.38 to 2.20 feet of water, with an average CIR of 1.77 feet.

- **System efficiencies** are a measure of the difference in the amount of water diverted from a stream versus the amount of water used by the crop. Such factors as ditch losses between the stream diversion and crop fields affect the system efficiency. In other words, the system efficiency is a measure of the losses to the stream system as a result of irrigation. For purposes of modeling, the system efficiency is calculated as the CIR divided by the diversion, with a maximum limitation based on the efficiency that can practically be achieved based on the method of irrigation. A monthly time series of system efficiencies, ranging from 20 to 44%, were applied in the StateMOD model (discussed in greater detail in the Stage 2 StateMOD model Memo, Appendix C2).

- The **tributary stream flow** of the streams tributary to the Nowood River, and that have established water rights, are incorporated in the StateMOD model. Stream flows to un-gaged tributaries are estimated using the “gain approach” or the “neighboring gage approach,” in which natural flows estimated at stream gage locations are distributed to upstream tributaries based on measured drainage area and average annual precipitation.

- **Return flows** from applied water that is not consumed by plants or evaporation are also incorporated into the model. The amount of return flows are based on monthly diversion multiplied by (1 – monthly efficiency) and routed to different locations throughout the model. Return flow locations were determined using the Basin Adjudication Maps, 2010 Spreadsheet Model assignments, and visual review using GIS.

### 6.1.2 BASELINE MODEL SCENARIO

An important first step in the development of a StateMOD model is to understand the hydrology of the Watershed absent the influences of man. To develop a simulation for natural flows, available records are used to recreate the stream flows as if no diversions or other uses of the water, including reservoir storage, had been made during the study period. The natural flow hydrology for the Watershed was modeled in StateMOD by accounting for flows during the gage record at each gage, adding the difference between upstream diversions and return flows, and accounting for the impacts of reservoirs. Two existing reservoirs (Carothers Lake and Meadowlark Lake) were included in the StateMOD model. These two reservoirs were assumed to be full every month during the study period to allow calculation of natural flows. Natural flows at gage locations were then distributed to upstream, un-gaged locations.
The Baseline Model Scenario incorporates the natural flows with water rights and demands to model available flows and shortages during the study period. The Baseline Model Scenario encompasses a 36-year study period (1973-2008), which takes in a broad range of hydrologic condition, including drought years and years with abundant water supplies. By modeling direct flow rights to meet historical irrigation demand over the study period, this model scenario provides an understanding of available water and shortages across the Watershed through time. The physical and legal availability of water estimated using the StateMOD model varies from year to year during the study period.

Development of the Baseline Model Scenario is described in the April 13, 2011 Tech Memo in Appendix C2 (Note: numbers presented in this Tech Memo were refined during the course of the Project; values presented in this report differ slightly from values in the Tech Memo). Graphic synopses of the results from the Baseline Model Scenario are shown on Figure 6-4 (simulated available flows) and Figure 6-5 (simulated shortages).

Available flows were simulated for 22 Priority 1 and Priority 2 potential storage sites throughout the Watershed in the Baseline Model Scenario. Pie chart symbols shown on Figure 6-4 at potential storage locations depict the seasonal timing of available flows. On average, most of the water is available early in the season, during the peak snowmelt runoff that typically occurs in late May through June. Only a limited water supply is available for diversion across the Watershed later during the irrigation season. There is potential to use winter flows to fill or partially fill potential storage sites, however this option was not considered due to typically lower flows and potential fisheries issues. The potential for using winter flows will be evaluated further during future Project phases.

As depicted on Figure 6-5, many areas of the Watershed are short of the needed supply of water during the late irrigation season (i.e., August and September). Water shortages quantified using the model are depicted for various stream reaches in Figure 6-5 using pie chart symbols, similar to Figure 6-4. These pie charts illustrate the seasonal timing of the shortages simulated by the model. Bar charts showing demands and shortages by drainage are provided in Appendix C3.

Review of the Baseline Model Scenario simulations indicates that the total Watershed demand for water during the irrigation season (April-October) in a year with average hydrologic condition is approximately 146,000 ac-ft. Of this total demand, the annual shortage is estimated to be approximately 10% (15,151 ac-ft) in an average year. In a dry year, the model estimates a water shortage of 12% (16,990 ac-ft) of the demand in the Watershed. The results from the model substantiate information regarding water shortages that has been provided by local stakeholders during the course of Level I and Level II studies. Shortages are concentrated in the upper portions of the Watershed above Tensleep Creek (an estimated shortage of approximately 6,471 ac-ft or 43% of the total shortage) and along Paint Rock Creek (5,647 ac-ft or 37% of the total shortage).
Available flows are summarized on Figure 6-4 for potential reservoir sites advanced for additional study. These reservoir sites were selected based on the total basin shortage estimated with the Baseline Scenario Model and the feasibility of storage at these locations reducing or potentially eliminating shortages throughout the Watershed. Reservoir sites located in the Paint Rock Creek drainage and those located in the upper Nowood River drainage appear to have the greatest potential to offset shortages throughout the Watershed. The potential benefits of storage at the sites that were evaluated with the StateMOD model, also considered the potential to exchange water. The model simulations for selected reservoir sites to evaluate needed storage supply to offset shortages identified in the Baseline Model Scenario are discussed in greater detail in Section 12.

6.1.3 MODEL VALIDATION

A third party peer review was performed to validate the StateMOD model and data inputs for the Baseline Model Scenario. It is important to recognize the StateMOD model follows a strict application of prior appropriation doctrine (Wyoming Water Law). Thus, the results from the model analysis may not necessarily correlate well with the historical record, particularly during water short years. Because of the potential disparity between model predictions and the expectations of stakeholders based on their observations and understanding of the watershed, Mr. Craig Cooper of Copper Consulting was engaged to review the StateMOD model and data input.

Mr. Cooper served on the Wyoming State Board of Control (SBOC) as the Division III Superintendent from 1981 to 2002. In that capacity, Mr. Cooper was responsible for the administration of water in the Watershed. He is intimately familiar with the water resources and historical administration in the Watershed. Following his review, Mr. Cooper indicated that the hydrologic input to the model is credible and confirmed the WWDC’s efforts to augment the database with stream flow data collected with temporary gages is sensible. He indicated the model reasonably represents the irrigated acreage and associated diversion infrastructure in use in the Watershed. Mr. Cooper also provided direction on changes to the cropping patterns simulated in the model needed to accurately reflect CIR above the confluence of the Nowood River with Paint Rock Creek. He provided insights on the practical outcome of the regulation of junior water rights and clarification on the water right and source of supply for several appropriations accounted in the Model. In summary, Mr. Cooper validated the structure and approach implemented in the StateMOD model. Mr. Cooper’s review is summarized in his June 27, 2011, which is included in the Project Notebook.

Mr. Cooper’s suggested revisions to the StateMOD model inputs and operation were incorporated and are represented in the model results presented in Section 6.1.2. Revisions to the Baseline Model Scenario are outlined in March 11, 2013 Tech Memo provided in Appendix C4.
6.1.4 SUMMARY FINDINGS AND CONCLUSIONS FROM STATEMOD MODELING

The StateMOD model for the Watershed provides a realistic simulation of the hydrologic characteristics of the Watershed. The model will continue to be refined based on new hydrologic data collected from temporary gage installations being maintained at location across the Watershed (Section 6.3), as well as information from other sources, such as the WSEO.

Based on an independent third party review, the StateMOD model of the Watershed is a reliable simulation tool capable of quantifying water availability and water supply needs across the Watershed. Thus far in the study, the model has also proven to be applicable for environmental evaluation and comparison of alternative surface water development opportunities to address seasonal shortages of irrigation supply (Section 12).

6.2 YELLOWSTONE RIVER COMPACT

The Nowood River is tributary to the Bighorn River, which in turn is tributary to the Yellowstone River in Montana. Wyoming’s use of water in the Bighorn River drainage is administrated by the Yellowstone River Compact. The Yellowstone River Compact was ratified in 1950 by the states of Wyoming, Montana, and North Dakota and provides a framework agreement for the allocation of the water tributary to the Yellowstone River among the states.

The Compact recognizes water rights on tributaries to the Yellowstone River existing as of January 1, 1950. Water that remains unappropriated after the needs of existing rights are fulfilled is allocated to Wyoming and Montana on a percentage basis. In the Bighorn River basin, 80% of the unused, unappropriated flows are allocated to Wyoming.

The water resources in the Watershed are available for appropriation under Wyoming’s allocation in the Yellowstone River Compact. Water available to Wyoming under its allocation is estimated for dry, average, and wet year hydrologic conditions in the 2010 Wind/Bighorn Update published in 2010 by Montgomery Watson Harza (MWH 2010). The estimates were derived using gage flows published by the USGS and the Spreadsheet Model to calculate unallocated flow under the three hydrologic conditions. The amount of water estimated to be available for appropriation under Wyoming allocation is presented in Table 6-1.
TABLE 6-1. AVAILABLE WATER UNDER WYOMING’S ALLOCATION IN THE
YELLOWSTONE RIVER COMPACT

<table>
<thead>
<tr>
<th>Calculation</th>
<th>Overall Average</th>
<th>Dry Condition</th>
<th>Avg. Condition</th>
<th>Wet Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wyoming Allocation</td>
<td>1,859,450</td>
<td>1,077,644</td>
<td>1,957,530</td>
<td>2,396,058</td>
</tr>
</tbody>
</table>

Adapted from Table 60 Wind-Bighorn Plan Update (MWH 2010)

Although the Spreadsheet Model used in the 2010 Wind/Bighorn Update to estimate unappropriated flows available under Wyoming’s allocation does not explicitly account for water rights administration, as is completed in the Watershed StateMOD model, it does account for the available supply based on the physical amount of water available at specific locations across the basin less downstream demands. Based on historical gage flows and diversion records, the Spreadsheet Model used in the 2010 Wind/Bighorn Update provides a realistic estimate of the water available to Wyoming under the Yellowstone River Compact.

Additional information regarding the provisions of the Yellowstone River Compact and its administration is available from the USGS at [http://yrcc.usgs.gov/index.html](http://yrcc.usgs.gov/index.html).

The administration of the water rights in the Watershed is performed by the SBOC in Riverton, Wyoming. Questions regarding the administration of water rights may be directed to the SBOC.

6.3 TEMPORARY STREAM GAGING

Temporary stream gages were installed throughout the Watershed during both the Level I and Level II studies to gather stream flow data for a network of un-gaged streams located near potential reservoir storage sites. The recorded gage data was used to better constrain hydrologic inputs and regressions in the StateMOD model. Four temporary stream gages were originally installed during the Level I Study by ACE, as follows:

- Brokenback Creek – a small perennial stream tributary to the Nowood River downstream from Tensleep. Stream flow is strongly influenced by snowmelt runoff and irrigation diversions.
- Buffalo Creek (Bruner Gulch) – an intermittent stream tributary to the Nowood River. The drainage area to this stream encompasses approximately 170 square miles in the southwest portion of the Watershed. The gage was
installed on this tributary to characterize ephemeral runoff where the site for a potential off-channel reservoir was identified.

- Big Cottonwood Creek – an intermittent stream tributary to the Nowood River in the lower (downstream) portion of the Watershed. Similar to Buffalo Creek, the Big Cottonwood Creek drainage encompasses an expansive portion of the west side of the Watershed, which has a lower elevation and contributes significantly less runoff than the eastern side of the Watershed.

- Otter Creek – a perennial tributary to the Nowood River. A temporary gage was established on Otter Creek to gather hydrologic data on a mid-sized stream sourced by runoff from the east side of the Watershed along the Bighorn Mountains

Information about these gages can be found in the Level I Study report.

A total of eleven temporary stream gages were installed during the Level II study (Table 6-2). The locations of the temporary stream gages and their respective periods of records are shown on Figure 6-2 and were established based on several criteria:

- Interest in storage alternative locations
- Locations of previously operated USGS gages
- Locations of temporary gages installed during the Level I Study
- Land ownership and access to gage sites
- Input from local stakeholders
- Opportunity to validate the statistical regressions used to develop hydrologic data for input to the StateMOD model

Each temporary stream gage was constructed with a datalogger and submersible pressure transducer combination (WL-16 Water Level Logger developed by Global Water Instrumentation, Inc.) designed for remote monitoring and recording of water level or pressure data. The gage combination was installed in a rugged PVC housing fabricated onsite so that the pressure transducer was established within the channel at low flow. The gages were installed and removed seasonally over a 2-year period beginning in 2010. Gages were installed in the spring once the winter ice had melted, and to the degree feasible, before spring runoff. The gages were left to record through the summer and fall months and then removed prior to winter freezing to limit damage to the gages.
The installed pressure transducers record water depth at the gage locations based on pressure readings. These depths are then correlated to measured flows to allow development of a rating curve. Once a rating curve is developed, flows can be calculated for each water depth recorded at the stream gage location. Developing the rating curve for each gage location requires that both the flow and the channel geometry be measured. Stream cross section surveys and flow measurements at each gage location were completed concurrent with the installation. A hydraulic model was used to establish the relationship between the water stage measured by the pressure transducer and the stream discharge. Stream flows were measured periodically during the season the gages were installed to calibrate the rating curve with measurements for a variety of flow conditions (i.e., discharges). The stream flow hydrographs presented in this report were developed using the rating curves established for each temporary gage site. The master temporary stream gage data set is included in electronic format (on CD only) as Appendix D.

Additional information regarding the layout and basis for each of the temporary stream gage sites selected for this Project follows.

### 6.3.1 ALKALI CREEK

The Alkali Creek stream gage is located along Alkali Creek and was first installed in June 2010. The stream gage was re-installed during the 2011 and 2012 (Level II, Phase II) field seasons. This gage location was identified to provide direct flow data for a potential off-channel reservoir (Alkali Creek) that would primarily be filled with water diverted from Paint Rock Creek and Medicine Lodge Creek via the Anita Ditch. The potential dam and reservoir site is located on Alkali Creek downstream of the gage location.

When compared to the StateMOD baseline simulated flows, the estimated physical flow is underestimated in the stream. The model estimates an average flow during the period of May through October of 1.4 cubic feet per second (cfs). The 2010 and 2011 temporary gage results estimate the average flow during the same time period to be approximately 2.5 cfs (1.3 cfs if 2011 major outliers are removed); a difference of approximately 1.1cfs; or 67 ac-ft per month. To improve the accuracy of the StateMOD model, additional field data will continue to be collected and input into the model. The hydrograph for the Alkali Creek temporary stream gage is provided in Figure 6-6.

### 6.3.2 ANITA DITCH

The Anita Ditch gage was installed during the second year of the Project on April 20, 2011, and removed in October 20, 2011. The gage was also re-installed during the 2012, Level II, Phase II field season. The Anita Ditch gage was installed to estimate the amount of flow passing through the ditch during the irrigation season and to provide constraints for a major point of diversion in the StateMOD model. The Anita and Anita Supplemental Ditches could
serve as diversions from both Medicine Lodge Creek and Paint Rock Creek to supply the proposed Alkali Creek storage location.

As expected, the ditch operates during the summer and fall months (May through October). Flows through the ditch ranged from an average in May of 6 cfs to a peak of approximately 50 cfs (a reading of 69 cfs was observed in October, however it was considered to be an outlier due to a possible error in the gage or debris/moss buildup) in September (Figure 6-7). The total runoff through the ditch during the study period was approximately 7,710ac-ft. It is important to note that errors can be associated with the gages due to variables such as weather, livestock, human error, etc. and the flow data presented should be interpreted as estimates. When compared to the StateMOD simulated flows, the timing of the model to engage the ditch is early during an average year. According to the temporary stream gage data the ditch is primarily used from the middle of June to the end of October. However, the StateMOD model shows higher flows between April and July for an average year. The diversions measured during 2011 may not be representative of typical irrigation practices, given the abundant water supply that year. Additional data was collected under the Level II, Phase II Study in 2012 and 2013 to better calibrate the StateMOD model.

6.3.3 AVENT DITCH

Similar to the Anita Ditch, the Avent (or Avant) Ditch temporary stream gage was installed during the second year of the Project. The gage was installed on April 20, 2011 and removed on October 20, 2011. The Avent Ditch gage was installed to calibrate and confirm flows estimated by the StateMOD model where flow demand by users was estimated to be the greatest.

Review of the 2011 hydrograph shows that the Avent Ditch supplied downstream users during the month of May and again at the end of June through October (Figure 6-8). Flows ranged from an average in May of 4 cfs to a peak of 40 cfs. The total runoff during the period of study was estimated to be approximately 6,332 ac-ft.

6.3.4 BRUNER GULCH

The Bruner Gulch temporary stream gage was originally installed during the Level I Study to record flows during 2009 and was reinstalled in 2010 for the Level II Study. The gage location was identified as a potential off-channel storage location for storing water from the Buffalo Creek watershed and water diverted from the Nowood River and Crooked Creek through a proposed diversion.
The Bruner Gulch gage was not reinstalled during 2011 based on input received from the adjacent landowners during gage servicing in 2010. Therefore, the gage was relocated to the Anita Ditch to measure diversion flows during the 2011 irrigation season and the reservoir location was not modeled in the StateMOD model.

The hydrographs measured at the site for 2009 and 2010 are shown in Figure 6-9. Over the 2 years of record, flows ranged from 1 cfs to a peak of 134 cfs between the study periods of March through mid-June. Around the middle of June during both years, flow in Buffalo Creek appears to dry up or have minimal flow rates unidentifiable by the gage. The increase in stream flow in October of 2009 is a result of bank sloughing and false reporting due to a change in channel geometry. Disregarding the reporting error in the 2009 data, the average total runoff during the periods of study was estimated to be approximately 1,000 ac-ft.

### 6.3.5 BROKENBACK CREEK

Similar to the Bruner Gulch gage, the Brokenback Creek temporary stream gage was originally installed during the Level I Study to record flows during 2009 and was reinstalled in 2010 for the Level II Study. The gage location was identified as a potential on-channel storage location(s) and a gage possible of representing a small perennial stream originating in the lower portion of the Watershed.

When compared to the StateMOD baseline simulated flows, the estimated physical flow is overestimated in the stream. The model estimates an average flow during the period of April through October of 11.3 cfs. The 2009 and 2010 temporary gage results estimate the average flow during the same time period to be approximately 2.2 cfs, a difference of approximately 9.1cfs; or 541 ac-ft per month. The hydrograph for the Brokenback Creek temporary stream gage is provided in Figure 6-10. The Brokenback Creek gage was relocated to the Avent Ditch to measure diversion flows during the 2011 irrigation season.

### 6.3.6 LOWER DEEP CREEK

The Lower Deep Creek stream gage was first installed in June 2010. The stream gage was re-installed during the 2011 and 2012 (Level II, Phase II) field seasons. The gage was installed to assist in calibrating the StateMOD model for a mid-size perennial stream located at the upper end of the Watershed.

During both the 2010 and 2011 study periods, peak flows were captured during the months of May and June (Figure 6-11). The total runoff during the period of study was estimated to be approximately 11,052 ac-ft in 2010 and 30,546 ac-ft in 2011, which was a year with high snowpack and above average summer precipitation. As expected, when the Lower Deep Creek gage is compared to the StateMOD model, a much higher yield is collected at the gage.
(average of approximately 20,800 ac-ft over the study period) than at the proposed reservoir site located upstream (approximately 7,100 ac-ft in an average year using the model). The additional yield at the gaging location can be contributed to the additional flow received from Lost Creek. A direct correlation cannot be made between the StateMOD model and the Lower Deep Creek gage.

6.3.7 UPPER DEEP CREEK
The Upper Deep Creek stream gage was first installed in June 2010. The stream gage was re-installed during the 2011 field season. The gage location was identified to provide direct flow measurements for a potential on-channel storage location storing water from the upper Deep Creek watershed.

Similar to the Lower Deep Creek gage, peak flows were captured during the months of May and June for the study periods (2010 and 2011). The 2010 study period shows a peak runoff of 148 cfs while the 2011 study has a peak runoff of 229 cfs (Figure 6-12). The peak runoff during the 2011 study period may have been higher, but due to high flows the gage was washed out and later recovered. The total runoff during the period of study was estimated to be approximately 5,715 ac-ft in 2010 (June-October) and 3,160 ac-ft in 2011 (April-May) prior to the gage washing out.

When comparing 1 year of complete study period (2010) temporary stream gage data to the StateMOD simulated flow results, the model appears to underestimate flows. The StateMOD model simulates an average of 7.4 cfs flowing in the stream between June and October. The average estimated flow based on the temporary stream gage data from 2010 for the same time period was approximately 17.4 cfs; a difference of approximately 10 cfs; or 607 ac-ft per month. The large difference in flow could be attributed to the lack of temporary stream gage data The data collected in 2010 occurred in a wetter year where as the model takes into consideration 23 years of data for both wet and dry years.

6.3.8 NOWOOD CRAWFORD
The Nowood Crawford stream gage was first installed in June 2010. The stream gage was re-installed during the 2011 and 2012 (Level II, Phase II) field seasons. The gage was installed to assist in calibrating the StateMOD model for flows on the main stem of the Nowood River at the upper end of the Watershed.
During both the 2010 and 2011 study period, review of the gage data indicated flow in this portion of the Nowood River is higher during spring runoff and tapers off to average around 3 cfs during later summer months. During the 2010 study period (June through October), an average discharge of 3.8 cfs was recorded by the gage while in 2011 (April through October) the average discharge was 4.3 cfs, as shown on Figure 6-13. The total runoff during the period of study was estimated to be approximately 1,145 ac-ft in 2010 and 1,609 ac-ft in 2011. The StateMOD model results correlate well with the discharges measured at the temporary stream gage. The model hydrograph estimates a peak of 21 cfs in May and then tapers off to an average of 3 cfs during the later summer months (August through November). The model estimated yield between June and October is approximately 1,585 ac-ft.

6.3.9 OTTER CREEK
The Otter Creek gage is located in the upper portion of the Watershed and was first installed in 2009. The stream gage was re-installed during the 2010, 2011, and 2012 (Level II, Phase II) field seasons. The temporary gage established at this site was maintained to further characterize flows available for diversion to the Taylor Draw reservoir alternative, as well to assess flows potentially available for storage in an alternative on Otter Creek.

Flows were recorded at this location during 2009, 2010, and 2011. Unfortunately, sometime around May 19, 2011, the stream bank where the gage was installed failed during high flows (Figure 6-14). The bank failure caused the stream section to change whereby the rating data for the remainder of the 2011 study period was not reliable. The data gathered during the 2009 and 2010 study period, follow a similar trend. They both peaked between April and May (80 cfs in 2009 and 150 cfs in 2010) during both years and tapered off to around 20 cfs for the remainder of the year. During the 2009 study period, an average discharge of 25 cfs was recorded by the gage while in 2010 the average discharge was 19 cfs, as shown on Figure 6-14. The total runoff during the period of study was estimated to be approximately 10686 ac-ft in 2009, 7,637 ac-ft in 2010, and 34,328 ac-ft in 2011, however as mentioned before this data is not reliable.

The StateMOD model has a node located at the proposed Otter Creek reservoir alternative, downstream of the gage location. During the months of April, May, and June the StateMOD model results slightly overestimate the flows when compared to the temporary stream gage estimated flows. During this period the average flow estimated by the gage for 2009 and 2010 was 30 cfs. During this same time period the model estimated the flow to be an average of 38 cfs. However, during the months of July through October the StateMOD results are slightly underestimated in Otter Creek as compared to the 2009 and 2010 study period gage data. The average flow calculated by the gage for 2009 and 2010 was 18 cfs. During this same time period the model estimated the flow to be an average of 9 cfs. Overall when
comparing the yield the model has an estimated yield from April to March of 12,212 ac-ft on an average year. The gages yield for 2009 and 2010 from April through November are 10,686 ac-ft in 2009 and 7,637 ac-ft in 2010.

6.3.10 PAINT ROCK CREEK
The Paint Rock Creek stream gage was first installed in spring 2011 to assist in calibrating StateMOD results for Paint Rock Creek and the lower, eastern portion of the Watershed. Unfortunately due to the high stream flows during the 2011 spring season, the gage was washed out and could not be recovered. The gage was reinstalled during the 2012 (Level II, Phase II) field season and is planned to be reinstalled for future studies.

6.3.11 SPRING CREEK
The Spring Creek stream gage was first installed in June 2010. The stream gage was re-installed during the 2011 and 2012 (Level II, Phase II) field seasons. The gage was installed to assist in calibrating the StateMOD model for physical flows on a perennial stream located centrally in the Watershed.

During the 2010 study period, the gage was installed after the spring runoff. The hydrograph represents (Figure 6-15) an average stream flow of approximately 8 cfs during the study period, except during the period from the beginning of July through mid-September. During this time the hydrograph reflects an irrigation demand from the stream and averages around 2.5 cfs. There are multiple irrigation ditches upstream of the gage, with the nearest being 500 feet upstream, that affect discharge in the stream at this location. The peak runoff during the 2010 study period was 12 cfs with a total runoff of approximately 1,683 ac-ft. The 2011 gage hydrograph displays similar results as the 2010 data. The 2011 gage record recorded the spring runoff in May (peak runoff of 92 cfs) and then lower discharges between July and September when irrigation diversions are made upstream from the gage. The estimated total runoff during the 2011 period of study was approximately 2,766 ac-ft.

The StateMOD model has a node located near the confluence of Spring Creek and the Nowood River. Between April and October the StateMOD results are slightly underestimated. During this period the average flow estimated by the gage for 2010 and 2011 was 7 cfs. During this same time period the model estimated the flow to be an average of 5 cfs. However, the flow timing during this period is similar when comparing the hydrographs and the model estimated yield of 1,800 ac-ft correlates to that estimated with the gage.
7.0 PURPOSE AND NEED

Much of the Watershed is a low precipitation, semi-arid environment. Precipitation throughout a large portion of the Watershed ranges from less than 11 inches to 13 inches annually (Figure 1-2). Consequently, crop consumptive use exceeds precipitation quantities and irrigation is required for successful crop production. Irrigated lands are present in valley bottoms throughout the Watershed with the majority of these lands located along the Nowood River below Big Trails as illustrated on Figure 6-3. According to the WCCD, the dominant irrigated crops within the Watershed are alfalfa and grass hay. Corn and oats are grown to a lesser extent. Irrigated pastures are also found in relatively small quantities. A few fields are planted in beets in the lower portion of the Watershed near Manderson (ACE 2010).

During the completion of both the Level I and Level II studies, stakeholders discussed issues related to late-season flow conditions that precluded adequate irrigation of irrigated lands during years of dry or normal hydrologic conditions. Anecdotal information gathered during public meetings and meetings with the Steering Committee indicate that irrigators frequently must make the difficult decision of choosing which field to allow to dry up during dry, late-season conditions.

The presence of irrigation shortages is substantiated by review of available WSEO records for the period of 2001 through 2009, which spans recent drought conditions. These records show that calls were placed on the Nowood River in 2001, 2003, 2005, 2006, and 2007. Calls were generally placed in July, August, or September of those years. Medicine Lodge and Paint Rock Creeks are subjected to calls more frequently on average.

The Wind/Bighorn River Basin Plan study conducted on behalf of the WWDC (BRS 2003) and updated in 2010 (MWH 2010) provides additional evidence of irrigation shortages within the Watershed. Based upon the results of the 2010 Wind/Bighorn Update, total water shortages within the Watershed for the dry, normal, and wet year conditions are approximately 10,200 ac-ft, 6,500 ac-ft, and 5,300 ac-ft, respectively. The Spreadsheet Model used in these studies provides a means of generating preliminary estimates of the hydrologic conditions present in the Watershed without identifying specific water rights, which generally substantiated the information that local irrigators provided.

As described in previous sections of this report, this Project was undertaken based on landowner input and information compiled during the Level I Study, including results from the Wind/Bighorn River Basin Plan, indicating late season water shortages in the Watershed. A StateMOD model was developed to quantify historic water availability and shortages in the Watershed. The StateMOD hydrologic model, the model’s operating assumptions, data input, and results are discussed in Section 6 of this report. Based upon the results of the StateMOD model, total irrigation demands for an average hydrologic year are approximately 146,000 ac-ft. Estimated shortages during normal and dry
years are estimated to be approximately 15,151 ac-ft and 16,990 ac-ft, respectively. A bar chart displaying the
distribution of shortages throughout the year for dry and average hydrologic conditions is provided as Figure 7-1.
StateMOD simulations also indicate that there is water available for storage during high spring flows. For these
reasons, the ability to develop storage reservoirs in the Watershed is being evaluated as part of this Project.

The purpose of developing storage in the Watershed is to store excess water available during high flows whereby the
water can be released later in the year or subsequent years to meet irrigation shortages. The need for storage is
supported by the StateMOD simulations indicating annual water shortages in the Watershed of 15,000 ac-ft for a
normal year and 17,000 ac-ft for dry years. Other objectives of developing storage would be reducing flooding and
stream erosion by capturing a portion of the high, spring flows, creating recreational opportunities, enhancing wildlife
habitat and fisheries, and improving stream ecosystems by providing additional late season flows.
8.0 GEOTECHNICAL INVESTIGATION

The Project team performed geotechnical evaluations, including detailed desktop evaluations and field investigations, to identify geotechnical concerns or fatal flaws with potential storage sites. Field-reconnaissance investigations were performed by HAI at seven sites (Appendix E1). The field investigations were performed early during the course of the Project to confirm the probable geotechnical feasibility of potential reservoir sites. The investigations were undertaken based on a detailed desktop review of available geologic, geotechnical and soils data. Subsurface investigations were not performed during this phase of study; rather an emphasis was placed on assessing potential geotechnical concerns or fatal flaws to construction of a dam at the sites that were identified for geotechnical evaluation. The information gathered during the geotechnical investigation was used to evaluate the feasibility of advancing reservoir sites for further study based on the analysis described in Section 9.0.

8.1 WATERSHED GEOLOGY

Trihydro initially researched and described the Watershed geology as part of the Level I Study. Excerpts from that report are reiterated here for context to the geotechnical analyses of potential reservoir sites evaluated during the Level II, Phase I study. The following subsections, from the Level I Study, provide an overview of the geology of the Watershed. This overview provides basic information about the surficial geology, bedrock geology, geological structure and the potential geological hazards present in the Watershed.

8.1.1 SURFICIAL GEOLOGY

The surficial deposits found within the Watershed are presented on Figure 8-1. The wide distribution of alluvium, glacial deposits, residuum, slope wash, and colluvium within the Watershed is illustrated on this figure. These sediment types constitute the dominant exposed geology within the Watershed. The remaining exposed geology is composed of bedrock, grus, landslide, and terrace deposits. A discussion of bedrock and landslides are presented in the bedrock geology and hazards sections below.

Alluvium is found adjacent to surface drainages and is of fluvial origin (produced by the action of a stream or river). The extent of the alluvial deposits varies with the size of the respective fluvial system. Headwater deposits are typically narrower and shallower compared to downstream areas in the Watershed. Alluvium ranges from 10-50 feet in thickness and is composed of sand, gravel, and loam (Cooley and Head 1979). These deposits are actively growing with the fluvial action of existing surface drainages. Fluvial action includes flooding (vertical deposition) and point-bar migration (lateral deposition).
8.1.2 BEDROCK GEOLOGY

The bedrock geology exposed and directly underlying the Watershed contains rock formations with ages ranging from the Cambrian Period to present. The bedrock geology outcropping at or near the surface is presented on Figure 8-2. The dominant formations in the Watershed (from youngest to oldest, top to bottom, then left to right) include the:

- Fort Union Formation
- Mesaverde Formation
- Cody Shale
- Frontier Formation*
- Mowry Shale*
- Thermopolis Shale*
- Cloverly shale*
- Morrison Formation*
- Sundance Formation*
- Gypsum Spring Formation*
- Chugwater Formation*
- Goose Egg Formation
- Tensleep sandstone
- Amsden Formation

Glacial till exists in the northeastern portion of the Watershed and is associated with lateral and terminal moraines. The lateral moraines typically begin at an elevation about 10,000 feet and can be traced to approximately 8,000 feet, where they meet the terminal moraines (Darton 1906). Drift composition is dominantly igneous and metamorphic rock from upland areas. Some Paleozoic sedimentary rocks also exist within the till located at lower elevations. These deposits consist of unconsolidated, poorly sorted, angular rock fragments. Some areas may display greater levels of sorting due to esker formation.

Residuum is an in-situ deposit formed from the weathering of bedrock. Soluble components of the bedrock were transported from the area by fluvial, fluvio-glacial, and groundwater processes. The insoluble portions of the rock experienced some mechanical weathering from freeze-thaw and rain-drop impact with little to no transport of the remaining materials. The residuum deposits within the Watershed are primarily derived from late Paleozoic to Mesozoic rocks. The deposits are relatively young and are therefore thin compared to other quaternary deposits.

Colluvium exists throughout the Watershed and has a genetic origin related to mass wasting mechanisms. These sediments were derived from the movement of material down slope under the influence of gravity. The colluvial deposits are composed of material derived from bedrock at higher elevations. Grain sizes range from silt to gravel, and grain shape is predominantly angular to subangular. These deposits have a maximum thickness of 15 feet (Cooley and Head 1979), but thin as they near the source material at higher elevations.
Other formations are mapped within the Watershed, but the above units have the greatest influence on the Watershed’s geology. The starred units were encountered at the various potential reservoir sites and are described in greater detail below.

The general pattern of outcrop of the units is of younger formations on the western side of the watershed and older units on the eastern side (Susong et al. 1993). An exception to the pattern is the quaternary, surficial deposits discussed in the previous section. The youngest Tertiary-age rocks that crop out in the Watershed are of the Fort Union Formation and are approximately 2-68 million years old (ma). This formation consists of interbedded layers of sandstone and shale. Coal seams exist within the formation, but are smaller and less frequent than those found in the Fort Union of southeastern Montana. In the area of the Nowood River, the Fort Union Formation is 1,000 to 1,500 feet thick (Cooley and Head 1979).

The next youngest rocks are of Cretaceous age (68-142 ma) and include units of the Mesaverde, Cody, Frontier, Mowry, Thermopolis, and Cloverly Formations. Within the Watershed, these formations comprise the bedrock (other than the Tertiary formations) found west of the Nowood River and the areas northwest of Hyattville. They are comprised of thick shale layers with thinner beds of sandstone. Coal is present within these rocks as well (Darton 1906). The thickness of the entire sequence is from 6,600 to 7,500 feet (Cooley and Head 1979; Fischer 1906).

The Frontier Formation is Upper Cretaceous and is composed of fine to medium lenticular sandstone with gray and black marine shale. Thin bentonite and tuff beds are present as well. The Mowry Formation is Lower Cretaceous and composed of black and gray thin-bedded resistant shale interbedded with thin sandstone and bentonite. The Thermopolis Shale is soft, black shale of the Lower Cretaceous. The Cloverly Formation is Lower Cretaceous and composed of light gray channel sandstones and pebble conglomerates interbedded with variegated bentonite mudstone (Weitz and Love 1952).

To the east of the cretaceous rocks are Jurassic to Pennsylvanian age (142-320 ma) rocks, which include the Morrison, Sundance, Gypsum Spring, Chugwater, Goose Egg, Tensleep, and Amsden Formations. These formations range from reddish-brown shale to silty sandstone to sandstone. Thin beds of limestone also exist. The Tensleep Formation consists entirely of lightly cross-stratified sandstone. Gypsum exists in the Gypsum Spring and Goose Egg Formations,
the solution of which has produced karst topography. The total thickness of these formations ranges from 2,000 to 2,400 feet (Susong et al. 1993; Cooley and Head 1979).

The Morrison Formation is Upper Jurassic and composed of calcareous gray silty sandstone and sandy claystone with lenticular limestone. The Sundance Formation is Middle Jurassic and is a greenish-gray glauconitic calcareous sandstone and shale. The Gypsum Springs Formation is Middle Jurassic and an interbedded red claystone, shale, siltstone and limestone with massive gypsum beds. The Chugwater Formation is Triassic and composed of massive, cross-bedded, very fine grained sandstone, siltstone, and shale.

Mississippian to Ordovician age rocks (320-505 ma) crop out further to the east and southeast. These rocks are composed of the Madison limestone and Bighorn dolomite. Both formations contain light-gray massive limestone with the Bighorn Formation also containing dolomite. Dissolution of these formations has also produced karst topography and cave systems in the Watershed. The extensive cave systems associated with these formations suggests a high volume of water is exchanged during surface water-groundwater interactions. The Madison limestone has a thickness of 500 to 700 feet, while the Bighorn dolomite is 300 feet thick (Susong et al. 1993; Cooley and Head 1979).

The oldest Phanerozoic rocks in the watershed were deposited during the Cambrian Period (505-560 ma) and are the Gallatin and Gros Ventre Formations. Both formations are a greenish to gray shale. The formations are in the southern portion of the watershed, adjacent to the Oldest Gneiss Formation and other plutonic rocks. These igneous and metamorphic rocks are the basement, Precambrian rocks found in the center of the broad anticlinal structure of the Bighorn Mountains (Susong et al. 1993; Darton 1906; Fischer 1906).

8.1.3 STRUCTURE

The Watershed is located in the southeastern portion of the Bighorn Basin. The basin was formed from folding and faulting during the Laramide orogeny, which occurred approximately 40-70 ma. The Laramide also produced the mountains that border the basin (Susong et al. 1993). To the east the basin is bordered by the Bighorn Mountains and to the south by the Owl Creek Mountains (Fischer 1906). Bounded by these mountain ranges, the Watershed drains the southeastern-most portion of the Bighorn Basin.

The general structure of the Bighorn Mountains is an anticline, and a portion of the Watershed drains the southwestern limb. The axial plane of the anticline strikes northwest to southeast, causing the west-east age pattern in the Phanerozoic rocks. The attitude of Phanerozoic rocks is similar to the anticline, with strikes ranging from north to
south to northwest to southeast. However, smaller scale anticlines and synclines are present within the watershed, and these local structures create variations in bed orientation.

The smaller scale anticlines and synclines are genetically related to the larger Bighorn anticline and; therefore, have similar orientations. The beds within them strike to the northwest and generally dip 5-12° to the southwest. Beds with an opposite dip direction (to the northeast) are present but less prevalent. This bed reversal typically indicates the presence of a local syncline (Hosterman et al. 1989; Cooley and Head 1979). Synclines can often be found associated with an anticline of similar size and extent. One anticline-syncline pair in the Watershed can be found along the western side of the Nowood River with the axial plane running from Manderson to Crooked Creek (Cooley and Head 1979). Similar but less extensive structures are also found in the northeastern portion of the Watershed, near Hyattville and Ten Sleep, as well as in the southern part of the Watershed in the vicinity of Mahogany Butte and Orchard.

Faulting is evident within the eastern portions of the Watershed (Figure 8-3). These faults are characterized as high-angle (60-90°) normal faults with the downthrown side located to the west of the fault line (Hosterman et al. 1989; Darton 1906). Faults of this type are associated with extensional tectonics. One distinctive fault that displays these characteristics is located adjacent to Big Canyon Creek and Ten Sleep. The fault displays a vertical displacement of 700 feet near Big Canyon Creek. This displacement decreases towards the west, and the fault eventually merges into a monocline approximately 4 miles west of Ten Sleep (Hosterman et al. 1989; Cooley and Head 1979; Darton 1906). Also, a large prominent fault, called the Big Trails Fault System, trends generally north-south along the eastern perimeter of the Watershed in the southern Bighorn Mountains (Verploeg 1992).

8.1.4 HAZARDS

Karst, landslide, and seismic geological hazards exist within the Watershed. Karst creates sinkhole hazards and occurs from the dissolution of chemical rocks (limestone, gypsum, dolomite, etc.). Landslides occur when sediment moves down slope under the influence of gravity, potentially damaging structures and altering the hydrogeology of the Watershed. Seismic events create a hazard to structures and tend to occur along fault lines, but earthquakes have occurred in areas with no known respective structural feature. The potential areas at risk for these hazards are presented on Figure 8-3.

Karst topography within the Watershed is predominantly located to the east of the Nowood River. Closed depressions and solution collapse features are found on the surface and have been associated with the Goose Egg and Gypsum Spring Formations (Cooley and Head 1979). These features were developed from the dissolution of gypsum and limestone underlying surficial deposits. The surficial deposits then reflected the karst topography below them. The
limestone and dolomite of the Madison, Bighorn, and Gallatin Formations have also developed karst topography. Some of this topography is concealed by the Amsden Formation, which unconformably overlies paleokarst features of the Madison (Hosterman et al. 1989). However, extensive, recently developed caves exist in the northeastern portion of the Watershed, near Medicine Lodge Creek (Susong et al. 1993).

Collapse risk due to sinkholes can be difficult to determine due to their subsurface nature. Certain features can be indicative of karst: closed depressions, sinking streams, blind valleys, and others. However, subsurface investigations (including geophysical, tracer dye, and field surveys) need to be conducted to provide an adequate assessment.

Landslide hazards exist in areas where the resisting forces (friction and cohesion/adhesion between sediment particles) have the potential to be exceeded by the driving forces (gravity). This condition can be found throughout the upland areas of the Watershed. Paleolandslides (“li” unit on Figure 8-1) are indicators of future landslide activity. Slopes experiencing undercutting due to lateral erosion of streams are also at high risk. Severe erosion problems have been noted on the Nowood River, with less severe erosion on the Paint Rock, Tensleep, Otter, and Canyon Creeks (USDA 1971). The lateral erosion by streams undercuts the toe of slopes and removes their underlying support. Other factors for potential landslide areas include grain size and shape, lateral and underlying support, slope angle, sediment composition, and water content.

The Watershed is an area with minor historical seismicity. According to Stover et al. (1984), epicenters of 11 earthquakes were recorded to have been in or near the Watershed. The largest magnitude earthquake, with a magnitude of 4.9, occurred in 1970. The epicenter was located approximately 8 miles southwest of Ten Sleep. The smallest magnitude earthquakes of 3.0 occurred in 1998 and 2000 (USGS 2009; Case et al. 2002). Two earthquakes recorded in 1925 and 1966, occurred before magnitude measurements were regularly recorded. The earthquakes were rated using the Modified Mercalli Intensity Scale. Intensity was not noted for the 1966 earthquake, and an intensity V level was applied to the 1925 event. The 1925 event was felt in Ten Sleep, Sheridan, Fort McKenzie, and Dome Lake Resort, but damage was not reported (Case et al. 2002).

Two fault systems are located adjacent to each other in the southern portion of Watershed: the Cedar Ridge and Dry Fork fault systems. Evidence suggests that the fault systems are inactive. However, one confirmed case of Pleistocene-aged movement, in the form of a fault scarp, was documented in northeastern Fremont County (Case et al. 2002). If either the Cedar Ridge or Dry Fork fault systems were to become active, they could potentially generate 6.7 and 7.1 magnitude earthquakes, respectively. A 6.7 magnitude earthquake at the Cedar Ridge System could produce a peak horizontal ground acceleration of 2.9%g at Ten Sleep and 2.0%g at Big Trails. A 7.1 magnitude earthquake at the
Dry Fork System could produce a peak ground acceleration of 3.8%g at Ten Sleep and 7.4%g at Big Trails. In either case, minor damage could result from these earthquakes at Big Trails (Case et al. 2002).

Although active fault systems are not currently identified near the Watershed, large earthquakes can still occur in areas without a known source structure. These earthquakes are known as “floating earthquakes.” Federal and state regulations require a floating earthquake analysis for certain structures (mill tailing sites, landfills, etc.). If a structure within the Watershed required such analysis, a 6.25 magnitude earthquake with an epicenter 15 miles from the structure could be used as a conservative estimate for design ground accelerations. An earthquake of this magnitude and distance could produce ground accelerations of 15%g (Case et al. 2002). A more detailed, site-specific, design analysis of seismological hazards is performed in association with the development of significant structures, such as large dams.

Another type of seismic hazard analysis, completed by the USGS, estimates the probability of exceeding the peak horizontal ground acceleration that could occur from an earthquake in the next 50 years. This analysis was most recently updated in 2008 and can be found at [http://gldims.cr.usgs.gov/nshmp2008/viewer.htm](http://gldims.cr.usgs.gov/nshmp2008/viewer.htm). For the Watershed, the peak horizontal ground acceleration that has a 10% chance of being exceeded from 2008 to 2058, is from 4-5%g. The peak ground acceleration that has a 2% chance of being exceeded from 2008 to 2058 is from 15-17%g. This methodology uses the frequency and magnitude of past earthquakes to estimate the frequency and magnitude of future earthquakes. A weakness to this method is that it can inaccurately predict earthquake risk in areas with a low frequency of earthquakes, like the Watershed. However, few other alternatives for estimating the risk exist.

### 8.2 PRELIMINARY GEOTECHNICAL INVESTIGATIONS

During September 2010, a geotechnical field investigation was conducted at seven potential reservoir sites within the Watershed. The field investigations were similar in scope to the field investigations of potential reservoir sites that were conducted by Trihydro during the Level I Study (ACE 2010). The Level II investigations were performed by HAI, with support from Trihydro. Both the Level I and Level II geotechnical investigations were undertaken to confirm the apparent feasibility of constructing a dam and reservoir at a site. The following sites were evaluated:
### Level I Investigations
- Nowood-Crawford
- Cottonwood Creek
- Taylor Draw
- Deep Creek
- Bruner Gulch
- Upper Nowood
- Meadowlark Lake (enlargement)
- Big Trails*

### Level II Investigations
- Lower Luman Creek
- Upper Luman Creek
- Paint Rock Creek
- Alkali Creek
- Cornell Gulch
- Lower Brokenback
- Big Trails*

Note: *Denotes sites that were investigated during both the Level I and Level II studies.

Technical memoranda detailing the findings from the preliminary field investigations of the 14 potential reservoir sites are included in Appendix E1 (Level II geotechnical investigation) and Appendix E2 (Level I geological investigations). Potential reservoir sites that were investigated in the field during the Level I Study were not revisited during this Project, with the exception of the Big Trails site. This site was revisited during the Project due to concerns raised with foundation conditions during the Level I Study and in consideration of the large storage capacity and other substantial benefits associated with the site. Fatal flaws were not noted at the sites visited, although questionable foundation conditions warranting detailed subsurface investigations were noted at the Deep Creek, Nowood-Crawford, and Big Trails sites. Subsurface investigations are also recommended for the other sites that are selected for further evaluation during future Project phases. The results from these field investigations are incorporated into the potential reservoir site evaluations and Matrix presented in Section 9 of this report.

### 8.3 FIELD INVESTIGATIONS OF POTENTIAL RESERVOIR SITES

Ultimately, five potential sites (Meadowlark Lake, Alkali Creek, Lower Luman Creek, Taylor Draw, and Cornell Gulch) were advanced for further design and study based on the site evaluation discussed in Section 9. The results and findings from the geological or geotechnical field investigations for these five sites are provided in this section. Findings for the other sites visited are included in Appendix E1 and E2. Because the sites visited during the Level I Study (excepting Big Trails) were not revisited during the Level II Study, the emphasis of the site evaluations differs...
for the sites described below. The Level I Study evaluations focused more on suitable geology, while the Level II Study evaluations focused more on geotechnical considerations.

### 8.3.1 MEADOWLARK LAKE (TENSLEEP RESERVOIR) ENLARGEMENT

Meadowlark Lake (permitted as Tensleep Reservoir) is an existing reservoir on East Tensleep Creek, 1.5 miles upstream of the confluence with Tensleep Creek (Figure 8-4). The reservoir was constructed in the late 1930s as a work project for the Civilian Conservation Corps (CCC).

A geological investigation of the site was performed as part of the Level I Study on July 28, 2009. The existing dam consists of a 30-foot tall embankment with a primary outlet channel near the right-center of the embankment, an auxiliary spillway near the left side of the embankment, and what appears to be a fish ladder adjacent to the spillway (Figure 8-5). The primary outlet and spillway channels, and the fish ladder are in need of repair. The internal condition of the primary outlet was not assessed during the site visit. Based on observations during the July 2009 site visit, an upstream raise was initially recommended to enlarge the reservoir.

Although the dam embankment appears to be a simple earthen structure, records uncovered at the WSEO Dam Safety Division near the conclusion of the Project indicate the dam was rehabilitated approximately 20 years ago. The rehabilitation included construction of a roller-compacted concrete (RCC) cap on the downstream face of the embankment to protect the embankment in case of overtopping. The rehabilitation also included repairing slumps on the upstream face of the embankment and replacing the hand-placed riprap. Presumably the RCC cap was covered by an earthen shell to maintain the reservoir embankment historical character. Based on the information discovered at the WSEO Dam Safety Division, HAI revisited the site to evaluate possible means for enlarging the reservoir. Based on discussions during the site visit, a downstream raise of the embankment may be more appropriate than the upstream raise envisioned in the conceptual design developed during the Project. If the Meadowlark Lake enlargement is advanced for further design, consideration of an RCC embankment design with a downstream raise is recommended.

### 8.3.2 ALKALI CREEK

The Alkali Creek alternative is located on Alkali Creek, approximately 1.6 miles upstream of the confluence with Paint Rock Creek (Figure 8-6). A preliminary geotechnical investigation was completed on September 29, 2010.

The site is located in a wide, U-shaped valley with Alkali Creek running on the right side of the valley in a channel approximately 15 feet deep (Figure 8-7). The bedrock is sandstone of the Cloverly and Morrison Formations. There are rock outcrops on both abutments with the right abutment steeper than the left abutment (Figure 8-7). The Anita Ditch flows into the valley upstream of the dam site and drops approximately 10 feet over a sandstone ledge into a
sandstone stilling basin in the valley floor. The soils in the valley bottom are sandy clays at least 15 feet in depth. There is a large exposure of claystone in the Alkali Creek drainage well upstream of the dam site which is most likely the source of the sandy clays at the dam site.

The site appears to be suitable for a homogeneous earthfill dam. Foundation preparation will most likely consist of excavation of the soils from beneath the entire footprint of the dam for a depth sufficient to avoid excessive consolidation of the dam foundation soils when wetted. The excavation depths are estimated to be 10 feet to 30 feet in the valley bottom and essentially nil on the abutments. The bedrock in the abutment may require a sandy clay blanket to control seepage through the abutments depending on the permeability of the rock. The maximum possible height of dam will be governed by the elevation of the right abutment which was assumed to be the potential location for a spillway during the field visit.

The site appears to be a viable reservoir site based on the surficial field observations.

8.3.3 LOWER LUMAN CREEK
The Lower Luman Creek alternative is located on the ephemeral Luman Creek drainage, approximately 1.6 miles upstream of the confluence with Paint Rock Creek (Figure 8-8). A preliminary geotechnical investigation was completed on September 29, 2010.

The site is located in a fairly well defined V-shaped valley with Luman Creek flowing through a meandering channel (Figure 8-9). The left abutment is significantly steeper than right abutment. The bedrock is sandstone of the Tensleep sandstone and Amsden Formation. The right abutment is mantled with fine grained silty sand, which appears to be at least 10 feet thick. Fine grained silty sand is exposed in the stream cut in the valley bottom for a depth in excess of 10 feet. The left abutment has a similar mantle of fine grained silty sands to just above the valley bottom and then exposed well cemented, fairly coarse grained brown sandstone. The site has a good grass cover with scattered shrubs and small trees, especially in the valley bottom.

The site appears to be suitable for a homogeneous earthfill dam if the silty sands have sufficient fines. Foundation preparation will most likely consist of excavation of the soils from beneath the entire footprint of the dam down to the bedrock to avoid excessive consolidation of the dam foundation soils when wetted. The excavation depths are estimated to be 15 feet on the right abutment, 20 feet to 30 feet in the valley bottom, and essentially nil on the left abutment. The foundation bedrock may require grouting to control under seepage depending on the permeability. The
maximum possible height of dam will be governed by the elevation of the right abutment which would be the logical location for a spillway based on observations in the field.

The site appears to be a viable reservoir site based on the surficial field observations.

### 8.3.4 TAYLOR DRAW

A potential dam and reservoir location site was identified near the mouth of Taylor Draw approximately 2,100 feet from the course of the Nowood River (Figure 8-10). A geological investigation of this site was performed on July 28, 2009.

The site is located in a broad, U-shaped valley, where two ephemeral drainages exit the draw. The embankment location is within the lower Cretaceous part of the section, with Thermopolis Shale outcropping near the left and right abutments (Figures 8-10 and 8-11). The shale at the ground surface is easily erodible, but the material is more competent with depth. The shale in outcrops on both sides of the drainage consistently dips to the west. Two soils samples were collected. The first sample was obtained from the right abutment and consisted of moderately hard, but friable, black clay shale. The second sample was collected from the channel bottom and consisted of brownish-tan silty clay.

The site appears to be suitable for either a homogeneous or zoned earthfill dam. Foundation preparation will most likely consist of excavation of the soils from beneath the entire footprint of the dam down to the bedrock to avoid excessive consolidation of the dam foundation soils when wetted. Estimated excavation depths to foundation materials were not noted during the field reconnaissance. Borrow material suitable for use as embankment fill appears to be available in the valley bottom. The site topography will not influence the maximum possible height of dam. A potential spillway location exists near the left abutment.

The site appears to be a viable reservoir site based on the surficial field observations.

### 8.3.5 CORNELL GULCH

The Cornell Gulch alternative is located on an ephemeral drainage that flows into the Nowood River from the west (Figure 8-12). The drainage is west of the Bear Creek and Nowood River confluence. A preliminary geotechnical investigation was completed on September 29, 2010.
The Cornell Gulch Site is located in a very wide, V-shaped valley with Cornell Gulch cutting through. Cornell Gulch was dry at the time of the field reconnaissance. The bedrock on the left abutment is the Nugget sandstone and siltstone of the Chugwater Formation. The bedrock on the right abutment is sandstone and shale of the Sundance Formation. Starting at Cornell Gulch, the left abutment is a soil mantled approximately 4H: 1 V slope rising to a near vertical sandstone outcrop (Figure 8-13). Starting at Cornell Gulch, the right abutment is a soil mantled approximately 6H: 1 V slope rising to a much steeper slope. There are no rock outcrops on the dam centerline on the right abutment, but sandstone was exposed in an erosion gully just upstream of the dam centerline. The surface soils in the reservoir area are red sandy silt. Approximately 10 feet of gray sandy clay is exposed in Cornell Gulch, which appears to have originated from a gray claystone outcrop upstream of the potential reservoir area. There is a thin sand and gravel deposit in the left side of the reservoir area upstream of the dam site that has been worked. The site has a good grass cover and scattered trees.

The site appears to be suitable for either a homogeneous or zoned earthfill dam. Foundation preparation will most likely consist of excavation of the soils from beneath the entire footprint of the dam down to the bedrock to avoid excessive consolidation of the dam foundation soils when wetted. The excavation depths are estimated to be 10 feet to 15 feet on the abutments and 30 feet in the valley bottom. The foundation bedrock may require grouting to control under seepage, depending on the permeability. The site topography will not influence the maximum possible height of dam. The right abutment would be the logical location for a spillway because the slope is less steep than the left abutment.

The site appears to be a viable reservoir site based on the surficial field observations.

8.4 FIELD INVESTIGATION SUMMARY AND FINDINGS

The geologic conditions for the reservoir sites were evaluated by mapping outcrops at the surface and by inferring subsurface conditions based on observed structure and stratigraphy. Outstanding geologic risk was not identified at the reservoir sites evaluated during the Project study. Based on the preliminary geotechnical investigations completed for this Project, fatal flaws were not identified at the Alkali Creek, Lower Luman Creek, Taylor Draw, or Cornell Gulch sites. Providing other evaluation criteria warrant advancement of one or more of these reservoir sites for further study, each of these sites appears feasible from a geotechnical standpoint and if warranted, additional geotechnical subsurface investigations would be needed to confirm the competency of the foundation materials and to estimate the quantity of borrow materials available for embankment construction.
The existing Meadowlark Lake dam embankment also warrants additional geotechnical evaluation, if enlargement of the existing reservoir is recommended for advancement for further consideration. Further geotechnical evaluation would likely need to address sourcing materials for RCC construction and foundation conditions.
9.0 IDENTIFICATION OF POTENTIAL WATER SUPPLY ALTERNATIVES

Identification of potential storage alternatives included developing a comprehensive list of potential storage sites, characterizing and evaluating the sites, and then, narrowing this list of sites to a short list of alternatives that would provide the greatest benefit to Wyoming and its residents. A thorough review of the Watershed and previous studies was completed to identify potential storage sites that could satisfy shortages estimated through the hydrologic analysis. The identified sites were then characterized and screened during the course of the Project to identify the storage sites that would best meet the needs of the Watershed. The top-ranked potential storage sites are those that could most efficiently capture and store available flows, provide secondary benefits (e.g., flood control, recreation, wildlife habitat, etc.), are positioned in the Watershed to effectively serve estimated shortages, and would result in the least impacts to the environment, landowners or lessees, and infrastructure.

9.1 IDENTIFICATION OF POTENTIAL STORAGE ALTERNATIVES

9.1.1 PREVIOUSLY IDENTIFIED POTENTIAL STORAGE ALTERNATIVES

The Level I Study included review of previous storage studies in the Watershed, identification of potential storage sites, and preliminary characterization and screening of the identified sites. Efforts during the Level I Study resulted in a list of 35 potential storage sites spread across the Watershed. The Level I Matrix (Appendix A) was developed to summarize relevant site characteristics for the potential storage sites that were compiled from the Watershed inventory results. The Level I Matrix allowed for comparison of information such as reservoir and watershed descriptions, hydrology, geology, environmental considerations, infrastructure considerations, land ownership, economic considerations, and potential benefits. This information was then used to screen the sites and assign each site a relative priority (ACE 2010).

- Priority 1 sites represent the most potentially feasible of the sites evaluated that provide the most benefit at the least cost or environmental impact. These alternatives were recommended for further evaluation in future investigations. The list of Priority 1 sites developed during the Level I Study is included in Table 2-4.

- Priority 2 sites represent storage sites that are potentially feasible, yet have attributes making them less desirable for further study than Priority 1 alternatives. For example, some Priority 2 sites have the same potential benefits as Priority 1 alternatives, but their overall costs were estimated to be higher. Designation as a Priority 2 site was not intended to preclude the site from being included in future studies. The list of Priority 2 sites developed during the Level I Study is also included in Table 2-4.
• Priority 3 sites represent potential storage sites that have either fatal flaws that eliminated them from recommendation for further study (e.g. location within the wilderness area), or other attributes causing them to be highly unlikely to be implemented. The list of Priority 3 sites developed during the Level I Study is included in Table 2-3.

Comprehensive review of previous storage studies addressing sites in the Watershed was completed as part of the Level I Study. Of the 35 sites identified in the Level I Study, 18 were identified in previous studies and re-evaluated during the Level I Study. The studies reviewed during the Level I Study included:

• May 1971 Nowood River Drainage Investigation Report, Type IV River Basin Survey, completed by the United States Department of Agriculture (USDA)

• October 1972 Water and Related Land Resources of the Bighorn River Basin, completed by the Wyoming Water Planning Program (WWPP)

• October 1972 Water and Related Land Resources of the Bighorn River Basin, completed by the WSEO

• December 1974 Wind-Bighorn-Clarks Fork River Basin, Type IV Survey, completed by the USDA and WSEO

• 2003 Wind/Bighorn River Basin Planning Report, completed on behalf of the WWDC

The list of sites identified during previous studies is provided in Table 9-1.

Each of the potential storage sites identified during the Level I Study, including the 17 sites screened as Priority 3 sites and not recommended for further study, were brought forward in the Level II Study for further evaluation. The site evaluations in the Level I Study, by necessity, were based on a broad range of screening criteria; therefore, a low priority in the Level I analysis was not considered a reason for discarding the site for further evaluation during the Project. For example, the Paint Rock Creek site was listed as a Priority 3 site in the Level I Study due to unfavorable geologic conditions. The conditions for this site were more thoroughly investigated in the field during the Level II Study and the site moved up to a Priority 1 site, before finally dropping out of the list of sites to be advanced for further evaluation based on landowner considerations.

9.1.2 ADDITIONAL POTENTIAL STORAGE ALTERNATIVES IDENTIFIED

The list of potential storage alternatives developed during the Level I Study provided good coverage of the Watershed and included sites identified during previous studies, sites apparent from review of topographic mapping and aerial images, and sites noted by stakeholders during the Level I Study. The sites were located such that demands throughout the Watershed could be served. The list included main stem sites, sites in the upper (southern) end of the Watershed,
sites in the lower (northern) end, off-channel sites in the dry western side, and sites in the Bighorn Mountains to the east. However, feedback from the WWDO and Project stakeholders following completion of the Level I Study suggested there might be additional locations to develop storage in the Watershed. Therefore, several geographic areas within the Watershed were targeted for reevaluation of potential reservoir development.

The areas evaluated included the Paint Rock Creek drainage; areas adjacent to the Nowood River, upstream from Big Trails, which might be suitable for development of off-channel storage; and the Little Canyon Creek and Box Elder/Redbank Creek drainages. The evaluation of these areas is discussed in the Further Evaluation of Proposed Storage Sites Tech Memo, dated February 8, 201. A copy of this Tech Memo is provided in Appendix F.

As described in the Tech Memo, the evaluation of potential storage alternatives in the recommended geographic regions considered the following site characteristics:

1. Consideration of the topography insofar as feasibility for constructing a reservoir.
2. Feasibility of diverting water and conveying it to the reservoir.
3. Opportunity for flood passage via an auxiliary spillway.
4. Site geology.
5. Landownership in the vicinity of the reservoir site, including the embankment and areas inundated by the reservoir pool, and appurtenant facilities such as the diversion and conveyance.

The evaluation was completed as a desktop study using digital USGS 7.5-minute topographic mapping, aerial photography, and DEMs included in the Project GIS. Favorable locations for dam embankments and reservoir impoundments were primarily identified based on site topography, location relative to supply, and demands/shortages. A summary of the drainages investigated and potentially viable sites is included in Table 9-2. A detailed discussion of the evaluation of each drainage or site evaluated is provided in the Tech Memo in Appendix F. As a result of the evaluation, five additional potential storage sites were identified. These sites are shown on Figure 9-1 along with the 35 sites identified during the Level I Study and include:

1. Upper Luman Creek, located in the Paint Rock Creek drainage. This site is located on a small tributary to Paint Rock Creek. The reservoir, supplied by diversion of available flows from the South Fork of Paint Rock Creek and Laddie Creek, appears feasible, but would be costly in comparison to other storage supply alternatives in the drainage. This site is located upstream of most of the irrigated acreage along Paint Rock Creek.
2. Lower Luman Creek, located in the Paint Rock Creek drainage. This site is located on a small tributary to Paint Rock Creek. The reservoir would also be supplied by diversion of available flows from South Paint Rock Creek and Laddie Creek identical to the upper dam site. This site is also located upstream of most of the irrigated acreage along Paint Rock Creek.

3. Willow Creek, located in the ephemeral Willow Creek that drains to the Nowood River from the west, downstream of Big Trails. This site is an alternative to the West Fork Willow Creek site identified during the Level I Study and would be developed as an off-channel reservoir. Available water would need to be diverted from the Nowood River. The Willow Creek site appears to provide more storage capacity, and diversion from the Nowood River appears more feasible, than for the West Fork Willow Creek alternative. The site is located in the upper portion of the Watershed, allowing benefits to irrigated acreage downstream along the Nowood River.

4. Cornell Gulch, located in the ephemeral Cornell Gulch that drains to the Nowood River from the west, upstream of Big Trails. This site was identified by the WWDO and would be developed as an off-channel reservoir. Available water would need to be diverted from the Nowood River. The site is located in the upper portion of the Watershed, allowing benefits to irrigated acreage downstream along the Nowood River. Bedrock in the area is the Gypsum Springs formation, which could be a concern for development of karst features.

5. Cherry Creek, located in the ephemeral Cherry Creek drainage that flows into Box Elder Creek just upstream of Box Elder Creek’s confluence with the Nowood River. Box Elder Creek joins the Nowood River at the upstream end of the Big Trails storage alternative. Cherry Creek yields little flow; the reservoir alternative would be filled via a diversion from Box Elder Creek. The site is located in the upper portion of the Watershed, allowing benefits to irrigated acreage along Box Elder Creek and downstream along the Nowood River.

9.2 CHARACTERIZATION OF POTENTIAL STORAGE ALTERNATIVES

The revised list of 40 potential storage alternatives were compiled into a matrix based on the structure of the Level I Matrix. This Matrix (Table 9-3) was compiled from the results of the Level I Matrix and updated based on the Level II Study analysis. The five additional alternatives were included and the criterions established during the Level I Study were applied to the new alternatives in order to compare and reprioritize the potential site alternatives. The Matrix includes the site name, site number, and the latitude and longitude of the alternatives identified to date, as well as characteristics under following information categories:

Category A: Reservoir Description

- On-channel vs. off-channel alternatives: Notes whether the alternative would be located on the primary supply drainage, or would be located off-channel from the primary supply drainage. An on-channel alternative is located...
on a main stem river or stream and filled directly from the upstream watershed. An off-channel alternative is located outside the main river valley, on a minor tributary, or completely off stream. Available water to fill the reservoir is primarily diverted by gravity or pumping from a larger, adjacent watershed to the off-channel site. Off-channel alternatives typically are the more environmentally friendly alternative and preferred if adequate water and storage capacity are available, and if diversion costs are not prohibitive.

- **Direct and indirect supply source:** Lists the supply source(s) for the alternative. A direct supply source is the river or stream that the potential reservoir alternative is sited on. The indirect supply source is the river or stream that the diversion is conveying water from to fill the reservoir (typically for off-channel reservoirs).

- **Supply mechanism:** Lists whether the on-channel alternative will be created by a new dam on the main stem of the Nowood River, a new dam on a tributary to the Nowood River, or enlargement of an existing dam. Lists whether the off-channel alternative will be supplied by an existing diversion/ditch, enlargement of an existing diversion, or a new diversion.

**Category B: Watershed**

- Watershed characteristics (direct and indirect drainage area, elevation, basin size, basin relief, and mean annual precipitation) calculated using the GIS.

**Category C: Reservoir Statistics**

- Reservoir impoundment characteristics (storage capacity, surface area, and water depth) calculated using the GIS and AutoCAD software. Impoundment characteristics are more refined for higher ranked sites that have been evaluated in greater detail.

**Category D: Dam Description**

- Dam embankment characteristics as calculated using the GIS and AutoCAD. The characteristics include the anticipated dam height, embankment length, and the embankment volume. Other characteristics include:
  - **Proposed Type:** The proposed dam type included three different recommendations: earthen, RCC, and concrete arch. The type of dam was proposed based on the site topography or as recommended during geological/geotechnical site visits (14 of the 40 alternatives) conducted in the Level I and II studies.
  - **Storage efficiency:** The storage efficiency for each dam is a measure of the efficiency of the embankment calculated as the ac-ft stored per 1,000 cubic yard (cy) of fill.
- **Method of Reservoir Fill:** Describes how the reservoir would be filled, including none/on channel for on channel reservoirs filled by the drainage they would impound, diversion via an existing irrigation ditch/canal, and diversion with a canal or pipe.

- **Appurtenances:** Describes the diversion proposed to convey water from an indirect source (off-channel alternatives only) in more detail (e.g., diversion via the existing Anita Ditch for Alkali Creek).

- **Size Class:** Alternatives were classified into one of three sizes including 1) small for embankments smaller than 500,000 cy; 2) medium for embankments between 500,000 cy and 1,500,000 cy; and 3) large for embankments larger than 1,500,000 cy.

**Category E: Hydrology**

- **Hydrology model:** Notes how the hydrology for the site was estimated. The estimated available flows for alternatives that were identified during the Level I Study, but were not evaluated in detail during the Project due to fatal flaws (e.g., known geologic constraints, size, wilderness, or landowner input) were derived from the Spreadsheet Model, from Miselis, or comparison to the Nowater drainage gages. Estimated flows for alternatives added or reevaluated during the Project were derived from the StateMOD model. Discussion regarding the hydrologic model development is provided in Section 6.

- **Storage Availability (direct):** Lists the estimated physical flow and the flow available (based on water rights) from the drainage impounded by the alternative. Flows are provided in ac-ft for both dry and normal year simulations.

- **Indirect Supply Source:** Identifies the indirect supply source for off-channel alternatives.

- **Storage Availability (indirect):** Lists the estimated physical flow and the flow available (based on water rights) from the indirect supply source. Flows are provided in ac-ft for both dry and normal year simulations.

**Category F: Geology**

- The suitability of surficial and bedrock geology for the development of a storage site are noted in terms of grades (A through F) or by reference to Tech Memos summarizing the findings from field investigations for those sites that were visited in the field. Red shading is applied to sites where surficial or bedrock geology is a concern. Yellow shading is applied for sites where the geology may be a concern. Green shading is applied for sites where the geology does not appear to be a concern. The assessment for alternatives with letter grades is based off of a desktop review of available geologic references and mapping. The assessment for the remaining alternatives is provided in the referenced Tech Memos. More detailed discussion of geology is provided in Section 8. Subsurface
investigations were not completed during this Project; however, more detailed geotechnical investigations are warranted for sites that are advanced for further study.

Category G: Environmental and Infrastructure Considerations

- Environmental Considerations note wetlands, habitat, fisheries, and water quality considerations for the storage alternatives. Red shading represents environmental considerations that could negatively impact the alternative; yellow represents environmental considerations that should be accounted for, but that might not impact the alternative; and green represents the absence of a particular environmental consideration (e.g., no identified wetlands).

  - Wetlands: Potentially affected wetland acres based on the 2011 National Wetlands Inventory (NWI); except for the wetland acreage noted for Meadowlark Lake and Alkali Creek which are based on the preliminary results from wetland delineations completed by Trihydro in September 2012. The acreage includes wetland acres affected by the proposed reservoir pool and embankment.

  - Big Game Habitat: Identifies the type (seasonal, crucial, or parturition [birthing] range) of big game range encompassed by the alternative footprint, including the proposed impoundment, embankment, and diversion feature(s). Big game considered includes antelope, elk, moose, mule deer, and whitetailed deer.

  - Sage-Grouse: Identifies number of sage-grouse leks located within 2 miles of the alternatives; whether portions of the potential alternative disturbance boundary are located inside the Sage-Grouse Core Area (Core Area); whether portions of the impoundment are within a 0.6-mile buffer of leks inside the Core Area; and notes how many leks inside the Core Area are located within a 4-mile buffer of the alternative disturbance. The estimated alternative disturbance relative to sage-grouse was calculated using the WGFD DDCT for six (Meadowlark Lake, Alkali Creek, Lower Luman Creek, Taylor Draw, Cornell Gulch, and Willow Creek) of the higher ranked alternatives. The DDCT approach is discussed in Section 10.

  - WDEQ Stream Classification: Stream classifications for the stream or drainage to be impounded based on Tables A and B of Wyoming Department of Environmental Quality (WDEQ) Surface Water Standards (WDEQ 2001).

  - Fisheries: Qualitative assessment of fisheries impacts associated with alternatives. Includes comments received from WGFD pertaining to each alternative location during the Level I Study and for six higher ranked alternatives during the Level II Study. Additional discussion of WGFD comments relative to the five (Meadowlark Lake, Alkali Creek, Lower Luman Creek, Taylor Draw, and Willow Creek) higher ranked sites is presented in Section 10.
Infrastructure Considerations note the impacts of each alternative relative to existing infrastructure and irrigated acreage. Red shading represents infrastructure considerations that could be negatively impacted by the alternative; yellow represents infrastructure considerations that should be accounted for, but that might not be impacted by the alternative; and green represents the absence of a particular infrastructure consideration (e.g., no residences directly impacted).

- Irrigated acres inundated: Inundated irrigated acres flooded or removed from production by the dam embankment and impoundment based on 2006 National Agriculture Imagery Program (NAIP) aerial photography.
- Residences: Number of houses and structures affected by the dam embankment and impoundment based upon 2009 NAIP aerial photography. Does not include structures that may be located immediately downstream, but outside the footprint of an embankment.
- Transportation: Length of roads affected by the dam embankment and impoundment based upon 2009 NAIP aerial photography and ESRI street mapping in the GIS.
- Other: Infrastructure such as communications including fiber optics that could be impacted, as well as the length of diversion, if required.

Category H: Economic Considerations

- Estimated construction costs: Estimated construction costs were estimated for the 35 Level I Study storage alternatives during the Level I Study. Construction costs include embankments, spillways, outlet works, and diversion structures. Cost estimates were not developed for sites with noted fatal flaws. Estimated construction costs were also developed during the Project for the five alternatives added during the Level II Study. Cost estimates were also updated during the Level II Study for four highest ranked sites (the fifth site was removed from consideration prior to developing conceptual cost estimates). Further discussion on the cost estimates for the top four ranked sites is provided in Section 13 of this report.
- Total project cost per cubic yard of fill: Provides a means of comparing sites based on the estimated construction costs per cubic yard of embankment fill.
- Total project cost per ac-ft of storage: Provides a means of comparing sites based on the estimated construction costs per ac-ft of storage.
Category I: Ownership

- Ownership for the proposed storage site embankment, impoundment, and diversion structures: Ownership plays an important role as to the feasibility/difficulty of gaining approval and permitting respective alternatives. Red shading represents sites located in the wilderness; these sites are not considered feasible alternatives. Yellow shading represents sites for which at least a portion of the site is located on federally-owned or managed lands. These sites are still considered feasible, but the permitting and approval process is often more onerous. Green shading represents sites that are located on either State or Private lands.

- Landowner interest: Landowners or land management agencies provided or were requested to provide input on the viability of several alternatives during the course of the Level I and Level II studies. Comments, where received, are provided for the alternatives. Red shading indicates sites that are located in wilderness areas or for which the landowner indicated they were not in favor of the site. Yellow shading indicates sites for which the landowner or land management agencies were not contacted. These sites are still considered feasible, but would require consultation prior to advancing for further study. Green shading indicates where the primary landowners were contacted and were in favor of developing the alternative.

Category J: Potential Benefits

- Potential benefits include amount of irrigated acres located directly downstream from the alternative as well as the downstream shortages for both normal and dry years as simulated during the Level I Study or through the StateMOD model (refer to Hydrology Method in Category E). Potential for irrigation water to be exchanged is possible for a majority of the sites; however acres available for irrigation through exchange were not reported under this Category. Potential benefits also include the level of potential flood protection provided by the alternative. Generally, off-channel sites were considered to offer low potential for flood protection while sites on the main stem of the Nowood River were considered to offer moderate to high potential for flood protection.

The results of this Matrix were primarily compiled using ArcGIS 10.0 and AutoCAD Map 3D software. ArcGIS was used to spatially estimate attributes such as watershed area, dam location, impacted wetlands, affected landowners, etc. AutoCAD Map 3D was primarily used to estimate reservoir storage capacities and embankment characteristics. Other information was compiled from input provided by landowners or State and Federal agencies.

9.3 SCREENING OF POTENTIAL STORAGE ALTERNATIVES

In conjunction with compiling the Matrix, a comparison of site characteristics and information gathered from landowners, stakeholders, the Steering Committee, and the WWDO was conducted. Potential storage alternatives
identified in both the Level I and Level II studies were screened using a three step process to identify the top five alternatives in the Watershed. The results of the screening process are summarized in Table 9-4. The screening process is discussed in the following sections.

9.3.1 LEVEL 1 SCREENING
The first screening step evaluated all 40 alternatives identified during the Level I and II studies for ownership constraints. Sites located in wilderness areas, or where private landowners who would be directly affected by the embankment, impoundment, or diversion structures indicated they did not support the alternative, were removed from further consideration. During the first screening level, 11 alternatives (28%) dropped out of the total list leaving 29 alternatives for further evaluation. Alternatives eliminated during the screening process are identified in Table 9-4. The alternatives eliminated due to landowner input could be reevaluated in the future if ownership or landowner perspectives change.

9.3.2 LEVEL 2 SCREENING
The second screening level evaluated alternatives based upon basic technical characteristics. Site evaluation during this level of screening focused on comparing the characteristics listed in the Matrix for the remaining 29 sites. Significant characteristics considered included:

- Feasibility of construction of the reservoir and available storage capacity
- Availability of water either by direct or indirect supply
- Feasibility of diverting water and conveying it to the reservoir
- Opportunity for flood passage via an auxiliary spillway
- Redundancy between alternatives
- Site geology
- Environmental concerns, including consultation with the WGFD
- Cost of construction per ac-ft stored
- Ability to serve downstream shortages
- Location in the Watershed

The second screening removed 17 potential storage alternatives (43%) from further consideration for various reasons noted in Table 9-4. Initially, 19 potential storage alternatives were removed from further consideration, but as
discussed in Section 9.3.3 two of these sites (Lower Luman Creek and Cornell Gulch) were ultimately added back in for further consideration. Generally, the reasons for removing sites from continued consideration were associated with limited storage capacity, high costs per ac-ft, redundancy, and fisheries or sage-grouse concerns.

9.3.3 LEVEL 3 SCREENING

Of the 40 potential storage alternatives identified, 10 alternatives (25%) initially advanced through the level 1 and level 2 screening processes. These 10 alternatives were discussed with the WWDO and the Steering Committee during the April 2011 Steering Committee Meeting in Ten Sleep. Based on these discussions, the Lower Luman Creek and Cornell Gulch sites were identified for further evaluation, bringing the total number of alternatives advanced through the level 1 and level 2 screening processes to 12 (30%).

The third screening step removed alternatives based upon discussion with the WWDO, Steering Committee, and additional analysis of site characteristics. Of the 12 alternatives remaining, four alternatives (Big Trails, Deep Creek, Otter Creek, and Paint Rock Creek) were eliminated based on lack of primary landowner support (Table 9-4). Three other alternatives were removed due to an insufficient water supply and wetland impacts (Lower Brokenback Creek), or a combination of insufficient direct water supply and difficulty of diverting water from the Nowood River to the site (Little Cottonwood Creek and Willow Creek). A short list of five alternatives was developed upon completion of the third screening process. The remaining five alternatives were considered the top potential reservoir storage alternatives in the Watershed.

The four sites removed due to lack of landowner support are considered technically viable sites. These sites may be considered in the future if ownership or landowner perspectives change. Alternatives removed based on low simulated water supply could also be evaluated in the future if continued data collection and refinements to the StateMOD model indicate more water is available for storage at these locations.

9.4 POTENTIAL STORAGE ALTERNATIVES IDENTIFIED FOR ADVANCEMENT

A total of five alternatives were identified during the Project as viable alternatives for beneficial surface water development. The top five storage alternatives identified through the screening process discussed above include: Alkali Creek, Cornell Gulch, Lower Luman Creek, Meadowlark Lake enlargement, and Taylor Draw. These alternatives are capable of providing storage supplies to address shortages across the Watershed, with the potential to provide benefits to irrigators located in both the upper and lower Watershed. Alternatives that were not-selected for the short list should not be discredited and may be revisited as conditions or landowner interests change in the future.
Future studies may discover fatal flaws to one or more of the top five alternatives warranting reevaluation of an alternative previously screened out. Further details of the top five alternatives are summarized below.

### 9.4.1 MEADOWLARK LAKE (TENSLEEP RESERVOIR)

Meadowlark Lake was identified as a Priority 1 alternative during the Level I Study. Enlargement or adjustments to the operation of this existing site is one of the top alternatives noted by local stakeholders. Meadowlark Lake is located on East Tensleep Creek, adjacent to Highway 16, upstream of the confluence with Tensleep Creek in Section 6, Township 48 North, Range 86 West (Figure 9-2). The reservoir is located in the Bighorn National Forest. The site, permitted as Tensleep Reservoir, was formed by the construction of an earthen dam by the CCC Company 841 in 1938. The existing dam consists of a 30-foot tall embankment with the capacity to impound a permitted 3,509 ac-ft. The reservoir has a permitted priority date of January 31, 1938, and includes permitted beneficial uses for: irrigation, domestic, water power, livestock, fish culture, recreational, flood control, erosion control, and fire protection. However, the reservoir, which is managed by the USFS, is not currently being operated to deliver irrigation supply.

Analysis of this alternative took into consideration the beneficial uses of the existing storage right and the ability to provide irrigation water supply downstream of the reservoir. Additional storage capacity could be created either by an upstream or downstream raise of the current dam embankment. The additional storage created by the raise would then be used to augment storage supplies needed to satisfy irrigation shortages that can be physically served by the reservoir, either directly or through exchange. This includes shortages downstream on Tensleep Creek, downstream on the Nowood River from the confluence of Tensleep Creek and the Nowood River, along tributaries to the Nowood River (e.g. Paint Rock Creek) located downstream of the confluence of Tensleep Creek and the Nowood River, and potentially upstream on the Nowood River above the confluence with Tensleep Creek. Additional details on the ability to serve simulated shortages are discussed in Section 12.2.1.6.

A preliminary geological field evaluation was conducted at this site in July 2009. The observations from this investigation are discussed in Section 8.3.1 and Appendix E2. The WGFD, FWS, and ACOE were consulted regarding potential permitting constraints or environmental concerns for this alternative. Preliminary feedback from these agencies is presented in Section 10.4.1. Similarly, a Class I cultural/archaeological literature review was performed for the site and is discussed in Section 11.1.

Primary considerations with this site include the effort/time required to gain approval and complete permitting through the USFS, the historical nature of the existing dam, surrounding cultural features, existing infrastructure, and potential
losses in downstream stream reaches that could reduce the percentage of released flow that reaches downstream irrigated lands.

9.4.2 ALKALI CREEK

During the Level I Study, the Alkali Creek alternative was ranked as a Priority 2 alternative because the available storage volume was assumed to be limited by the alignment of the Anita Ditch along the southern end of the site. However, late in the Level I Study, discussions with the primary landowner indicated the Anita Ditch could be relocated in the area of the proposed reservoir to accommodate additional storage. Additionally, one of the concerns voiced during the end of Level I Study and early in the Level II Study was the absence of a feasible storage site that could serve demand in the Paint Rock Creek tributary. For the above reasons, the Alkali Creek alternative was reevaluated during the Level II Study and the reservoir storage capacity was enlarged (from 2,900 ac-ft to approximately 7,400 ac-ft).

The Alkali Creek dam embankment is located on Alkali Creek, 1.6 miles upstream of its confluence with Paint Rock Creek, north of State Highway 31 in Section 34, of Township 50 North, Range 90 West (Figure 9-3). The embankment and auxiliary spillway would be located on private land, while the impoundment would be partially on private lands and partially on lands administered by the BLM. Preliminary dam and spillway design during the Level II Study indicated that residential homes and irrigated land (irrigated by both flood irrigation and a sprinkler) would be impacted by the auxiliary spillway, embankment, and reservoir pool area. However, discussions with the landowner indicated that these were not significant concerns. Based on the discussions with the landowner, the embankment was enlarged and the auxiliary spillway was relocated so that flows could be routed into a natural drainage channel located to the west of the site.

Along with flows in Alkali Creek, the Anita Ditch could be improved to supply the storage site with water from Medicine Lodge Creek and/or Paint Rock Creek (via the Anita Supplementary Ditch). The Alkali Creek alternative would serve irrigators below the dam embankment along Alkali Creek, along Paint Rock Creek, and along the lower reach of the Nowood River directly and through exchange agreements. Additional details on the ability to serve simulated shortages are discussed in Section 12.2.1. If constructed, this alternative would be able to serve a portion of the overall demand in areas of the Watershed that were communicated to have shortages during the Level I Study. This alternative could also reduce flooding risks to landowners along Alkali Creek, while also providing recreational opportunities in an area that is partially located on lands managed by the BLM.
A preliminary geotechnical field evaluation was conducted at this site in September 2010. The observations from this investigation are discussed in Section 8.3.2 and Appendix E1. The WGFD, FWS, ACOE, and BLM were consulted regarding potential permitting constraints or environmental concerns for this alternative. Preliminary feedback from these agencies is presented in Section 10.4.2. Similarly, a Class I cultural/archaeological literature review was performed for the site and is discussed in Section 11.2.

Primary considerations with this site include the effort/time required to gain approval and complete permitting through the BLM, cultural features, improvements necessary for Anita Ditch, refining the actual storage capacity, sage-grouse considerations, and downstream structures.

### 9.4.3 LOWER LUMAN CREEK

After a topographic review of the Watershed during the Project, two storage alternatives were identified in the Luman Creek drainage: Upper Luman Creek and Lower Luman Creek. The sites were identified to provide additional storage alternatives in the Paint Rock Creek tributary, an area of concern mentioned in public and Steering Committee meetings. However, due to similar capacities between the sites but higher costs associated with the Upper Luman Creek site, only the Lower Luman Creek storage site was advanced for further evaluation. The Lower Luman Creek alternative was considered a favorable site because of its location above irrigated lands in the Paint Rock Creek drainage. Water stored in the reservoir could directly supply irrigated land with supply shortages along the length of Paint Rock Creek. This site also appears to have favorable geotechnical and topographical conditions for construction of an embankment and spillway.

The Lower Luman Creek site is located approximately 1.6 miles upstream of the Luman Creek confluence with Paint Rock Creek in Section 36, Township 50 North, Range 89 West (Figure 9-4). The embankment would be located on lands owned by the State of Wyoming, while the impoundment would be partially on State of Wyoming and partially on private lands. Luman Creek is a small tributary to Paint Rock Creek that flows northwesterly with a contributing drainage area that encompasses a low-elevation (relatively) drainage of the Watershed, which is not expected to yield significant water annually. However, a viable source of water does appear to be available in South Paint Rock Creek. Water from this drainage could be conveyed to Laddie Creek via a 6.2 mile canal/pipeline. The water would then flow downstream in Laddie Creek before being diverted a second time to Luman Creek through a 2,000-foot long tunnel.

A preliminary geotechnical field evaluation was conducted at this site in September 2010. The observations from this investigation are discussed in Section 8.3.3 and Appendix E1. The site does not impact irrigated acres or infrastructure.
and was well-received by the landowner. However, the cost to divert water from South Paint Rock Creek is high, elevating the storage cost per ac-ft.

The Lower Luman Creek site was discussed with the WGFD and the ACOE in December 2011. The WGFD indicated that South Paint Rock Creek is critical habitat for the Yellowstone Cutthroat and requested that alternatives diverting water from this drainage be removed from further consideration. Other feedback from the WGFD relative to the Lower Luman Creek site is presented in Section 10.4.3. A preliminary design, in more detail than completed for other sites screened out during the second or third screening processes discussed in Sections 9.3.2 and 9.3.3, was completed for this site and is discussed in Section 12.2.3. However, the site was ultimately pulled from continued consideration prior to development of conceptual designs based on the WGFD concerns.

9.4.4 TAYLOR DRAW

Taylor Draw was identified as a Priority 1 alternative during the Level I Study. Taylor Draw is a proposed off-channel alternative on an ephemeral drainage adjacent to Otter Creek that flows into the Nowood River from the east. The site is located in Section 25, Township 46 North, Range 88 West (Figure 9-5). The proposed dam location for the Taylor Draw site is near the mouth of Taylor draw upstream of the confluence with the Nowood River and located entirely on State of Wyoming owned land. The preliminary impoundment is also located entirely on State of Wyoming land. Due to the limited direct water supply, a 6.5-mile gravity fed diversion from Otter Creek is proposed to supply water to the reservoir location. This diversion would cross private lands, State of Wyoming lands, and BLM. The alternative is located in the upper portion of the Watershed where the greatest shortages along the Nowood River have been identified, making this a favorable alternative. The Taylor Draw alternative could supply water to irrigators along the Nowood River and its tributaries.

A preliminary geological field evaluation was conducted at this site in July 2009. The observations from this investigation are discussed in Section 8.3.4 and Appendix E2. The WGFD, FWS, and ACOE were consulted regarding potential permitting constraints or environmental concerns for this alternative. Preliminary feedback from these agencies is presented in Section 10.4.4. Subsequently, a Class I cultural/archaeological literature review was performed for the site and is discussed in Section 11.3.

Similar to the Lower Luman Creek alternative, a preliminary design was completed for this alternative and is discussed in Section 12.2.4. The Taylor Draw alternative is located within the Core Area, and approximately 0.6 miles from a known lek. A DDCT analysis was performed and the impacted area percentage was calculated to be 1.6%, less than the 5% criteria established by the WGFD. Additional discussion on sage-grouse considerations for this site is provided
in Section 10.4.4. This site appears to be technically viable with a sufficient water supply. Additionally, with the exception of its proximity to the sage-grouse lek, this alternative has limited environmental concerns. However, the site was ultimately pulled from continued consideration prior to development of conceptual designs due to discussions with landowners that would be crossed by the proposed diversion (Table 9-4). The Taylor Draw alternative has the potential to benefit water supply and should be maintained as an alternative for future consideration should there be a change in land ownership or landowner perspectives.

9.4.5 CORNELL GULCH

Cornell Gulch is a storage alternative that was identified by the WWDO during the Project as an off-channel reservoir that could store available water diverted from the Nowood River. The dam embankment is located west of the Bear Creek and Nowood River confluence in Section 20, Township 42 North, Range 88 West (Figure 9-6) on an ephemeral drainage that flows into the Nowood River from the west. The storage site was identified as favorable due to its location in the upper Watershed and potential to supply downstream users. The site topography also appeared to be feasible for development of a reservoir. An approximately 3-mile long diversion would be needed to convey water from the Nowood River to fill and maintain water levels in the reservoir. The Cornell Gulch alternative would serve irrigators along the Nowood River.

This off-channel alternative would provide the potential to store available flows from the Nowood River with reduced environmental impacts and concerns as compared to an alternative on the main stem. The site is located in the Core Area, but is not located near known leks. A DDCT analysis was performed and the impacted area percentage was calculated to be 3%, less than the 5% criteria established by the WGFD. This site was not discussed with the WGFD, FWS, ACOE, or BLM. However, input received on the Willow Creek site from the WGFD and ACOE would be representative of issues to consider for this site.

A preliminary geotechnical field evaluation was conducted at this site in September 2010. The observations from this investigation are discussed in Section 8.3.5 and Appendix E1.

Similar to the Lower Luman Creek alternative, a preliminary design was completed for this alternative and is discussed in Section 12.2.5. However, the site was ultimately pulled from continued consideration prior to development of conceptual designs due to the difficulty of conveying water from the Nowood River to the site and concern about available flow for storage (Table 9-4). Consequently, this site has the potential to provide benefits with limited environmental and landowner concerns and should be reviewed in the future as additional data is collected and the StateMOD model is refined.
9.5 ADDITIONAL STORAGE ALTERNATIVES ELIMINATED

Of the top five alternatives discussed above, two alternatives are recommended for further evaluation in future studies; Alkali Creek and Meadowlark Lake. Based on issues discussed during meetings with environmental agencies (discussed in Section 10), further engineering evaluation, and additional discussions with landowners, Lower Luman Creek, Taylor Draw, and Cornell Gulch are not recommended for further evaluation at this time. Unfortunately this places an emphasis on storage development in the lower portion of the Watershed, providing limited benefits through exchanges to the irrigators in the upper portion of the Watershed. As described in previous sections, Taylor Draw and Cornell Gulch should be maintained as potential alternatives should additional data result in changes to StateMOD model simulations of the water supply available for storage, or changes in ownership of affected lands in the upper portion of the Watershed take place.
10.0 PERMITTING AND ENVIRONMENTAL MITIGATION

Development of storage alternatives in the Watershed will require following the NEPA (National Environmental Policy Act) process, coordinating with affected or interested federal and state agencies, and obtaining appropriate permits. These processes and coordination can be arduous, taking several years or more to complete. Investigations, modeling, and analysis completed under the Level I and Level II studies is targeted not only at evaluating the need for and feasibility of providing storage in the Watershed, but also at developing information that will be used to support the NEPA process. During the course of the Level II Study, the project team commenced the process of coordinating with affected or interested agencies and soliciting their initial feedback on the top five storage alternatives. Collection of environmental baseline data that will be used to compare and contrast alternatives also began during the Level II Study. These efforts, discussed in the following sections, provide guidance for investigations to be completed during future Project phases.

10.1 NEPA

The Level I Study included a review of the NEPA process as applicable to development of a reservoir. A synopsis of the information presented in the Level I report is provided within this section.

Enacted in 1969, NEPA was one of many legislative and executive responses to the growing concern regarding the condition of the environment and the affect that human actions were having on it. NEPA is an open, public involvement process that must be undertaken to evaluate projects that are located on federally managed or owned lands, projects funded with federal funds, and/or projects that require federal permits or other federal actions. The purpose of NEPA is to evaluate and avoid (if possible), or minimize and mitigate the environmental impacts resulting from projects that involve federal resources. The process requires documentation and evaluation of impacts and benefits associated with a project, including consideration of multiple alternatives (ACE 2010).

An abridged discussion of NEPA process steps summarized in the Level I Study follows:

- **Purpose and Need Statement.** The Purpose and Need statement should be developed early in or prior to commencing the NEPA process. This statement should provide the purpose for the project and provide data or details to support the need for the project. Development of the Purpose and Need should consider the range of alternatives available for the project, as well as the agencies involved with the NEPA process (ACE 2010).

The hydrologic modeling performed as part of the Level II Study provides much of the data to support the need for storage in the Watershed. Other supporting data and potential benefits were identified during discussions with Watershed stakeholders and as part of the Watershed Management Plan prepared during the Level I Study.
• **Project Alternatives.** Appropriate alternatives, including a No Action alternative, are required to be evaluated under the NEPA process. This allows project sponsors, the lead and coordinating agencies, and the public to evaluate a range of impacts and benefits. Impacts typically considered as part of reservoir alternatives include: loss of or impacts to the nature of wetland or riparian areas; impacts to threatened and endangered species, impacts on aquatic species of concern; impacts to cultural resources; and impacts on terrestrial species of concern (ACE 2010).

While numerous storage alternatives were screened out during the potential site evaluation process or during consultation with agencies, these sites may still be considered as alternatives to a preferred alternative site. These sites may be evaluated during the NEPA process to determine if they have lower environmental impacts (while still providing benefits) as compared to one of the preferred alternatives. For example, the Upper and Lower Luman Creek sites provide benefits to similar areas as the Alkali Creek site and could be considered as alternatives to the Alkali Creek site. Based on evaluations during this Project, both the Upper and Lower Luman Creek sites result in more significant environmental impacts as compared to the Alkali Creek site, but they could still be considered under the NEPA process.

• **NEPA Documentation Path.** There are essentially two documentation options under NEPA. The first is an Environmental Impact Statement (EIS), which evaluates multiple alternatives and can take several years to complete. The second option is an Environmental Assessment (EA), which can involve the analysis of one or more alternatives. While still requiring considerable time, an EA can often be completed in less than 18 months. The result of an EA is either a Finding of No Significant Impact (FONSI) or a recommendation to complete an EIS. Choosing to pursue an EA has the potential to save project time, but if the EA does not result in a FONSI and an EIS is required, the project can be delayed (ACE 2010). The decision on which documentation approach to pursue will be determined in consultation with the WWDC and the lead NEPA agency, but will likely be an EIS.

• **Public Involvement.** Public outreach and involvement is critical to, and continuous through the NEPA process. The level of involvement and input received can greatly affect the alternatives screening process, mitigation measures, and the documentation approach (EIS or EA). For these reasons, it is important that the public understand the Purpose and Need for the project and that the benefits and impacts associated with project alternatives are well documented and clearly presented (ACE 2010).

The process of informing the local public about the Project, its purpose, and the need for the Project has begun with the Watershed meetings held during the course of the Level I and Level II studies. However, additional public meetings and more rigorous public involvement will be associated with the NEPA process.

• **Environmental Baseline Data.** Collecting and analyzing comprehensive environmental data is an important step in the NEPA process. This data allows for analysis of impacts associated with alternatives. Collecting this information early in the project allows for the impacts to be considered and integrated into the development of
alternatives; allowing for alternatives that are more likely to avoid or minimize impacts. Collaborating with agencies early in the process can also aid in the development of appropriate alternatives and speed up the subsequent NEPA analyses (ACE 2010).

Collection of baseline environmental data commenced during the Level I Study and continued through the Level II Study. Coordination and requests for input from some of the key agencies that will be involved with the NEPA process was also initiated during the Level II Study. This information is presented in later subsections.

• **EA or EIS.** The Draft and Final EA or EIS are developed to present an assessment of the project alternatives, and the benefits and impacts associated with each alternative. The stages of document development include:

  1. Preparation of a Preliminary Draft for internal review.
  2. Preparation of a Draft that incorporates comments from the Preliminary Draft and is then circulated for public review. This document would be the subject of a public hearing.
  3. Preparation of a Preliminary Final that incorporates feedback on the Draft and is provided for internal review.
  4. Preparation of a Final that incorporates comments on the Preliminary Final. This document would also be circulated for public review and be the subject of a public hearing.
  5. A Record of Decision (ROD) would then be prepared as the final step of the NEPA process (ACE 2010).

### 10.2 AGENCY COORDINATION

As outlined in the Level I Study, agency coordination will include those agencies involved in the NEPA process as well as agencies with other land use or environmental regulatory authority. Federal agencies that are likely to be involved with evaluation, clearance, approval, and permitting of storage alternatives for this Project include, but may not be limited to:

- USFS (for alternatives located on USFS lands)
- BLM (for alternatives located on BLM managed lands)
- Environmental Protection Agency (EPA)
- ACOE
- FWS
Either the USFS or the BLM (depending on the storage alternative under consideration) will likely assume the role of lead federal agency, although the ACOE could assume the lead role for alternatives not located on federal lands, but that still include impacts to wetlands.

Wyoming state agencies that may be involved with the process include, but may not be limited to:

- WDEQ
- WSEO
- State Historic Preservation Office (SHPO)
- Board of Land Commissioners / State Lands and Investments Board (SLIB)
- WGFD

### 10.2.1 PRELIMINARY CONSULTATIONS

Initial consultations with agencies that are anticipated to be involved with the NEPA process and those responsible for managing potentially impacted resources were undertaken during the Project. Preferred water supply alternatives were discussed with resource and permitting agencies to gain technical input regarding potential environmental and permitting concerns and approaches. Agencies contacted include the WGFD, ACOE, FWS, and BLM.

While not formally contacted to request input, the WSEO has been involved during the course of the Project through representation from the SBOC District III office. The WWDO had informal discussions with the USFS regarding the Meadowlark Lake alternative, but a request for technical input was not submitted. Coordination with the USFS will be necessary during future phases of the Project, if an enlargement to Meadowlark Lake continues to be evaluated.

Trihydro and the WWDO met with the WGFD and the ACOE on December 2, 2011, to discuss the Project background and goals, the list of top-ranked alternatives, associated concerns/issues, and the approach for gaining agency input on the alternatives. The meeting minutes are provided in Appendix G1. During this meeting, five storage alternatives were reviewed, including:

1. Alkali Creek
2. Meadowlark Lake enlargement
3. Upper and Lower Luman Creek
4. Taylor Draw

5. Willow Creek (not on the short-list of alternatives, but was viewed as a favorable site until late in the Project)

Based on issues discussed during the meeting, further engineering evaluation, and additional discussions with landowners, Luman Creek, Taylor Draw, and Willow Creek were not advanced for further consideration. Therefore, environmental reviews and comments provided by the BLM, FWS, and further review completed by the WGFD were focused on the evaluations of the Meadowlark Lake enlargement and Alkali Creek alternatives.

Trihydro provided Project documentation and requested feedback on alternatives from the WGFD, FWS, and BLM in early spring 2012. The request letters and the agency response letters are provided in Appendix G2 (WGFD), Appendix G3 (FWS), and Appendix G4 (BLM). The ACOE indicated during the December 2011 meeting that they would prefer to provide their comments via a review of the Level II report. Environmental and permitting concerns and considerations identified through communication with these agencies and review of public documents is discussed in Section 10.3. Concerns and considerations specific to the five storage alternatives discussed are presented in Section 10.4.

10.3 ENVIRONMENTAL CONSIDERATIONS

10.3.1 TERRESTRIAL RESOURCES

10.3.1.1 PROPOSED, THREATENED, ENDANGERED, AND EXPERIMENTAL SPECIES

Proposed, threatened, endangered, and experimental species potentially affected by the proposed alternatives require a formal consultation with the FWS. In response to the request for comments on the Alkali Creek and Meadowlark Lake alternatives, the FWS reviewed the alternatives according to the Endangered Species Act of 1973 as amended, (16 U.S.C. 1531 et seq.), Migratory Bird Treaty Act (MBTA), 16 U.S.C 703, and the Bald and Golden Eagle Protection Act (BGEPA), 16 U.S.C. 668. The FWS also review the alternatives relative to the Fish and Wildlife Coordination Act and the Fish and Wildlife Act of 1956, as amended, 70 Stat. 1119, 16 U.S.C. 742a-742j (FWS 2012). The FWS indicated that there are no known threatened or endangered species in the area of the two alternatives. If other alternatives are evaluated in the future, research on threatened and endangered species in those areas would still need to be conducted.

The FWS did indicate that migratory birds should be considered for both alternatives and that sage-grouse should be considered for the Alkali Creek site (consistent with discussions with the WGFD during the December 2011 meeting).
10.3.1.1 MIGRATORY BIRDS

The FWS explained in their response letter that federal agencies have an obligation to protect all species of migratory birds, including eagles and raptors, under the MBTA, BGEPA, and Executive Order 13186 (66 FR 3853; January 17, 2011) which may occur on lands under their jurisdiction (FSW 2012). Under the MBTA it is unlawful to pursue, hunt, take, capture, kill, or sell birds listed as migratory birds (a list of Migratory Birds protected by the MBTA can be found on the FWS website at www.fws.gov). The statute does not discriminate between live and dead birds and grants full protection to any bird parts including feathers, eggs, and nests. The BGEPA prohibits anyone, without a permit issued by the Secretary of the Interior, from pursuing, shooting, shooting at, poisoning, wounding, killing, capturing, trapping, collecting, molesting, or disturbing bald eagles, including their parts, nests, or eggs. Work that could lead to the taking of a migratory bird or eagle, their young, eggs, or nests should be coordinated with the FWS before any actions are taken.

10.3.1.1.2 SAGE-GROUSE

The Greater Sage-Grouse has been subject to several petitions to list the species as threatened or endangered under the Endangered Species Act. However, the FWS has determined that listing the sage-grouse under the Act is currently precluded by other higher priority actions resulting in the species being listed as a candidate species; meaning the species and its habitat still needs effective management, albeit at the state or local level. The FWS is required to review the status of all candidate species yearly and determination of the final listing by the FWS is expected sometime in 2015. Until a final listing is made, the State of Wyoming has management authority over the species within Wyoming (FWS 2012).

The State of Wyoming has determined that if the species is listed as threatened or endangered it would have a significant adverse effect on the economy, custom, and culture of the State of Wyoming. Therefore, the State of Wyoming has adopted a Core Population Area strategy to provide for sage-grouse conservation. The strategy is set forth in the Governor’s Executive Order 2011-5. According to the Executive Order 2011-5, any new development or land use post August 1, 2008, that occurs within an identified Core Area should only be undertaken when no decline in sage-grouse populations can be demonstrated (Core Areas and leks in the Watershed are mapped on Figure 10-1). To determine if populations are affected, all activities are evaluated within the context of maximum allowable disturbance of suitable sage-grouse habitat. The maximum disturbance allowed is analyzed using the DDCT (Density Disturbance Calculation Tool), which includes any sage-grouse leks (gathering of males for the purposes of competitive mating display) within a 4-mile radius of the project. The evaluation is then submitted to the WGFD for review and approval. The methodology involved in running the DDCT can be found in Executive Order 2011-5 or on the Wyoming DDCT website (http://ddct.wygisc.org/).
Activities planned within a Core Area must meet the following conditions:

- **Surface Disturbance** - The total surface disturbance calculated by the DDCT is limited to no more than 5% of the total suitable habitat within the DDCT examination area.

- **Surface Occupancy** - All activities are prohibited within 0.6 miles of the perimeter of occupied sage-grouse leks.

- **Seasonal Use** - Activity is allowed from July 1 to March 14 outside of the 0.6 mile perimeter of a lek in Core Areas where breeding, nesting, and brood-rearing habitat is present. In areas with winter use only, activity is allowed from March 14 to December 1.

Activities in habitat not suited to sage-grouse (area outside of the delineated Core Area) will be allowed year-round; however, no more than a ¼-mile no surface occupancy standard and a 2-mile seasonal buffer should be applied to occupied leks. The WGFD (and other applicable agencies) should be consulted regarding any proposed or alternative projects that may have the potential to impact sage-grouse habitat.

### 10.3.1.2 BIG GAME

As discussed in the Level I Study, the Watershed contains both seasonal and crucial habitat for multiple big game species including, pronghorn (antelope), elk, moose, mule deer, and white-tailed deer. Figures illustrating these habitat areas are provided in Appendix G5. The WGFD develops maps and datasets for statewide and regional use to aid in the understanding of the spatial and temporal patterns of land/habitat use of each species. With this increased understanding, wildlife managers are better able to maintain and enhance populations and important habitats.

Seasonal ranges are defined as delineated ranges that are important in each season for certain biological processes in a species. Seasonal range boundaries are based on long-term observation data, specific research projects, and professional opinion. Crucial habitat or range is defined as those seasonal ranges or habitats that have been documented as the determining factor in a population’s ability to maintain itself at a certain level over an extended period of time. Data used during the Level II Study represents updated range boundaries included in the 2011 dataset available from the WGFD. Ongoing coordination with the WGFD (and other applicable agencies) is recommended regarding potential impacts and potential mitigation measures for crucial big game habitat as alternatives advance to the next level of study.
10.3.2 AQUATIC RESOURCES

10.3.2.1 FISHERIES AND OTHER AQUATIC RESOURCES

A preliminary characterization of aquatic considerations relative to the Watershed was discussed in the Level I Study. For the Level II Study, range datasets developed for Wyoming’s State Wildlife Action Plan (SWAP) in 2010 were evaluated along with the information collected during the Level I Study for the Watershed. Range datasets were created for the SWAP to classify fish species classified as Species of Greatest Conservation Need (SGCN). Areas were mapped by the WGFD using the 5th level Hydrologic Unit Code (HUC) boundaries and refined based on public input.

Fish species identified in the Watershed using the SWAP range dataset include:

- Burbot
- Flathead Chub
- Mountain Whitefish
- Plains Minnow
- Sauger
- Shovelnose Sturgeon
- Sturgeon Chub
- Western Silvery Minnow
- Yellowstone Cutthroat

A majority of the identified fish species use the lower portion of the Nowood River, with the exception of the Yellowstone Cutthroat, Mountain Whitefish, Flathead Chub, and Burbot. These species are shown to use the higher portions of the Watershed. Habitat extents for each individual SGCN fish species are shown on Figures G5-6 through G5-14 in Appendix G5.

During the December 2011 meeting with the WGFD, a species of particular interest was the Sauger. The WGFD discussed that the Sauger is a high priority fish species that use the lower portion of the Nowood River and travel upstream along the Nowood River beginning in April and going through May. The WGFD expressed concerns regarding the potential to entrain these fish in the reservoirs due to the design of diversion structures. Therefore, diversions structures would need to include measures/screens to limit fish entrainment. The WGFD also discussed the effect of reservoirs on late season flows and water temperatures, but these were determined to be less of a concern.
10.3.3 WETLAND RESOURCES

Recognizing the potential for continued loss or degradation of the Nation's waters, the US Congress enacted the Clean Water Act, formerly known as the Federal Water Pollution Control Act (33 U.S.C. 1344). The objective of the Act is to maintain and restore the chemical, physical, and biological integrity of the waters of the United States, including wetlands. Riparian areas and wetlands are ecologically important as they aid in maintaining stream flows, reducing erosion, and providing wildlife habitat.

GIS mapping from the NWI was acquired to geospatially identify the potential extent, approximate location, and type of wetlands within the Watershed. NWI mapped wetlands are shown on Figure 10-2. The total estimated acreage inundated by each alternative dam embankment, impoundment, or diversion are presented in the Matrix in Table 9-3. Formal wetland delineation in accordance with ACOE guidelines was beyond the scope of this Level II Study and was not conducted with the exception of wetlands at the Alkali Creek and Meadowlark Lake sites. At the time of this report, formal wetland delineations following ACOE guidelines were completed for Phase II of the Study along Alkali Creek and around Meadowlark Lake. Delineated values from the September 2012 wetland delineations for these two sites are presented in this report. All other sites report inundated wetlands based on NWI mapped wetlands. Qualitative observations of whether or not wetlands existed within the approximate footprints of storage alternatives were made during geotechnical/geological site visits, but mapping was not completed.

A formal delineation of wetlands will be required prior to, or as part of the NEPA process for selected alternatives, including other areas of potential disturbance (e.g., off site borrow areas) to determine the level of impacts to wetlands and potential mitigation measures. A more formal consultation will be initiated with the ACOE in the next level of study to check that wetland delineations are acceptable and comply with Section 404 of the Clean Water Act. Discussion regarding the nature and extent of required mitigation will also be undertaken. The WGFD and BLM (if applicable) will be consulted if loss of wetlands or riparian habitat is anticipated to impact terrestrial or aquatic species (e.g., moose, song birds, migratory birds).

10.4 ENVIRONMENTAL SITE EVALUATIONS

Specific issues, concerns, or considerations raised during the December 2011 meeting with the WGFD and the ACOE, or in comment letters received from the WGFD, FWS, and BLM relative to five storage alternatives are presented in this section. Specific comments are provided in the December 2011 meeting minutes and the response letters from the individual agencies that are provided in Appendix G.
10.4.1 MEADOWLARK LAKE

Terrestrial Considerations
Preliminary evaluation provided by Trihydro identified that the site is seasonal habitat for mule deer, moose, and elk. The site does not appear to affect crucial wildlife range and, therefore, was not evaluated further for terrestrial concerns by the WGFD. The site also does not fall within the Core Area and sage-grouse concerns were not raised for this alternative.

The FWS indicated that there were no threatened or endangered species identified near the Meadowlark Lake site. However, the FWS also provided additional comments on migratory birds and explained that work that could lead to the take of a migratory bird or eagle, their young, eggs, or nests should be coordinated with the FWS.

Aquatic Considerations
The primary concern with the site from the WGFD during the December 2011 meeting was fish loss from the reservoir. The WGFD mentioned that fish tend to leave the reservoir during high flows and become trapped downstream of the dam as the fish ladder at this site no longer functions. Fish that leave the reservoir tend to stay between the dam and a steep, losing reach of East Tensleep Creek, approximately 0.5 miles downstream. The WGFD expressed concern that a reservoir enlargement would increase flows from the reservoir and increase fish loss. The WGFD recommended identifying methods to limit fish leaving the reservoir as well as a means (e.g., reconstructed fish ladder) for fish that do leave to return to the reservoir. Previously the WGFD considered installing a sill to limit fish loss.

The WGFD also raised concerns with an approximately 100-yard losing stream section/sink downstream of the reservoir, as well as other losing reaches downstream. The WGFD noted that year-round flow releases would be best for fisheries, but that due to the downstream sinks this would not be an effective practice. The WGFD also recommended that a stream loss study/ additional stream gaging be conducted along Tensleep Creek and its tributaries to gain a better understanding of losses and possible ways to convey water from the reservoir for downstream users and fisheries. Additional concerns were raised relative to the Wigwam Fish Rearing Station, located downstream on a tributary to Tensleep Creek. This hatchery complex is fed by springs in the area. The WGFD wants to avoid impacts to the quality or quantity of the spring water and would like a better understanding of flows relative to the Meadowlark Lake enlargement alternative.

Wetlands
Various raises to the embankment have been considered, including 5-foot, 10-foot, and 15-foot raises. These raises have the potential to impact 3.2, 6.8, and 12.3 acres of on-site delineated wetlands, respectively (based on Level II, Phase II wetland delineations). Discussions during the December 2011 meeting with the ACOE indicated that wetland
mitigation should be evaluated in more detail after the ability to permit the alternative is determined. The ACOE stated that on-site wetland mitigation is preferred and should be investigated prior to looking at off-site mitigation.

10.4.2 ALKALI CREEK

Terrestrial Considerations

In the letter response provided by the FWS, there were no threatened or endangered species identified near the Alkali Creek site. However, the FWS provided additional comments on migratory birds and sage-grouse that are/could reside in the area. According to the FWS, work that could lead to the take of a migratory bird or eagle, their young, eggs, or nests should be coordinated with the FWS before any actions are taken. Also activities that result in loss or degradation of sage brush habitats that are important to the sage-grouse should be closely evaluated and discussed with the WGFD.

Evaluation provided by the WGFD determined that the site is a yearlong habitat for antelope and winter to yearlong habitat for mule deer and white-tailed deer. The WGFD determined that development of riparian habitat on the edges of the reservoir should mitigate for loss of existing upland habitats for big game species. However, they raised the concern that by enhancing the habitat around the reservoir, additional problems could be created on the adjacent crop lands due to the increase in deer and antelope.

The Alkali Creek site is located within (along the edge) of the Core Area delineated in 2010. A DDCT was originally calculated by Trihydro resulting in an 11.9% surface disturbance (Figure 10-3). An additional DDCT was also completed and evaluated by the WGFD resulting in an 11.9% surface disturbance. The percent surface disturbance included 11.7% existing disturbance, largely associated with irrigated lands, only 0.2% associated with the potential reservoir. The 11.9% surface disturbance calculated through the DDCT is over twice the threshold of 5% as required in the Governor’s Executive Order 2011-5. For future consideration of the Project, the WGFD recommended that the site be significantly reconfigured to meet compliance with the Governor’s Executive Order 2011-5. Evaluation of the habitat suitability for sage-grouse is also recommended to determine if the proposed disturbance will affect suitable sage-grouse habitat or not.

A portion of the reservoir impoundment would be located on BLM owned lands. Therefore, a technical evaluation was also completed by the BLM. Evaluation by the BLM did not identify additional wildlife issues beyond the WGFD comments. Additional resource concerns or issues including realty, cultural-paleontology, soils, grazing, hydrology/riparian, and recreation were identified by the BLM (Appendix G4).
Aquatic Considerations
Concerns with the site in regard to aquatic life were initially discussed during the December 2011 meeting. During the meeting, the WGFD suggested that a minimum fish pool should be determined. The WGFD discussed that a guideline or rule of thumb is typically 25% to 30% of the overall storage should be associated with the minimum pool, with 25% of the area 12 to 15 feet deep. At the time of the meeting, minimum pools had not yet been established.

The WGFD was also concerned with the potential for fish entrainment (a concern for all sites involving diversions) in the reservoir due to the diversion from Medicine Lodge Creek. Medicine Lodge Creek and Paint Rock Creek are both productive game fisheries. The WGFD recommended that the diversion structure(s) include some form of screen and that a screen at the diversion from Medicine Lodge Creek would be preferred; as opposed to installing a screen on the downstream diversion from the Anita Ditch near the reservoir embankment.

The amount of water diverted was also a concern to the WGFD. The WGFD does not want Medicine Lodge Creek to dry up from diversions to the reservoir. The WWDO and Trihydro explained that a minimum flow would be left in the stream and that flow would not be significantly depleted in Medicine Lodge Creek as a result of diversions to the reservoir.

Wetlands
Construction of Alkali Creek could impact approximately 1.8 acres of on-site delineated wetlands (based on Level II, Phase II wetland delineations). BLM identified in their comments that a riparian segment was inventoried and assessed in 1999 (0.69 miles in length and located on public land P0076A) and would need to be mitigated. This riparian segment corresponds to the mapped wetland acreage.

The ACOE noted during the December 2011 meeting that wetlands disturbed by diversion pipelines or ditches should also be accounted, as ditches tend to seep and wetlands can be created downslope. The ACOE cautioned that converting an existing ditch to a pipe may cause wetlands created by ditch seeps to dry-up. The ACOE recommended that anything with surface flow be considered as jurisdictional at this stage of the Project.

Water Quality
During their evaluation, the FWS identified that the site may have potential water quality concerns due to the geologic substrate. The Alkali Creek watershed is located on potentially seleniferous geologic formations. Impoundment of water that has come into contact with seleniferous formations could possibly create a hazard for sensitive species of fish and aquatic birds. The FWS recommended that water quality impacts, specifically selenium, be assessed for this alternative (FWS 2012). According to the BLM evaluation there has been continuous water quality data, along with
stream flow measurements and soil moisture data collected on Alkali Creek upstream of the site since 2009. The BLM noted that this data may be beneficial to increase the accuracy of the hydrology model and water quality parameters.

Additional Considerations
Evaluation provided by the WGFD and discussed in their response letter indicated that a guaranteed public access road to the site was not mentioned in the letter. The WGFD commented on how a designated road for public access should be part of the mitigation. The designated access was previously brought up during the December 2011 meeting when funding for the reservoir was discussed. The access route for the site, if it crosses public land, could in turn provide an access point to public (BLM) lands that were previously difficult to access due to surrounding private lands. This may be viewed as an additional benefit, but could potentially also cause concern for landowners.

10.4.3 LOWER LUMAN CREEK
The Lower Luman Creek site (and Upper Luman Creek site by association) was discussed during the December 2011 meeting. Based on WGFD concerns with diverting water from South Paint Rock Creek, which is critical habitat for Yellowstone Cutthroat, this alternative was removed from further consideration. Therefore, formal requests for input on the site were not submitted to the agencies.

Terrestrial Considerations
The Lower Luman Creek site falls within seasonal habitat for antelope, mule deer, white-tailed deer, moose, and elk; and within the crucial ranges for elk and mule deer.

The dam embankment and reservoir impoundment are located entirely within the Core Area delineated in 2010. A preliminary DDCT was completed by Trihydro, but this was not submitted to the WGFD due to the site being removed from the short list of alternatives. A preliminary surface disturbance amount of 2.18% (2.03% associated with existing disturbance) was calculated for the site (Figure 10-4). The surface disturbance falls within the 5% disturbance limit set in the Governor’s Executive Order 2011-5. The DDCT amount should be recalculated and confirmed if this alternative is recommended for further evaluation in future investigations.

Aquatic Considerations
The greatest concern raised by the WGFD during the December 2011 meeting was the presence of Yellowstone Cutthroat Trout in South Paint Rock Creek. Luman Creek is an ephemeral drainage and the conceptual design anticipated water being diverted via a pipeline from South Paint Rock Creek to Laddie Creek. The water would then be diverted from Laddie Creek through a tunnel to Luman Creek. During the meeting, the WGFD discussed that South
Paint Rock Creek is a critical stream to the Yellowstone Cutthroat. The WGFD is currently working on a restoration project in the upper end of this drainage specifically for the Yellowstone Cutthroat. The WGFD highlighted this as their biggest fisheries concern of any of the alternatives discussed during the December 2011 meeting. Therefore, this site was withdrawn from further consideration under this Project. However, if the site is recommended for evaluation in future investigations, the potential entrainment of fish in the diversion/reservoir is a concern and some means of screening fish should be incorporated into the design.

Wetlands
Based on a review of the 2011 NWI mapping, wetlands do not appear to exist within the alternative footprint.

10.4.4 TAYLOR DRAW
The Taylor Draw site was discussed during the December 2011 meeting; however, the site was later removed from the list of alternatives due to landowner input. The site was removed prior to requests for information being forwarded to agencies. Therefore, formal requests for input on the site were not submitted to the agencies.

Terrestrial Considerations
The Taylor Draw site falls within seasonal habitat for antelope, mule deer, white-tailed deer, and elk; and within the crucial range for mule deer.

The dam embankment, reservoir impoundment, and diversion are located entirely within the sage-grouse Core Area delineated in 2010. A preliminary DDCT was completed by Trihydro, but not submitted to the WGFD due to the site being removed from the short list of alternatives. A preliminary surface disturbance amount of 1.6% (1.34% associated with existing disturbance) was calculated for the site (Figure 10-5). The surface disturbance falls within the 5% disturbance limit set in the Governor’s Executive Order 2011-5. The DDCT amount should be recalculated and confirmed if this alternative is recommended for further evaluation in future investigations.

Aquatic Considerations
The WGFD recommended that flows not be diverted during the winter months due to potential impacts to fish. Lower Otter Creek is a productive fishery and studies performed by the WGFD have shown that winter flows are critical to fish survival and that reducing the flows during winter months could be detrimental to the Otter Creek fishery. The WGFD also recommended that some form of fish screen be incorporated into the diversion structures to reduce fish entrainment.
During the December 2011 meeting, the ACOE questioned the effect of this site on other drainages due to water exchanges. Their point was that a junior water right on another drainage (e.g., Spring Creek) that would not have been able to divert water later in the year might now have the ability to divert water as a result of exchanges or downstream senior rights being satisfied. Under this scenario less flow might then be in the stream than would have been present under previous practice. This decrease in flow could have a negative effect on surrounding habitat used to sustain certain aquatic species. The ACOE suggested this possibility be reviewed as part of site analysis.

Wetlands
Based on a review of the 2011 NWI mapping, wetlands do not appear to exist within the alternative footprint.

10.4.5 WILLOW CREEK
The Willow Creek alternatives was discussed during the December 2011 meeting; however, the site was later removed from the list of alternatives due to a limited supply of available water, costs, and geotechnical concerns near the dam embankment. Therefore, formal requests for input on the site were not submitted to the agencies.

Terrestrial Considerations
Willow Creek falls within the seasonal habitat for antelope, mule deer, white-tailed deer, and elk; and within the crucial range for mule deer.

The dam embankment, reservoir impoundment, and diversion are located entirely within the Core Area delineated in 2010. A preliminary DDCT was completed by Trihydro, but not submitted to the WGFD due to the site being removed from further consideration. A preliminary surface disturbance amount of 2.6% (1.21 % associated with existing disturbance) was calculated for the site (Figure 10-6). The surface disturbance falls within the 5% disturbance limit set in the Governor’s Executive Order 2011-5. The DDCT amount should be recalculated and confirmed if this alternative is recommended for further evaluation in future investigations.

Aquatic Considerations
The WGFD expressed during the meeting that they would like to see how the downstream flows are altered due to the diversion and release from the reservoir. However, they felt that due to its location, and if flow was diverted during peak flows, this site would have minimal effect on fish species, specifically Sauger.
Wetlands
Construction of the Willow Creek reservoir site could potentially impact approximately 5 acres of wetlands based on a review of the 2011 NWI mapping. Future investigations should take into account the mitigation needs of wetlands if the site is re-evaluated.

10.5 PERMITTING, CLEARANCES AND APPROVALS
A discussion of permits, clearances, and approvals that may be required for development of storage alternatives is provided in the Level I Study. As discussed earlier in Section 10, applications for permits and coordination for clearances and approvals should be coordinated with the NEPA process, as much of the information and analysis required will overlap. A synopsis of the information presented in the Level I Study is provided below:

- **Section 404 Permit.** A Section 404 Dredge and Fill permit from the ACOE will be required for construction of a new reservoir or enlargement of an existing reservoir. This will likely be the most significant permit required for the Project and could take several years. For this reason, the permit process should be started early in the process and coordinated with NEPA.

- **Endangered Species Action (Section 7 Consultation).** A biological assessment will be required as part of the NEPA process and will typically be prepared by the lead NEPA agency or their contractor. The results of the assessment will be provided to the FWS and they will issue an opinion on whether or not the action jeopardizes threatened or endangered species or their habitat. Based on the preliminary feedback from the FWS relative to Meadowlark Lake and Alkali Creek, these alternatives do not appear to have negative impacts.

- **Fish and Wildlife Coordination Act.** This act requires that agencies take action to protect fish and wildlife resources that may be affected by control or structural modification of a stream (ACE 2010). The act requires consultation with state and federal wildlife agencies to assess impacts and mitigate or compensate for these impacts.

- **Cultural Resources Coordination and Consultation.** Impacts to cultural resources will be required for storage alternatives. Delineation of cultural resources and evaluation of alternative impacts will be coordinated with SHPO. Impacts must be considered under the National Historic Preservation Act (NHPA) of 1966 (16 U.S.C. § 470 et seq.); NEPA; the Archaeological Resources Protection Act (ARPA) of 1979 (16 U.S.C. §470aa et seq.); the Advisory Council on Historic Preservation's Procedures for the Protection of Cultural Properties (36 CFR Part 800); the Treatment of Archaeological Properties of 1980: Determination of Eligibility for Inclusion in the National Register of Historic Places (National Register) (36 CFR 63); the Secretary of Interior’s Standards and Guidelines for Archaeological Historical Preservation of 1983; Reservoir Salvage Act of 1960; and the I974
Amendment to the Reservoir Salvage Act of 1960 (ACE 2010). Coordination and consultation with pertinent Native American groups will also be required.

- **Wyoming Board of Land Commissioners.** The Wyoming Board of Land Commissioners, through the SLIB, regulates activities on Wyoming state lands. Construction of reservoirs or appurtenances on Wyoming State lands will require permitting a right-of-way through this agency.

- **WSEO Surface Water Storage Permit.** Water rights permits to divert and store water will need to be obtained through the WSEO.

- **WSEO Permit to Construct / Dam Safety Review.** Construction of storage facilities that are greater than 20 feet high or that will impound more than 50 ac-ft of water, or diversions that will divert 50 cfs or more must be approved by the WSEO. The approval depends on the WSEO’s approval of construction plans and specifications. The design, construction, and operation of these facilities must also comply with the Dam Safety Act regulations (ACE 2010).

- **WSEO Ditch Enlargement Permit.** Enlarging an existing irrigation ditch or canal to convey additional flow to a new reservoir (such as would be the case for the Alkali Creek alternative) requires an enlargement filing with the WSEO.

- **WDEQ – National Pollution Discharge Elimination System (NPDES) Permit and Section 401 Certification.** The WDEQ Water Quality Division (WQD) administers the Clean Water Act in combination with the Wyoming Environmental Quality Act. Under this regulation, detailed in Chapter 2 of the Wyoming Water Quality Rules and Regulations, facilities or construction projects that may discharge stormwater are required to obtain a permit through the Wyoming Pollution Discharge Elimination System (WPDES). For storage alternatives considered in this Project, a Large Construction General Permit (Permit WYR100000) would be required. To obtain a permit, a Stormwater Pollution Prevention Plan (SWPPP) must be prepared and submitted with a Notice of Intent (NOI) form to the WDEQ WQD at least 30 days prior to initiation of construction activities.

- **Mining Permit.** As described in the Level I Study, a mine permit is not required for development of a borrow source that will be used solely for a construction of a reservoir alternative. However, material vendors are required to hold appropriate permits.

- **Special Use Permits / Rights-of-Way / Easements.** Temporary or permanent special use permits, rights-of-way, and/or easements may be required for the construction of reservoirs and their appurtenances, including access roads and diversions. The process and requirements for these vary with the agency or the type of landownership (federal, state, and private). In some cases, lands that will be permanently affected may be purchased in place of obtaining...
these permits if agreeable to the landowner or management agency. These processes can be lengthy and should be commenced early in the alternative development (ACE 2010).

- **Others.** Other temporary permits may be required as part of the construction of a reservoir, including permits that would typically be obtained by the general contractor.
11.0 ARCHEOLOGICAL INVESTIGATION

A Class I cultural/archaeological literature review was completed for three top storage alternatives by LTA, Inc (LTA). Sites reviewed include Alkali Creek, Meadowlark Lake, and Taylor Draw. Reviews were not completed for Lower Luman Creek and Cornell Gulch, two of the five top storage alternatives, as they were removed from further consideration due to other factors prior to the archeological investigation.

Multiple levels of cultural resource inventory have been conducted in the Watershed over the past 20 years, with the most recent occurring during the Level I Study. The Level I Study provides general information on the cultural resources across the entire Watershed as inventoried by SHPO and the National Park Service in the National Register. The National Register serves as the nation’s official list of cultural resources worthy of preservation. The Level I Study specifically discusses five sites (County Line Bridge, Ainsworth House, Paint Rock Creek Archaeological Landscape, Medicine Lodge Creek [a prehistoric campsite], and the Ten Sleep Mercantile) within the Watershed that have been included in the National Register. This Level II Study cultural review includes a more detailed look at cultural resources that have been mapped in the vicinity of the top sites based on the National Register and additional sources. Sources consulted for this literature review include hard copy and digital records maintained by SHPO’s Cultural Records office, National Register listings for Big Horn and Washakie Counties, and General Land Office plats and surveyor’s notes covering the three project areas (LTA 2012). Results of the review are presented in the following sections and in LTA’s survey report, which is included in the Project Notebook due to the potentially sensitive information contained in the report.

11.1 MEADOWLARK LAKE

Approximately 585 acres of cultural resource inventory meeting current Wyoming SHPO and USFS guidelines have been completed for Meadowlark Lake (Figure 11-1). As listed and referenced in LTA’s survey report, the following studies comprise this resource inventory area:

- A 1987 Forest Service 11-acre survey encompassing the Meadowlark Lake Dam (48BH927) (Accession #87-824; Wood 1988).
- A 1994 Forest Service 60-acre survey for a Lakeview Campground expansion (Accession #94-915; Sutton 1994).
- A 2001 Forest Service 4-acre survey for recreation improvements (Accession #1-725; Bean 2001).

- A 2007 Office of the Wyoming State Archaeologist 20 to 130-foot wide linear corridor survey along the exposed shoreline of Meadowlark Lake (Accession #7-1672; Eckles 2008).

A total of 30 known sites, districts, and/or structures have been recorded in the four sections containing the Meadowlark Lake (Table 11-1). None of the sites are enrolled in the National Register. Of the 30 known sites, 9 are located within the footprint of the proposed Meadowlark Lake enlargement alternative (designated with bold font and an asterisk in Table 11-1). Two of the sites located within the site footprint (site numbers 48BH746/48WA382 and 48WA927) have been determined eligible for inclusion in the National Register. The remaining sites are listed as either not eligible for inclusion or have not gone through a full SHPO review process.

Review of the General Land Office plats show only one potential historic site within the project area. The Tensleep Reservoir (Meadowlark Lake) is shown on the 1944 plat in Township 48 North, Range 86 West, Sections 5 and 6. No historic sites or structures were evident in the review of the 1885 plat for Township 48 North, Range 86 West, or the 1884 plat for Township 49 North, Range 86 West.

LTA concluded that there are sufficient previous cultural resource inventories to provide adequate coverage of the proposed alternative and allow an assessment of the cultural resources. The archaeological sites are located along the shoreline of the reservoir, so they would be affected by increasing the water level. These actions would affect the cultural resources and further consultation with SHPO will be required. LTA also noted that an enlargement would also affect the Tensleep Reservoir dam, which is eligible for the National Register. However, the dam was previously modified by the USFS in 1992.

### 11.2 ALKALI CREEK

LTA’s review of the Alkali Creek project area identified approximately 355 acres of cultural resource inventory meeting current Wyoming SHPO and BLM guidelines for the seven sections containing the project area. However, none of these studies appear to be within the Alkali Creek project limits. A total of seven sites have been recorded in the sections containing the Alkali Creek alternative (Table 11-2). Only two of these sites, the Highland Ditch and the Anita Ditch are located in the Alkali Creek project area. The Anita Ditch was previously determined to not be eligible for the National Register. A determination for the Highland Ditch has not been completed (LTA 2012).

Review of the General Land office plats indicates multiple unnamed roads, ditches, fences, and structures around the project area. Descriptions of individual features are provided in Table 11-3.
Results of the review concluded that the Alkali Creek project likely will not have a direct effect on known National Register properties. LTA recommended that a new Class III inventory be conducted to fully assess the cultural resources that may be present within the proposed reservoir footprint, impoundment facilities, and portions of the proposed diversion canal that do not follow the National Register ineligible Anita Ditch. LTA also concluded that tribal consultation likely will be needed concerning the possible visual intrusion of the Project and other indirect impacts to three sites consisting of cairns and an eagle trap (site numbers 48BH3887, 48BH4033 and 48BH4034) (LTA 2012).

11.3 TAYLOR DRAW

LTA’s review of the Taylor Draw project area identified approximately 5 acres of cultural resource inventory meeting current Wyoming SHPO and BLM guidelines in the ten sections containing the Taylor Draw project area. None of the acreage inventoried is located within the footprint of the Taylor Draw alternative (LTA 2012).

There is only one cultural resource site (48WA1431) identified in the inventoried area. This area of lithic scatter was determined not to be eligible for the National Register.

Review of the General Land office plats indicates multiple roads, ditches, fences, and utility lines around the project area. Descriptions of individual features provided in Table 11-4.

Results of the review identified that there are no cultural resource inventories that cover portions of the Project area. LTA recommended that a new Class III inventory be conducted to fully assess the cultural resources that may be present within the proposed reservoir footprint, impoundment facilities, and proposed diversion canal footprint (LTA 2012).
12.0 CONCEPTUAL DESIGNS

Conceptual designs were developed for the top ranked five storage alternatives identified in Section 9. The level and detail of the design varied for the sites as three of the sites (Taylor Draw, Lower Luman Creek, and Cornell Gulch) were removed from ongoing consideration during design development. However, design effort, including embankment and spillway configurations, was completed for these sites. This section includes the basis for developing the conceptual designs and discussions of the design components for each of the alternatives. Estimated costs are provided in Section 13 for each storage alternative.

12.1 DESIGN APPROACH

The conceptual designs for each site are based on site-specific information collected and analyzed through the course of both the Level I and Level II studies. The primary factors influencing conceptual designs include location/topography, reservoir capacity, embankment size, anticipated geologic conditions, and flood hydrology. Other considerations that will be evaluated in greater detail as the designs are refined under future Project phases include environmental impacts and mitigation, permitting, landowner input, agency input, recreational benefits, and purpose and need.

The size of the proposed new reservoirs or enlargements are based on site topographic constraints, infrastructure and environmental impact constraints, the quantity of water available for storage, and the downstream demands, as well as needs that can be satisfied through exchange agreements. Reservoir storage includes qualitative consideration of a minimum pool, which was typically assumed to be 25% of the storage capacity. Spillways were designed through evaluation of flood hydrology, including determination of Intensity-Duration-Frequency / Probable Maximum Floods (IDF/PMF), flood storage/attenuation, and hazard to downstream resources. The conceptual designs presented are based on contours generated from a 10-meter National Elevation Dataset (NED) downloaded from the National Map Seamless Server Viewer (http://seamless.usgs.gov/website/seamless/viewer.htm). Additional site data will be needed to refine designs for alternatives that are recommended for further evaluation.

12.1.1 EMBANKMENT

The embankment sizes are based on the site topography and constraints, and/or the desired storage capacity. For conceptual design purposes, Trihydro assumed the majority of overburden soils are not potentially liquefiable and may be left in place under the embankment. A typical key trench has been designed as part of the overall embankment design. This major assumption should be verified during site-specific explorations during the next phase. If the subsurface materials are deemed liquefiable, it may be necessary to remove and replace or modify in place (i.e., in-situ stabilization) in order to establish appropriate slope stability factors of safety under seismic loading conditions. For
cost estimating purposes, the embankments are assumed to be constructed with locally-available material adjacent to the site (excepting slope protection). Final dam design configurations and details such as filter size, drainage layers, and other design features will require further refinement based on future site-specific, subsurface investigations and geotechnical laboratory results.

### 12.1.2 SERVICE SPILLWAYS

Site conditions greatly influence the selection of a spillway alignment including location, type, and components. A specific spillway layout and alignment can be developed by considering site specific conditions such as topography and foundation conditions, and by fitting the control structure and the various components to the prevailing conditions. Primary and auxiliary spillways were designed and evaluated for the preferred alternatives.

#### 12.1.2.1 PRIMARY SPILLWAY

For conceptual design purposes, the primary spillway is sized to accommodate the 24-hour / 100-year storm (IDF event). Typically, the primary spillway will be uncontrolled and located next to the right or left abutment. The primary spillway will have a crest elevation close to the normal high water line. Specific freeboard analyses were not completed; a minimum freeboard height of 5 feet was used as required by WSEO Surface Water Regulations and Instructions, Chapter 5 Reservoirs (WSEO 1977). The conceptual designs assume the flood discharge will pass through the spillway, through an energy dissipation structure, and back into the natural drainage. The spillway may incorporate an underdrain system to intercept leakage that occurs through the embankment, and direct it to the natural drainage channel downstream. Rock riprap is identified to be placed in strategic areas to reduce scouring and erosion.

#### 12.1.2.2 AUXILIARY SPILLWAY

The primary purpose of the auxiliary spillway is to protect the embankment in the event of an extreme flood. Typically, an auxiliary spillway is excavated in a location, usually the left or right abutment of the dam, to take advantage of existing topography to route flood flows. The excavated material is then used for construction of the dam embankment and appurtenances, as feasible. The auxiliary spillway is designed to accommodate the applicable PMF event based on the following hazard classification criteria:

- **High Hazard** – potential for loss of life (full PMF)
- **Significant Hazard** – potential for total damage greater than $1 million (half PMF or 500-year storm)
- **Low Hazard** – potential for total damage less than $1 million (24-hour /100-year storm)
The design discharges used in this report are derived using data and procedures presented in Hydrometeorological Report No. 55A (June 1988). The PMF analysis, including how flood waters will be managed at each site will be further refined during the next phase of the Project.

12.1.3 OUTLET WORKS
The purpose of the outlet works is to regulate flow through the embankment and release excess runoff from the watershed. The hydraulic capacity of the outlet works for a reservoir depends upon legal considerations (i.e., downstream water rights, pollution abatement, fish propagation, etc.), downstream needs (irrigation, domestic use, municipal use, etc.), flood control considerations, and storage requirements. The outlet works layout is influenced by conditions directly related to the hydraulic requirements, topography and geology, embankment design and construction procedures, and other dam appurtenances (e.g. hydropower). The conceptual design of the outlet works for the alternatives addressed in this report include closed conduit structures through the base of the embankment, and control valves near the inlet in order to preclude pressurized pipe within the embankment structure. The pipe inlet on the upstream side is placed at an elevation established to avoid potential siltation issues. As design of a particular structure is advanced, alternative outlet configurations may be considered to address more detailed information regarding the dam site and/or facility operations.

12.2 PROPOSED SITE DESIGN SUMMARY
Conceptual design details for the identified preferred alternatives (Meadowlark Lake, Alkali Creek, Lower Luman Creek, Taylor Draw, and Cornell Gulch) are summarized below. Calculations for the embankment size, flood hydrology, outlet works, and spillway sizing are documented in the Project Notebook.

12.2.1 ALTERNATIVE 1 – MEADOWLARK LAKE EXPANSION
Note: Based on the information obtained from the WSEO at the conclusion of the Project, as well as subsequent site visits and discussions with the WWDO, the conceptual design approach provided in this report likely will be modified during future Project phases. These modifications may include consideration of a downstream RCC embankment raise to increase the WSE by approximately 10 feet.

A conceptual design was developed for the expansion of the Meadowlark Lake embankment. Based on the WSEO permit dated 1938, the existing embankment structure is a homogeneous earthen dam legally impounding approximately 3,509 ac-ft of water. The existing normal high water line is approximately 8,467 feet above mean sea level (ft-amsl). Analysis, using available NED topography and digitized topography from the original permit drawing, estimates current capacity at 3,316 ac-ft, less than the permitted value. Records obtained from the WSEO Dam Safety
Division near the conclusion of the Project indicate the dam was rehabilitated approximately 20 years ago. The rehabilitation included construction of a RCC cap on the downstream face of the embankment to protect the embankment in case of overtopping. Presumably, the RCC cap was covered by an earthen shell to maintain the reservoir embankment’s historical character.

Trihydro evaluated three raises to the current water surface elevation (WSE) (approximately 5, 10, and 15 feet) to estimate potential impacts to facilities or structures at the site. As part of these evaluations, an upstream embankment raise at a 3H: 1V slope was assumed. Additional storage capacities and anticipated effects associated with each raise are discussed in the following paragraphs and displayed graphically on Figures 12-1 and 12-2. In addition to existing improvements identified on the figures, the USFS is planning to create a handicap accessible trail around the existing reservoir. Moreover, potential modifications to the existing dam embankment would also need to account for the historic nature of the dam, which is not addressed in the discussions below.

5-Foot Raise in Water Surface Elevation
Based on the layout of the topography generated by the NED and the 1938 site map, a reservoir enlargement associated with raising the dam embankment to allow a 5-foot raise in WSE would increase the storage by approximately 1,360 ac-ft. An increase in the WSE of 5 feet would likely:

- Inundate approximately 3.2 acres of wetlands (based on on-site delineated acres)
- Encroach on the North Cove parking lot and boat ramp located on the northwest side of the reservoir
- Encroach upon the dock on the northeast side, south of the Meadowlark Lake Resort cabins
- Inundate portions of the proposed handicap accessible trail around the reservoir

10-Foot Raise in Water Surface Elevation
A 10-foot raise in WSE would increase the storage by approximately 2,782 ac-ft. In addition to the potential impacts noted for a 5-foot raise, an increase in the WSE of 10 feet would likely:

- Inundate approximately an additional 3.6 acres of wetlands (6.8 acres total)
- Encroach on Meadowlark Ski Lodge’s Cloud Peak chair lift and counter weight located along the southeast corner of the Lake
- Inundate a section of the access road to the parking lot west of the Bull Creek Camp Ground
- Inundate the North Cove boat ramp and a section of the North Cove parking lot located on the northwest side of the reservoir
15-Foot Raise in Water Surface Elevation

A 15-foot raise in WSE would increase storage by an estimated 4,273 ac-ft. In addition to the potential impacts noted for the 5-foot and 10-foot raises, an increase in the WSE of 15 feet would likely:

- Inundate approximately an additional 5.5 acres of wetlands (12.3 acres total)
- Inundate Meadowlark Ski Lodge’s Cloud Peak chair lift and counter weight and encroach on the small cabin or storage building adjacent to the chairlift
- Inundate a portion of Meadowlark Ski Lodge’s parking lot and ground used for the on-site wastewater treatment system for the Lodge (Royster 2007)
- Inundate the lower access road to the parking lot west of the Bull Creek Camp Ground and encroach on the outhouse building adjacent to the parking lot
- Inundate the dock, building structure, and parking lot on the northeast side, south of the Meadowlark Lake Resort cabins
- Encroach on approximately six Meadowlark Lake Resort cabins located along the east side of the reservoir
- Encroach on the Lake View campground and parking lot
- Inundate the North Cove boat ramp and approximately a quarter of the North Cove parking lot

Based on the evaluations completed during the Level II Study, the conceptual design incorporates an upstream embankment raise to increase the WSE by approximately 5 feet. Proposed expansion dam and reservoir design expansion details include:

- Reservoir storage capacity (active and dead) = 4,672 ac-ft
- Reservoir footprint area = 279 acres
- Top of dam (crest) elevation = 8,487 ft-amsl
- Normal water surface (operating elevation) and service spillway elevation = 8,472 ft-amsl
- Maximum water surface elevation (flood stage) = 8,482 ft-amsl
- Minimum water surface elevation = 8,450 ft-amsl
- Freeboard above maximum high water = 5 feet (minimum)
A site plan for the conceptual layout, as well as for the other WSE raises considered is shown on Figure 12-1. Cross sections and a stage-storage table and curve are shown on Figure 12-2. Conceptual design details for the proposed expansion, as well as detail from the original permit are shown on Sheets ML-1 through ML-3.

**12.2.1.1 EMBANKMENT EXPANSION**

Based on observed conditions, the embankment raise was assumed to be a homogenous earthen dam. The maximum height of the embankment is constrained by the existing infrastructure adjacent to the reservoir shoreline. Therefore, the proposed reservoir enlargement was based on an embankment crest elevation of 8,487 ft-amsl. The primary dam dimensions are approximately 400 feet in length, approximately 25 feet wide at the crest, and a maximum height of approximately 43 feet above the streambed. This elevation would provide a total freeboard distance of 15 feet between the normal high water line and the dam crest. A detailed plan view of the conceptual layout is shown on Sheet ML-3. The earthen dam cross section and details are also shown on Sheet ML-3.

Conceptual design of the earthen dam includes an upstream slope of 2.5H: 1V and a downstream slope of 2H: 1V. The final slopes and dimensions should be refined based on results of site-specific explorations, geotechnical testing, slope stability analyses, seepage analyses, and foundation stability evaluations. The upstream slopes are considered to be protected with riprap to minimize erosion.

A raise of the homogenous existing earthen dam would be designed and constructed using soil materials available on site. The location of the borrow area(s) will be identified during the next phase of work based on a geotechnical investigation. For cost estimating purposes, the borrow area(s) was assumed to be located in the immediate vicinity of the existing embankment.

The upstream face of the existing dam embankment is faced with hand-placed riprap material. Similar riprap material will likely need to be procured for enlargement of the reservoir. Additional research will need to be undertaken to confirm the mechanical properties of the existing riprap material, its suitability and possible sources to supply new material with similar characteristics. The thickness and rock size of the riprap layer used will be established as needed to resist wave action. Although equipment-placed riprap may be more economical and satisfactory from an engineering standpoint; hand-placed riprap placed in a manner consistent with the work that was performed by the CCC would help to maintain the historic character of the dam.
12.2.1.2 RESERVOIR FOOTPRINT
The proposed normal operating surface water elevation is approximately 8,472 ft-amsl, and results in a reservoir footprint of approximately 279 acres. The high surface water elevation (i.e., flood stage) is approximately 8,482 ft-amsl, and a minimum freeboard distance of 5 feet. The conceptual increase to the reservoir footprint area is shown on Figure 12-1 and Sheet ML-3.

12.2.1.3 SERVICE SPILLWAY
Releases from Meadowlark Lake to benefit irrigation are expected on a more regular basis following the embankment raise and initial filling. As previously stated, the reservoir will store an estimated 4,672 ac-ft of water at the normal high water line at elevation 8,472 ft-amsl. The elevation versus capacity data is presented on Figure 12-2, and is based on 10-meter NED contours as well as digitized contours form the original permit drawing.

The service spillway will be designed to accommodate up to the full PMF based on a high hazard dam classification. The estimated peak discharge from the PMF is approximately 44,300 cfs. Assuming the reservoir is full during this event, this flow rate will require a channel 65 feet in width to pass a routed flow of approximately 45,000 cfs. The service spillway elevation would have an elevation of 8,472 ft-amsl. The discharge would pass through the spillway, and outfall back to East Tensleep Creek a safe distance downstream of the toe of the embankment.

The service spillway design consists of a 65-foot wide, reinforced rectangular concrete chute section. The spillway extends through the left side of the dam crest, down the abutment face, and ends at a stilling basin. The spillway would include an underdrain system to intercept leakage that may occur from the spillway or earth embankment and direct it to the natural drainage downstream. Cost for riprap material placed downstream of the energy dissipater to prevent scouring of the natural drainage channel is accounted in the conceptual design estimate. The spillway design details are shown on Sheet ML-3.

12.2.1.4 OUTLET WORKS
As part of the conceptual design, the condition of the existing outlet works was not assessed. The mechanical components of the outlet works may need to be rehabilitated to control flow through the embankment depending upon downstream water needs, available storage capacity, and stream inflows. The outlet works would also be extended as needed based on the modification of the dam embankment.

The existing outlet works discharge into a rock and mortar lined channel which outfalls to East Tensleep Creek. The hydraulic energy at the channel outlet has caused damage to rock and mortar construction. Riprap or other measures to
dissipate the flow energy at the outfall will be placed to reduce scouring of the natural drainage channel and undermining of the channel walls. The outlet works conceptual design details are shown on Sheet ML-3.

12.2.1.5 APPURTENANCES
Rehabilitation of the existing fish ladder is included as part of the conceptual design for the proposed expansion. The details of the fish ladder rehabilitation will be further evaluated during the next phase of work. Other appurtenances may include fish screens (if identified by the WGFD) and safety railings or similar fall protection measures to safeguard recreationalists traversing the dam.

Depending on losses quantified in East Tensleep Creek, downstream of the reservoir, a delivery pipe or other structure may also be needed to effectively convey flows to Tensleep Creek. The need for conveyance facilities downstream of the reservoir to augment releases to the East Tensleep Creek will be assessed with temporary stream gages.

12.2.1.6 STATEMOD RESERVOIR ALTERNATIVES SIMULATION

12.2.1.6.1 EXISTING RESERVOIR SIMULATION
The existing reservoir was permitted to apply stored water for irrigation, water power, domestic, livestock, fish culture, recreational purposes, flood control, erosion control, and fire protection. While irrigation is listed as one of the uses for water stored in the reservoir, the reservoir is typically not operated in a manner to provide flows for irrigation. Prior to performing analysis on the benefits of an enlarged reservoir, four scenarios were simulated in StateMOD. These simulations were performed to better understand operations at the reservoir and how releases from the reservoir could address irrigation needs, as well as what affect these releases might have on the reservoir pool under alternative operational scenarios.

Scenario 1
Scenario 1 does not include releases to meet irrigation demand or other downstream needs. Under Scenario 1, the reservoir was modeled assuming administration in strict compliance with the one-fill rule of Wyoming Water Law. The one-fill rule states that a reservoir is entitled to store natural flow available in priority beginning on October 1st in a volume equal to the difference between the carry-over storage observed on September 30th, and the permitted capacity of the reservoir. Thus, storage water that remains in the reservoir at the end of the water year is designated as carry-over storage and counts toward the storage appropriation available to meet the following year's demand. The State Engineer may also allow that reservoir evaporation losses incurred during the water year be recovered when a water supply is available in priority.
Applying the estimated physical storage capacity of 3,316 ac-ft (as discussed in Section 12.2.1), results from model analysis for Scenario 1 predict the end-of-month (EOM) contents of the reservoir fluctuate between 3,313 ac-ft and 2,986 ac-ft (Figure 12-3). With this scenario the model rules allow for the reservoir to be filled in accordance with the one fill rule, including recovery of approximately 522 ac-ft that is lost to evaporation over the course of a year.

**Scenario 2**

Under Scenario 2, the reservoir is modeled under a fill and refill administration that allows the reservoir to be refilled continuously to replace losses (Figure 12-4). Scenario 2 is consistent with the water allocation conditions assumed for the Baseline model analysis initially completed to assess potential Watershed shortages. Similar to Scenario 1, Scenario 2 does not include releases to meet downstream irrigation or other needs. The assumptions inherent in Scenario 2 appear to be consistent with the historic administration of Meadowlark Lake.

The model results for Scenario 2 show EOM contents ranging from a maximum of 3,313 ac-ft in February to a minimum of 3,167 ac-ft, generally occurring in July. The main difference between Scenario 1 and Scenario 2 is that under Scenario 1 the reservoir cannot be refilled as storage water is depleted (by evaporation), and can only be refilled following the start of a new water year. Under Scenario 2, the reservoir continuously refills throughout the year.

**Scenario 3**

The model analysis for Scenario 3 allocates the reservoir storage using fill and refill administration (similar to Scenario 2), and includes releases to meet late-season irrigation shortages on lands supplied from Tensleep Creek and lands supplied from the Nowood River between its confluence with Tensleep Creek and its confluence with Paint Rock Creek. Modeled EOM contents range between a maximum of 3,313 ac-ft occurring every year in February to a minimum of 1,746 ac-ft in August 2001 (Figure 12-5).

**Scenario 4**

The analysis for Scenario 4 is similar to Scenario 3, except that this scenario regards releases to satisfy all irrigation shortages that can be physically served by the reservoir, either directly or through exchange. This scenario simulates releases to first meet downstream irrigation shortages (directly). The model also simulates releases to supply irrigation shortages that can be satisfied by exchange. This includes shortages upstream of the confluence of Tensleep Creek and the Nowood River, and upstream along tributaries to the Nowood River (e.g. Paint Rock Creek) located downstream of the confluence of Tensleep Creek and the Nowood River. However, the exchange potential is limited, particularly upstream of the confluence of Tensleep Creek and the Nowood River.
Results for this scenario show releases from the reservoir approximately 4 to 5 out of every 10 years (Figure 12-6). The available storage pool (which excludes the dead pool and minimum pool) is emptied twice (August 1983 and August 2001) over the 36-year study period. Based on the model, an additional 568 ac-ft per year of shortages are satisfied under Scenario 4 as compared with Scenario 3. The additional releases are predominantly made to satisfy shortages on the Nowood River below the confluence with Paint Rock Creek. There are also some years where exchange potential exists up Brokenback Creek and Buffalo Flat Creek.

Operating the Reservoir under Scenario 4 would reduce the overall average shortages experienced by irrigators in the Watershed, specifically irrigators downstream of the reservoir along Tensleep Creek and Nowood River to the confluence with the Bighorn River. With releases from the reservoir, shortages below the reservoir are reduced by approximately 33% per year under Scenario 4 when compared to the Baseline model (Scenario 2); with the greatest reduction of shortage occurring during the months of July (43%) and August (53%). Shortages for the entire Watershed are reduced by approximately 7% under the Scenario 4 administration when compared to the Baseline model. The percent of reduction by month between Scenario 4 and the Baseline Model is tabulated in Table 12-1.

### 12.2.1.6.2 RESERVOIR ENLARGEMENT SIMULATION

The proposed enlargement would raise the normal high water line 5 feet, resulting in a 1,360 ac-ft increase in storage. This enlargement was modeled in StateMOD to estimate reduction in shortages and identify potential beneficiaries. In the model, Meadowlark Lake was assigned a one-fill right with a storage capacity of 4,672 ac-ft. Beneficiaries were identified based on the general proximity of irrigated land to the reservoir location and the reservoir was assumed to operate under strict Wyoming Water Law. The storage right was operated in the model to allow storage from on-channel inflows under a junior 2012 storage right from East Tensleep Creek. Beneficiaries (direct and through exchange) were identified based on shortages estimated in the Baseline Model and include users along: Tensleep Creek, the Nowood River, Paint Rock Creek, Medicine Lodge Creek, and tributaries to the Nowood River.

Model results for the Meadowlark Lake enlargement alternative are summarized in Table 12-2. Reduction in shortages is summarized in Table 12-3. Review of the simulation results suggest that the Baseline shortage for the entire Watershed could be reduced to 14,103 ac-ft or a 9.7% shortage (Table 12-2); a reduction of 1,048 ac-ft or 7% reduction (Table 12-3). Based on the simulation, the enlargement of Meadowlark Lake would eliminate estimated shortages along Tensleep Creek. Shortages in other reaches were also partially eliminated, largely due to the limited ability to exchange water.
12.2.2 ALTERNATIVE 2 – ALKALI CREEK

A conceptual design was developed for a new on-channel reservoir along Alkali Creek. The proposed dam and reservoir design details include:

- Reservoir capacity (active and dead) = 7,401 acre feet
- Reservoir footprint area = 288 acres
- Top of dam (crest) elevation = 4,490 ft-amsl
- Normal water surface (operating elevation) and primary spillway elevation = 4,479 ft-amsl
- Spillway elevation = 4,479 ft-amsl
- Maximum water surface elevation (flood stage) = 4,485 ft-amsl
- Minimum water surface elevation = 4,420 ft-amsl
- Freeboard above maximum high water = 5 feet (minimum)

A conceptual site plan and conceptual design details for the proposed reservoir are shown on Sheets AC-1 and AC-2. A stage / storage curve is provided on Sheet AC-2.

12.2.2.1 EMBANKMENT STRUCTURE

Based on the preliminary geotechnical investigation, Alkali Creek is most suitable for a homogeneous earthen dam. The maximum height of the embankment is constrained by a topographic saddle located to the east of the left abutment. Therefore, the dam will have a crest elevation of 4,490 ft-amsl. The primary dam dimensions are approximately 2,384 feet in length, approximately 25 feet wide at the crest, with a maximum height of approximately 84 feet above the streambed. This elevation will provide a normal freeboard distance of approximately 11 feet between the normal high water line and the dam crest, and a minimum freeboard distance of 5 feet between the maximum high water line and the dam crest. A detailed plan view of the conceptual layout alignment is shown on Sheets AC-1 and AC-2. Details of the embankment design are shown on Sheet AC-2.

Conceptual design of the earthen dam includes a minimum upstream slope of 2.5H: 1V, and a minimum downstream slope of 2H: 1V. These slopes were designed based on the assumption that bedrock foundation may contain weak seams with low shear strength and adverse orientation. The final slopes and dimensions should be designed based on results of site-specific explorations, geotechnical testing, slope stability analyses, seepage analyses, and foundation stability evaluations. The upstream and downstream slope will be protected with riprap to minimize erosion. The
location of the borrow area will be identified during the next phase of work. For cost estimating purposes, the borrow area was assumed to be relatively close to the project site, most likely in the area upstream of the proposed dam that would be inundated by the reservoir pool.

The earthen dam will be designed and constructed to reduce seepage through the embankment and upper foundation bedrock. The least permeable soil available on site will be used for construction. The cutoff trench will be located along the centerline of the dam and extend through the upper (i.e., highly-weathered) portion of the bedrock. Based on the preliminary geotechnical evaluation, the depth of overburden soils in the valley bottom may vary from 10 to 30 feet in depth. Site-specific bedrock depth seepage conditions should be evaluated if this site is determined to be highly favorable for future development. Additional seepage cutoff features or realignment of the dam axis may be required as part of the final design. A summary of the soil volumes anticipated for this structure are summarized on Sheet AC-2.

The upstream slope of the embankment structure must be protected against destructive wave action, burrowing animals, and slope instability from rapid drawdown. Typical surface protection for upstream slopes is rock riprap. The upstream slope protection should extend from the crest of the dam to a safe distance below the minimum water level. The thickness of the riprap layer should be sufficient to accommodate the weight and size of the rock necessary to resist wave action. The Bureau of Reclamation recommends a 3-foot thickness of dumped riprap to be the most economical and satisfactory for large dams. Downstream slopes of homogeneous earthfill dams should be protected against erosion caused by wind and rainfall runoff by a layer of rock, cobbles, or sod. Due to the uncertainty of obtaining adequate protection by vegetative cover at dam sites (especially in arid regions) protection by cobbles or rock is preferred and should be used where the cost is not prohibitive. Typically, a layer 12 inches thick provides sufficient protection, but layers 24 inches thick may be easier to place. The rock riprap size ($D_{50}$) and thickness for the upstream and downstream slopes will be evaluated in future design phases.

12.2.2.2 RESERVOIR FOOTPRINT

The normal operating surface water elevation is approximately 4,479 ft-amsl, and results in a reservoir footprint of approximately 288 acres. The high surface water elevation (i.e., flood stage) is approximately 4,485 ft-amsl, with a minimum freeboard distance of 5 feet. The conceptual reservoir footprint area is shown on Sheet AC-2. As shown on Sheet AC-1, the normal water surface elevation and reservoir footprint may impact the following landowners:
• Mercer Land & Livestock Co.
• BLM
• Hamilton Ranch, Inc. (dependent upon reservoir height)

12.2.2.3 SERVICE SPILLWAYS

Alkali Creek reservoir is considered an off-channel reservoir, although it will impound Alkali Creek. The size of the Alkali Creek drainage is small compared to the storage capacity of the reservoir. However, the reservoir could spill at times of higher flows.

As previously stated, the reservoir will store approximately 7,401 ac-ft of water at the normal high water line at elevation 4,479 ft-amsl. The elevation versus capacity data is presented on Sheet AC-2. This curve is based on 10-meter NED data. The spillway will be uncontrolled and located west of the reservoir in a topographic saddle. This reservoir is considered high hazard due to the local proximity of residential structures and the highway/bridge. Therefore, the full PMF analysis was completed for this site evaluation. The peak inflow is estimated to be 22,044 cfs based on the full PMF analysis. Assuming the reservoir is full during this event, this flow rate will require a spillway 250 feet in width. Assuming a water depth of approximately 3.7 feet, a spillway of this size is capable of passing a routed flow of 22,398 cfs. The spillway will have an elevation of 4,479 ft-amsl. The peak inflow for a 100-year / 24-hour storm analysis is 2,946 cfs. Assuming the reservoir is full during this event, this flow rate will require a primary spillway 50 feet in width to pass the estimated peak inflow.

The service spillway (primary and auxiliary) will be a riprap-reinforced trapezoidal section. The spillway will extend through the natural drainage adjacent to the reservoir impoundment and end at a stilling basin. The spillway would include an underdrain system to intercept leakage that may occur from the spillway and direct it to the natural drainage downstream. Riprap will be placed downstream of the energy dissipater to prevent scouring of the natural drainage channel. The extent of the riprap dissipation structure will be refined during the next design phase. The spillway flow will be directed into the natural drainage with some grading required. The spillway alignment and cross section are shown on Sheet AC-2.

12.2.2.4 OUTLET WORKS

The outlet works are designed to be placed along the existing natural drainage. The outlet works will be sized to meet the requirements for emergency lowering of the reservoir, to allow passage of natural, base inflows from Alkali Creek, and to provide for anticipated irrigation uses. The outlet works will have valves to control flow through the
embankment depending upon downstream water needs, available storage capacity, and stream inflows. Evaluation of the need for a multiple level outlet structure to provide some control of temperature of released water may be required at the next level of study based on the results of further environmental studies.

For this conceptual design, the outlet works incorporate two reinforced, encased 18-inch diameter welded steel pipes in parallel. The hydraulic valve will be controlled with the operator stem mounted on the upstream slope of the dam, and manually operated from the dam crest in order to control flow through the dam both for a drawdown and demand purposes.

The outlet works would discharge into a stilling basin, which will dissipate the flow energy at the toe of the dam. Rock riprap will be placed downstream of the impact basin to prevent scouring of the natural drainage channel and undermining the toe of the dam. The extent of the riprap will be determined in future design phases. Some minor grading of the channel will be required to divert flow from the impact basin to the natural drainage channel.

### 12.2.2.5 APPURTENANCES

The water supply canal for the proposed Alkali Creek reservoir would divert flow from Medicine Lodge Creek and Paint Rock Creek via the existing Anita Ditch (approximately 4.3 miles) and Anita Supplemental Ditch (approximately 0.5 miles). Enlargement of the existing irrigation ditches would likely be required to provide hydraulic capacity for irrigations flows and the flow needed to fill the reservoir. The Anita Ditch is currently designed to convey a maximum flow of 60 cfs (WWDC 2012). Flows were observed to range from an average of 6 cfs in May to a maximum of approximately 50 cfs (a reading of 69 cfs was observed in October; however, this reading is considered to be an outlier due to a possible gage error) during stream gaging on the Anita Ditch completed in 2011 (Figure 6-7).

The flow needed to fill the reservoir, if the reservoir were initially empty and filled over a 3-month period, would be approximately 42 cfs. An analysis of the physically and legally available flow to fill Alkali Creek is provided in Table 12-4. A comparison of the 42 cfs needed to fill the empty reservoir versus available flows is illustrated in Figure 12-7. Assuming that the ditch is required to convey its full capacity of 60 cfs plus an additional 42 cfs to fill the reservoir over a 3-month period, a clean trapezoidal ditch with an 8-foot bottom, side slopes of 2H: 1V, flowing at a depth of 4 feet would be required (assuming no ditch conveyance loses). For comparison a ditch with the same dimensions flowing at a depth of approximately 2.75 feet would be able to convey 60 cfs. As shown in Table 12-4 and on Figure 12-8, there appears to be sufficient peak flows to fill Alkali Creek in a shorter duration (e.g., 125 cfs would fill the reservoir in 1 month). However, the additional flow would require substantial increases in the Anita Ditch capacity. Conversely, the reservoir could be filled over a longer period, or possibly over the winter months, reducing
the flow required to pass through the Anita Ditch. This would require operation and maintenance of the ditch outside of the irrigation season and may raise concerns regarding in-stream flows.

Designing the enlargements, as needed, to the Anita Ditch and the Anita Supplemental Ditch will be completed under future design phases. Likewise, design of the diversion structure, which may need to incorporate some form of fish screen or similar structure to prevent fish entrainment, will be evaluated during future design phases. An outlet from the reservoir to the downstream reach of the Anita Ditch will also need to be considered as part of future evaluations, as will the stability of the Alkali Creek channel downstream of the dam.

During the next phase of work, further evaluation will need to be completed to route flow under the existing Wyoming Highway 31 (Cold Springs Road) and around infrastructure in the event that the spillway was activated. For the purposes of the Level II, Phase I estimate, the costs for constructing an additional bridge and underpass for Wyoming Highway 31 were assumed and not estimated at length. This cost estimate will be further refined during the next phase of work.

12.2.2.6 STATEMOD RESERVOIR SIMULATION

Additional analysis of the Alkali Creek alternative was performed in the StateMOD model. The reservoir was modeled to estimate reduction in irrigation shortages and identify potential beneficiaries. In the model, Alkali Creek was assigned a one-fill junior 2012 right with a storage capacity of 7,401 ac-ft. Beneficiaries were identified based on the general proximity of irrigated land to the reservoir location and the reservoir was assumed to operate under strict Wyoming Water Law. The storage right was operated in the model to allow storage from on-channel inflows from Alkali Creek and water diverted from Medicine Lodge Creek and upper Paint Rock Creek through the Anita Ditch and Anita Supplemental Ditch. Beneficiaries (direct and through exchange) were identified based on shortages estimated in the Baseline Model and include users along: Alkali Creek, Medicine Lodge Creek, Paint Rock Creek, and the Nowood River below Paint Rock Creek.

Model results for the Alkali Creek alternative are summarized in Table 12-5. Reduction in shortages is summarized in Table 12-6. Review of the simulation results suggest that the Baseline Model shortage for the entire Watershed could be reduced to 12,002 ac-ft or an 8.2% shortage (Table 12-5); a reduction of 3,149 ac-ft or 21% reduction (Table 12-6). Based on the simulation, the Alkali Creek alternative would essentially eliminate shortages on Alkali Creek, and significantly reduce estimated shortages along Tensleep Creek and the Nowood River below Paint Rock Creek. Shortages on Paint Rock Creek were estimated to be reduced by 39%. Shortages in other reaches were only minimally, if at all, reduced, largely due to the limited ability to exchange water.
12.2.3 ALTERNATIVE 3 – LOWER LUMAN CREEK

A conceptual design was developed for the Lower Luman Creek site. The design was not completed to the level of the Meadowlark Lake enlargement or Alkali Creek site, as the Lower Luman Creek site was removed from consideration during the conceptual design process due to concerns raised by the WGFD. A simulation in StateMOD to identify beneficiaries and estimate shortage reductions was not completed for the Lower Luman Creek site. This site could be considered as an alternative to the Alkali Creek site during the NEPA process.

The dam and reservoir design details for this site include:

- Reservoir storage capacity (active and dead) = 2,421 ac-ft
- Reservoir footprint area = 57 acres
- Top of dam (crest) elevation = 5,320 ft-amsl
- Normal water surface (operating elevation) and primary spillway elevation = 5,305 ft-amsl
- Auxiliary spillway elevation = 5,305 ft-amsl
- Maximum water surface elevation (flood stage) = 5,315 ft-amsl
- Minimum water surface elevation = 5,190 ft-amsl
- Freeboard above maximum high water = 5 feet (minimum)

A conceptual site plan and conceptual design details for the proposed reservoir are shown on Sheets LC-1 and LC-2. A stage / storage curve is provided on Sheet LC-2.

12.2.3.1 EMBANKMENT STRUCTURE

Based on the preliminary geotechnical investigation, the Lower Luman Creek site is suitable for a homogeneous earthen dam if the silty sands have sufficient fines. The maximum height of the embankment is constrained by the right abutment, and the topographic saddle on the west side of the proposed reservoir. Therefore, the dam would have a crest elevation of 5,320 ft-amsl. The primary dam dimensions are approximately 861 feet in length, approximately 40 feet in width at the crest, and a maximum height of approximately 150 above the streambed. This elevation would provide a normal freeboard distance of approximately 15 feet between the normal high water line and the dam crest, and a minimum freeboard distance of 5 feet between the maximum high water line and the dam crest. A detailed plan view of the conceptual layout alignment is shown on Sheets LC-1 and LC-2. Details of the embankment design are shown on Sheet LC-2.
Conceptual design of the earthen dam includes a minimum upstream slope of 2.5H: 1V and a minimum downstream slope of 2.5H: 1V. These slopes were designed based on three assumptions: 1) dam height; 2) uncertainty of adequate cohesion of site specific soils; and 3) bedrock foundation that may contain weak seams with low shear strength and adverse orientation. The final slopes and dimensions should be designed based on results of site-specific explorations, geotechnical testing, slope stability analyses, seepage analyses, and foundation stability evaluations. The upstream and downstream slope will be protected with riprap to minimize erosion. The location of borrow areas will be identified during the next phase of work. For cost estimating purposes, the borrow areas (excepting riprap) were assumed to be relatively close to the site.

The earthen dam will be designed and constructed to reduce seepage through the embankment and upper foundation bedrock. Low permeability soils available on site would be used for construction. The cutoff trench would be located along the centerline of the dam and extend through the upper (i.e., highly-weathered) portion of the bedrock. Based on the preliminary geotechnical evaluation, the depth of overburden soils (i.e., depth to bedrock) in the valley bottom may vary from 0 feet (abutments) to 30 feet (valley bottom) in depth. Site-specific bedrock depth seepage conditions should be carefully evaluated if this site is determined to be favorable for future development. Additional seepage cutoff features or realignment of the dam axis may be recommended as part of future design. A summary of the soil volumes anticipated for this structure are summarized on Sheet LC-2.

The upstream slope of the embankment structure must be protected against destructive wave action, burrowing animals, and slope instability from rapid drawdown. Typical surface protection for upstream slopes are rock riprap (dry dumped or placed). The upstream slope protection would extend from the crest of the dam to a safe distance below the minimum water level. The thickness of riprap would be of sufficient weight and size to resist wave action.

### 12.2.3.2 RESERVOIR FOOTPRINT

The normal operating surface water elevation is approximately 5,305 ft-amsl, and results in a reservoir footprint of approximately 57 acres. The high surface water elevation (i.e., flood stage) is approximately 5,315 ft-amsl, with a minimum freeboard distance of 5 feet. The conceptual reservoir footprint area is shown on Sheet LC-2. The normal water surface elevation and reservoir footprint will impact the following landowners:

- State of Wyoming
- John Alm
12.2.3.3 SERVICE SPILLWAYS

The Lower Luman Creek reservoir is considered an off-channel reservoir, although it would impound Luman Creek. The size of the Luman Creek drainage is small compared to the storage capacity of the reservoir. However, the reservoir could potentially spill at times of higher flows. Elevation versus capacity data for the reservoir is presented on Sheet LC-2. This curve is based on 10- meter NED data.

The spillway would be located on the west side of the reservoir in a topographic saddle. This reservoir may be considered high hazard due to the local proximity of residential structures downstream of the proposed site; at the confluence with Paint Rock Creek. Therefore, the service spillway was designed to accommodate the full PMF event (28,580 cfs). Assuming the reservoir is full during this event, this flow rate would require a spillway approximately 140 feet in width. The spillway elevation would have a crest elevation of 5,305 ft-amsl. The discharge would pass through the spillway, through a dissipation structure (riprap), and into an unnamed drainage that flows into Paint Rock Creek.

The service spillway (primary and auxiliary) design includes a riprap-reinforced trapezoidal section. The spillway extends over the topographic saddle, down the existing topography, and terminates at a stilling basin. Riprap will be placed downstream of the energy dissipater to prevent scouring of the natural drainage channel. Discharges from the spillway would be directed into the ephemeral drainage west of Luman Creek with some grading required. The spillway alignment and cross section are shown on Sheet LC-2.

12.2.3.4 OUTLET WORKS

The outlet works are designed to be placed along the existing natural drainage. The outlet works will be sized to meet the WSEO requirements for emergency lowering of the reservoir and to provide for maximum anticipated irrigation uses, as well as to pass natural stream base flows. The outlet works will have valves to control flow through the embankment depending upon downstream water needs, available storage capacity, and stream inflows.

The outlet works will incorporate two, 18-inch diameter pipes in parallel. The hydraulic valve will be controlled with the operator stem mounted on the upstream slope of the dam, and manually operated from the dam crest in order to control flow through the dam for both drawdown and demand purposes.

The outlet works would discharge into a stilling basin, which will dissipate the flow energy at the toe of the dam. Riprap will be placed downstream of the impact basin to prevent scouring of the natural drainage channel and
undermining the toe of the dam. The extent of the riprap will be determined in future design phases. Some minor grading of the channel will be required to direct flow from the impact basin to the natural drainage channel.

12.2.3.5 APPURTENANCES

The water supply delivery system for the Lower Luman Creek Reservoir would divert out of South Paint Rock Creek and Laddie Creek. The delivery system would conceptually consist of a 6.2 mile, 24-inch gravity fed pipeline diverting from South Paint Rock Creek at a 0.5% slope transferring flow into an existing tributary of Laddie Creek and discharging into Laddie Creek. Approximately 1 mile downstream of the pipeline discharge point into Laddie Creek, a 2,000-foot long, 36-inch diameter (capable of conveying approximately 100 cfs if needed) tunnel is proposed to divert water to the Luman Creek watershed. The tunnel will discharge flow into the Luman Creek watershed approximately 4.5 miles above the dam site via an existing tributary of Luman Creek. The water supply system would have a design capacity of up to approximately 40 cfs allowing the diversion to be able to support filling of a totally empty reservoir in approximately 30 days, assuming the reservoir would be filled during the spring runoff when surplus flow is available. The proposed Lower Luman Creek delivery system alignment is shown on Sheet LC-1.

12.2.4 ALTERNATIVE 4 – TAYLOR DRAW

A conceptual design was developed for the Taylor Draw site. The design was not completed to the level of the Meadowlark Lake enlargement or Alkali Creek site, as the Taylor Draw site was removed from consideration during the conceptual design process due to stakeholder input. A simulation in StateMOD to identify beneficiaries and estimate shortage reductions was not completed for the Taylor Draw site.

The general dam and reservoir design details include:

- Reservoir storage capacity (active and dead) = 2,435 ac-ft
- Reservoir footprint area = 103 acres
- Top of dam (crest) elevation = 4,630 ft-amsl
- Normal water surface (operating elevation) and service spillway elevation = 4,619 ft-amsl
- Auxiliary spillway elevation = 4,619 ft-amsl
- Maximum water surface elevation (flood stage) = 4,625 ft-amsl
- Minimum water surface elevation = 4,553 ft-amsl
- Freeboard above maximum high water = 5 feet (minimum)
A conceptual site plan and conceptual design details for the proposed reservoir are shown on Sheets TD-1 and TD-2. A stage / storage curve is provided on Sheet TD-2.

12.2.4.1 EMBANKMENT STRUCTURE

Based on the preliminary geotechnical investigation, the Taylor Draw site is suitable for a homogeneous earthen dam if the onsite materials have sufficient fines. The primary dam dimensions are approximately 1,200 feet in length, approximately 30 feet in width at the crest, and a maximum height of approximately 87 feet above the streambed. This elevation would provide a normal freeboard distance of approximately 11 feet between the normal high water line and the dam crest, and a minimum freeboard distance of 5 feet between the maximum high water line and the dam crest. A plan view of the conceptual layout alignment is shown on Sheets TD-1 and TD-2. Details of the embankment design are shown on Sheet TD-2.

Conceptual design of the earthen dam includes a minimum upstream slope of 2.5H: 1V and a minimum downstream slope of 2H: 1V. These slopes were designed based on three assumptions: 1) dam height; 2) uncertainty of adequate cohesion of site specific soils; and 3) the bedrock foundation may contain weak seams with low shear strength and adverse orientation. The final slopes and dimensions should be designed based on results of site-specific explorations, geotechnical testing, slope stability analyses, seepage analyses, and foundation stability evaluations. The upstream and downstream slope would be protected with riprap to minimize erosion. The location of borrow areas will be identified during the next phase of work. For cost estimating purposes, the borrow areas (excepting riprap) were assumed to be relatively close to the project site.

The earthen dam will be designed and constructed to reduce seepage through the embankment and upper foundation bedrock. Low permeability soils available on site would be used for construction. The cutoff trench would be located along the centerline of the dam and extend through the upper portion of the bedrock. Site-specific bedrock depth seepage conditions should be carefully evaluated if this site is determined to be favorable for future development. Additional seepage cutoff features or realignment of the dam axis may be required as part future design phases. A summary of the soil volumes anticipated for this structure are summarized in Sheet TD-2.

The upstream slope of the embankment structure must be protected against destructive wave action, burrowing animals, and slope instability from rapid drawdown. Typical surface protection for upstream slopes are riprap (dry dumped or placed). The upstream slope protection would extend from the crest of the dam to a safe distance below the minimum water level. The thickness of riprap would be of sufficient weight and size to resist wave action.
12.2.4.2 RESERVOIR FOOTPRINT
The normal operating surface water elevation is approximately 4,619 -amsl, which results in a reservoir footprint of approximately 103 acres. The high surface water elevation (i.e., flood stage) is approximately 4,625 ft-amsl, with a minimum freeboard of 5 feet. The conceptual reservoir footprint area is shown on Sheet TD-2. The normal water surface elevation and reservoir footprint will impact lands owned by the State of Wyoming.

12.2.4.3 SERVICE SPILLWAYS
The Taylor Draw reservoir is considered an off-channel reservoir. The reservoir is not expected to spill frequently due to the ephemeral nature of the upstream watershed. Elevation versus capacity data for the reservoir is presented on Sheet TD-2. This curve is based on 10- meter NED data.

The spillway would be located on the north side of the reservoir. This reservoir is considered high hazard due to the local proximity of residential structures and Highway 434 downstream of the proposed site. If this site is considered for further advancement, the service spillway would be required to accommodate the full PMF event. A PMF analysis was not completed during this study as the site was removed from further consideration prior to calculation of the flood hydrology. The service spillway (primary and auxiliary) design includes a riprap-reinforced trapezoidal section. The spillway extends over a topographic knob, down the existing topography, and terminates at a stilling basin. Riprap will be placed downstream of the energy dissipater to prevent scouring of the natural drainage channel. Discharges from the spillway would be directed back into Taylor Draw with some grading required. The spillway alignment and cross section are shown on Sheet TD-2.

12.2.4.4 OUTLET WORKS
The outlet works are designed to be placed along the existing natural drainage. The outlet works will be sized to meet the WSEO requirements for emergency lowering of the reservoir and to provide for maximum anticipated irrigation uses. The outlet works would have valves to control flow through the embankment depending upon downstream water needs, available storage capacity, and stream inflows. The outlet works are assumed to incorporate two, 18-inch diameter pipes in parallel. The hydraulic valve would be controlled with the operator stem mounted on the upstream slope of the dam, and manually operated from the dam crest in order to control flow through the dam both for a drawdown and demand purposes.

The outlet works would discharge into a stilling basin, which will dissipate the flow energy at the toe of the dam. Rock riprap will be placed downstream of the impact basin to prevent scouring of the natural drainage channel and
undermining the toe of the dam. Some minor grading of the channel will be required to direct flow from the impact basin to the natural drainage channel.

12.2.4.5 APPURTENANCES

Taylor Draw is an off-channel location and would need to be filled using water diverted from Otter Creek. The length of the proposed diversion would be approximately 34,250 feet (~6.5 miles). Measures would need to be implemented to allow continued ranching operations on both sides of the diversion ditch (e.g., cattle crossings). Based on feedback from landowners/operators and review of geology in the area, portions of the diversion could be susceptible to losses. Portions of the diversion may need to be lined or the diversion could be placed in a pipe

Two scenarios were evaluated for filling the reservoir (Table 12-7). Both scenarios accounted for maintaining a minimum flow in Otter Creek as well as satisfying existing water rights. The first scenario assumes the reservoir is empty and is filled over the winter months (from November through April). This scenario, which is shown graphically as Figure 12-8, would divert flows ranging from 4 to 13 cfs. The second scenario assumes the reservoir is filled in the spring, during high runoff (April through June). This scenario, which is shown graphically as Figure 12-9, would divert flows ranging from 6 to 23.5 cfs.

The diversion alignment shown on Sheet TD-1 was sized to convey water to fill the reservoir in less than a month (approximately 50 cfs). The diversion consists of an open trapezoidal channel with a bottom width of 4 feet, 2.5H: 1V side slopes, which would have the capacity to convey the water at a 2-foot depth. In areas where a pipe is required, a 36-inch diameter pipe would be required. The alignment and structure dimensions will be revised if this site is reconsidered during future Project phases. Likewise, design of the diversion structure, which may need to incorporate a fish screen or similar structure to prevent fish entrainment, will be evaluated during future design phases.

The proposed location for the auxiliary spillway is located to the north of the proposed embankment. In the case of a full PMF event, the water would spill down the engineered spillway. This water would need to be routed under Wyoming Highway 434. A bridge or culvert system would need to be constructed to avoid washing out the road during a flood emergency situation. For the purposes of the Level II estimate, the costs for constructing an additional bridge and underpass were assumed and not estimated at length.

12.2.5 ALTERNATIVE 5 – CORNELL GULCH

A conceptual layout only was developed for the Cornell Gulch site. A conceptual design was not completed as the site was removed during the design process due to the logistics of supplying water to the site and the limited water supply.
in the Nowood River at that location in the Watershed. A simulation in StateMOD to identify beneficiaries and estimate shortage reductions was not completed for the Cornell Gulch site.

The proposed location would be an off-channel reservoir storing waters diverted from the Nowood River (Sheet CG-1). The site is located in the upper end of the Watershed in a broad valley on lands owned by the State of Wyoming. The site would be capable of storing approximately 17,000 ac-ft of water (with a 220 feet high embankment); however, after considering the local hydrology and storage efficiency curve; a reservoir capable of storing approximately 2,660 ac-ft was the most economical option.

During the conceptual design discussions, there were concerns regarding the flow available to fill the reservoir through a diversion from the Nowood River. A temporary stream gage (Nowood Crawford) was installed slightly upstream from the proposed diversion for Cornell Gulch on the Nowood River. A StateMOD model node was also located slightly upstream from the proposed diversion to estimate physical and available flows in the upper reach of the Nowood River. As discussed in Section 6.3, there is a correlation between the StateMOD simulated flows and the temporary stream gage during the study period. If the reservoir were filled by both the Cornell Gulch watershed and the diversion from the Nowood River (accounting for no baseflow) for an entire year, a total of 4,988 ac-ft (average year) or 2,835 ac-ft (dry year) would be available to annually fill the reservoir. Assuming a baseflow of approximately 2.5 cfs is maintained in the Nowood River, a total of approximately 3,390 ac-ft would be available in an average year and approximately 1,320 ac-ft during dry years (Table 12-8). Both scenarios assume no calls are placed on the river by downstream users. Additionally, the estimated storage efficiency for the proposed site is considered to be poor.

This site, which would provide benefits to the upper portion of the Watershed may be reconsidered in the future based on further refinement to the StateMOD model.
13.0 COST ESTIMATES

Conceptual level cost estimates were developed for four of the top five alternative storage sites. Conceptual level costs were not developed for the Cornell Gulch site as the level of design completed for this site was not adequate for developing a cost estimate at the same level as the Meadowlark Lake enlargement, Alkali Creek, Lower Luman Creek, and Taylor Draw alternatives. However, a cost estimate commensurate with sites not advanced to conceptual designs was developed for Cornell Gulch to allow for comparison of site characteristics in the Matrix. Cost estimates for the remaining four top ranked alternative sites were developed using the WWDC standard format. This includes costs associated with the preparation of final plans and specifications, permitting and mitigation, legal expenses, acquisition of access and rights-of-way (ROW), construction, construction engineering, and contingencies. The cost estimates are conceptual, with a confidence level of +/- 30% to 50%, and will be revised and further developed during future Project phases for sites that are advanced.

Pre-construction costs (preparation of final plans and specifications, permitting and mitigation, legal expenses, acquisition of access and ROW) were estimated using a percentage of the total capital construction costs or as a lump sum. The cost for preparation of final plans and specifications is estimated to be approximately 8% of the total construction costs. The cost for permitting and mitigation is estimated to be a lump sum price based on applicable agency involvement (i.e., private, state, and/or federal). The cost for legal expenses (attorney’s fees, documentation, permitting assistance, etc.) is estimated to be a lump sum value of $100,000. The cost for acquisition of access and ROW for irrigated land and rangeland is estimated to be $2,500 and $500 per acre, respectively.

Construction costs were estimated for the primary reservoir components (e.g., dam embankment, slope protection, spillway[s], outlet works, supply canals, etc.), infrastructure relocations or modifications (e.g., road relocation, utility relocation, road crossings/bridge, etc.), and miscellaneous items (e.g., contractor mobilization, clearing and grubbing, fencing, etc.). Construction cost estimates were prepared by developing a list of construction components, estimating construction quantities for major work items, and estimating unit prices and lump sum costs. Quantity takeoffs were based on the conceptual designs discussed in Section 12 and were based on 10-meter NED topography. The quantities should be considered rough estimates and will require refinement after more precise topographic surveys are completed. Unit prices and lump sum estimates were based on an internal database of recent bid tabs for large earthwork projects, information presented in the previous Level I Study and WWDC studies for similar projects, and engineering experience.

A summary of the conceptual level cost estimates for the four top ranked alternatives are provided in Table 13-1. Cost estimate breakdowns for each of the sites are included in Tables 13-2 through 13-5. The estimated costs range from
$2,800,000 for a 5-foot upstream embankment raise for Meadowlark Lake to $15,750,000 for construction of a new reservoir on Alkali Creek. The costs presented are based on 2013 economics. Typically, an assumed annual inflation rate of 2-3% may be applied based on actual project implementation dates and schedules for budgetary purposes.

Conceptual level annual operations and maintenance (O&M) costs were also estimated. These costs are provided in Table 13-6. The O&M costs are based on assuming a dam tender working 20 hours per week over an approximate 7-month period each year plus 0.5% of the alternative capital costs, excluding the embankment (dirt) cost. O&M costs were assumed for Meadowlark Lake for comparison between sites; however, Meadowlark Lake is located on lands administered by the USFS and is agency-owned. Water would most likely be sold to the irrigators and O&M costs would not be covered by the landowner’s association.
14.0 ECONOMIC ANALYSIS

An economic and financing analysis was completed for the top two alternatives in the Watershed: Alkali Creek and enlargement of Meadowlark Lake. The analysis used a farm budget type of analysis to determine the most beneficial alternative. The farm budget analysis takes into consideration the potential increase in farm income due to direct and indirect benefits if additional water storage is available. This type of approach was used to complete a benefit-cost analysis and an ability-to-pay analysis for each alternative. Potential funding sources and scenarios for the construction of each alternative were also evaluated and are discussed in the following sections.

14.1 BENEFIT-COST ANALYSIS

A benefit-cost analysis measures the benefits and costs of a project in terms of its equivalent money value to determine if the project will be economical and beneficial to the public. Both direct and indirect benefits were analyzed to develop a benefit-cost analysis for each alternative.

14.1.1 DIRECT BENEFITS

Direct benefits of providing additional water storage are the availability of water to downstream users for irrigation operations. The economic benefit of additional water for irrigation is measured by the potential increase in a farm’s income due to an increase in crop yields. According to the Level I Study (ACE 2010) and the WCCD, the dominant irrigated crops within the Watershed are alfalfa and grass hay. Corn, oats, and beets are also grown to a lesser extent; however, for this analysis the focus was placed on an irrigated alfalfa hay crop production.

To estimate the potential income increase for the benefit-cost analysis, several variables had to be determined. Variables include the crop efficiency, crop yield response, market value of the crop being examined, and the increase in production costs that would be needed to harvest the crop. Because of the conceptual level of this analysis, assumptions/estimates were made based on a literature research for the area. Local beneficiaries have not yet been interviewed to confirm their willingness to participate in the reservoir storage projects identified during the Project by purchasing water. Rather, this analysis is intended to provide preliminary economic information regarding the cost and benefits to Wyoming and the potential sponsors of alternative water storage projects who live in the Watershed.

Estimates of annual irrigation efficiency were developed using the 2010 Wind/Bighorn Update Task 3A – Agricultural Water Use Technical Memorandum (MWH 2010). The 2010 Wind/Bighorn Update provides estimates of overall efficiencies for multiple study areas within the Wind/Bighorn Basins that range between 20% and 44% for small systems with unlined canals and sufficient management. With the exception of the Anita Ditch (which was assigned a
pattern of higher efficiencies due to its improved irrigation delivery system), the average efficiency used in the
StateMOD model for this Project, was 29%, which took into consideration efficiencies for typical small, unlined flood
systems (Stage 2 StateMOD model Memo, Appendix C2). An efficiency estimate of 29% was used in developing the
cost-benefit estimate described in this section.

The crop yield response to additional irrigation water was developed using the CIR estimated for alfalfa and the
irrigated alfalfa yields for Big Horn and Washakie Counties. A CIR for alfalfa was estimated during the development
of the StateMOD model for the Watershed. Discussion regarding the development of this value is provided in the
Stage 3 StateMOD Tech Memo provided in Appendix C4. A value of 2.08 ac-ft/acre is estimated for alfalfa in the
StateMOD model and was also used for this analysis. As stated in the 2010 Wind/Bighorn Update, crop irrigation
requirements presented in the Consumptive Use and Consumptive Irrigation Requirements – Wyoming (Pochop, et al
1992) are usually used to determine the CIR. For comparison, the estimated CIR determined from the Pochop report
for growing alfalfa in the Ten Sleep area is approximately 2.16 ac-ft/acre, which is reasonably consistent with the
2.08 ac-ft/acre used for this analysis.

To calculate the crop yield response, the irrigated alfalfa yields were estimated for Big Horn and Washakie Counties
using data available from the Wyoming Office of the National Agricultural Statistics Service
counties over an 8-year period (2000 to 2007) was approximately 3.5 tons/acre. Using the CIR discussed above and
alfalfa yield estimates, the crop yield response is calculated. A crop yield response averaging 1.68 tons/ac-ft of
consumptively used irrigation water was estimated.

The market value of the additional yield generated from an ac-ft of additional irrigation water is dependent on crop
prices. Crop selling prices for alfalfa hay in Wyoming have fluctuated since 2000 (Figure 14-1). According to
statistics provided by the Wyoming Office of the National Agricultural Statistics Service, from 2000 to 2009 the
average price per ton of alfalfa was approximately $96. In the last 2 years (2010 to 2012) the price per ton has
increased to an average of approximately $174/ton. Given the variability in pricing, an average selling price of
$135/ton is used as a basis to estimate the cost-benefit.

The economic benefit of an additional ton of hay production can be established based on the difference between its
selling price and increased production costs that are incurred by the producer in order to harvest the additional crop
yield. The increase in production costs primarily regards increases in irrigation, baling, loading, and storing the hay.
The production cost per ton of alfalfa hay was estimated using the 2013 Crop Budgets developed by the University of
Nebraska Extension (Klein and Wilson 2013). According to the crop budget, it is estimated that production costs for a
gravity irrigated field yielding 6.6 tons/acre of large square alfalfa bales would be approximately $66/ton. For this analysis a yield of 3.5 tons/acre was used, therefore the associated estimated production cost was reduced to $55/ton.

Using the variables described above and an increase in available water in the Watershed, a cost-benefit can be estimated. If one additional ac-ft of water is applied at an irrigation diversion point with an efficiency of 29% and a crop yield response of 1.68 tons/ac-ft, an estimated increase in hay production of 0.49 tons/ac-ft (0.29 X 1 ac-ft X 1.68 tons/ac-ft = 0.49 tons/ac-ft) could be expected. At an average selling price of $135.00/ton, the estimated increase value in production is $65.77/ac-ft ($135/ton X 0.49 tons/ac-ft). Subtracting the production cost increase of $26.80/ac-ft ($55/ton X 0.49 tons/ac-ft) yields a net benefit of $38.98/ac-ft. The net benefit for each additional ac-ft of irrigation water that is available for diversion would be $38.98. A summary and result of the cost-benefit analysis are displayed in Table 14-1.

Both storage alternatives, Alkali Creek and Meadowlark Lake, were analyzed based on values estimated from the above cost-benefit analysis. Net return benefits were calculated by estimating the increase in hay production in tons for additional applied irrigation water. To calculate the increase in hay production, the additional available water and the alfalfa yield increase per additional ac-ft of water (0.49 tons/ac-ft) were used. Site specific analyses are discussed in the following sections.

### 14.1.1.1 ALKALI CREEK

As described previously in this report, the Alkali Creek reservoir has a storage capacity of approximately 7,400 ac-ft with approximately 5,550 ac-ft available for irrigation, assuming 25% of the reservoir capacity is set aside as a conservation pool. There is approximately 4,880 acres of irrigated land located directly downstream of the reservoir consisting of alfalfa and grass hay, corn, various grains, and beets (personal communication with Craig Cooper, 2012). For this cost-benefit analysis benefitting irrigated acreage downstream of the storage alternative was assumed to consist of irrigated alfalfa. Using the cost-benefit estimated above, the estimated increase in hay production resulting from an additional 5,550 ac-ft of water per year, or 1.14 ac-ft/acre, would be approximately 2,700 tons/year (Table 14-2). Note that if the water was applied in a manner to overcome system efficiencies and provide the CIR of 2.08 ac-ft/acre, the served acreage would decrease to 2,688 acres. However, the calculated increase in alfalfa would remain the same (2,704 tons/year) as this is based on the ac-ft of water available. This increase in alfalfa hay would result in a direct net income increase of approximately $216,300 per year. The estimate of the increase in alfalfa hay production and income is likely at the upper range of what could be realized from the reservoir storage. This increase in production assumes that the entire 4,880 acres of downstream irrigated land will use the additional supplemental water, whereas realistically a portion of the irrigated demand may already be satisfied.
To find the lower range of gain, results from the StateMOD model were analyzed. Although the model assumes additional crop types other than just alfalfa, changes in results were assumed to be insignificant and to have little effect in this cost-benefit analysis. Model results show that the average annual demand downstream of the Alkali Creek storage location is approximately 35,500 ac-ft (March 11, 2013 Tech Memo provided in Appendix C4). Of this demand, approximately 33,000 ac-ft are satisfied under the current water use and adherence to Wyoming Water Law; resulting in a shortage of approximately 2,500 ac-ft. Dividing the shortage by the CIR identified above (2.08 ac-ft/acre) results in approximately 1,200 acres of irrigated land below the reservoir that could benefit from additional water for irrigation. If the shortage was met, an increase in hay production of 1,220 tons/year could be achieved resulting in an annual increase in net income of approximately $97,450/year.

Based on the cost-benefit analysis above, a net income increase in the range of $97,450 to $216,300 per year is estimated for the Alkali Creek alternative. This range is based on the current water use in the Watershed. As opportunities for enhanced irrigation are identified, this cost-benefit analysis should be updated.

### 14.1.1.2 MEADOWLARK LAKE

An enlargement of Meadowlark Lake would result in a storage capacity increase of approximately 1,360 ac-ft (representative of a 5-foot water surface elevation raise) for a total storage capacity of approximately 4,680 ac-ft. Assuming 25% of the total storage capacity is reserved as a conservation pool, the storage available for irrigation is approximately 3,510 ac-ft. Approximately 6,870 acres of irrigated land may be served by storage supply in the reservoir. Following the same procedure that was used for the Alkali Creek alternative, a cost-benefit was estimated and is provided in Table 14-2. If available storage water is applied (assuming alfalfa crop production) by downstream irrigators, approximately 1,710 tons per year of additional alfalfa hay could be produced. As noted for the Alkali Creek analysis, if the water was applied in a manner to overcome system efficiencies and provide the CIR of 2.08 ac-ft/acre, the served acreage would decrease to 1,690 acres. However, the calculated increase in alfalfa would remain the same (1,710 tons/year) as this is based on the ac-ft of water available. This would result in a net income increase of approximately $136,800 per year. Similar to the cost-benefit analysis for Alkali Creek alternative, the increase in production and income is likely at the upper range of what could be realized from the reservoir storage.

The lower range of gain was estimated based on the same procedure discussed for the Alkali Creek alternative. The StateMOD model simulate the average annual demand downstream of Meadowlark Lake at approximately 66,400 ac-ft (March 11, 2013 Tech Memo provided in Appendix C4). Of this demand approximately 63,400 ac-ft is satisfied under the current water use and adherence to Wyoming Water Law; resulting in a shortage of approximately 3,000 ac-ft. If
the shortage was met, an increase in hay production of 1,460 tons per year could be achieved resulting in an annual increase in net income of approximately $116,950.

An estimated net income increase for the Meadowlark Lake storage alternative is in the range of $116,950 to $136,800 annually. The income estimate is based on the current water use practices in the Watershed. As understanding of improved irrigation practices or crop changes that will result in response to the access to storage water is refined through input from beneficiaries and modeling, this cost-benefit analysis should be updated.

### 14.1.2 INDIRECT IRRIGATION BENEFITS

Whereas direct benefits generally accrue to the farming community or landholders, indirect benefits accrue to wide sectors of the economy. Indirect benefits are those benefits that accrue from the processing of goods produced by the project. An example would be a farm machinery supplier whose business is stimulated by increased crop yields. The indirect benefit can be measured from the economic multiplier effect due to increases in income in the economy.

The Bureau of Economic Analysis of the U.S. Department of Commerce (USDOC) produces periodic estimates of indirect income multipliers for the agricultural sector in Wyoming. The latest published estimate of this multiplier is 2.63 (USDOC 2007), meaning that for every $1.00 of net farm income and farm labor payments, $2.63 of entrepreneurial income, property income, and labor income are created elsewhere in the local economy. The $2.63 is comprised of $1.00 of farm income plus a $1.63 increase in indirect income in other economic sectors. Applying this multiplier results in a combined direct and indirect benefit of between $256,250 to $568,900 for the Alkali Creek alternative, and $307,500 to $359,800 for the Meadowlark Lake alternative. Total indirect benefits associated with a new irrigation project may be larger than the increases estimated in this analysis.

### 14.1.3 ADDITIONAL BENEFITS

In addition to direct and indirect benefits, additional storage and reservoir supplies in the Watershed will also provide other benefits, including:

- Enhanced opportunity for recreational water use
- Improved fisheries
- Created wetlands
- Enhanced wildlife habitat
• Improved water quality
• Flood management

Water storage at both reservoir sites would provide recreational benefits. Currently Meadowlark Lake is a popular recreational location for travelers along the scenic Cloud Peak Skyway (Highway 16). Increasing the storage capacity of the Meadowlark Lake, may improve fish habitat and provide additional opportunities for water-based recreation for visitors.

The Alkali Creek alternative may also provide recreational opportunities to the public in area where flat-water recreation is limited. Public access would be allowed at the reservoir site as a stipulation of State funding, thereby allowing access to adjoining public land for recreational activities. Much of the area adjoining the reservoir site is BLM-administered public lands that are not managed specifically for recreation.

Enhanced stream flow at the outfalls of the reservoirs will also provide ancillary benefits. During the summer and winter months, water released from Meadowlark Lake is lost to subsurface flow in downstream areas along East Tensleep Creek. Trout that escape from the reservoir become trapped in small pools along the creek. If additional water was released for irrigation, it is possible that East Tensleep Creek would maintain viable surface flow to allow fish passage. Tensleep Creek below the reservoir will also benefit due to increased flows. Tensleep Creek is a popular fishery and is also associated with two important fish production facilities operated by the State; the Ten Sleep Fish Hatchery and the Wigwam Rearing Station. Wetland and wildlife habitat will benefit from the additional water available through both alternatives. The area surrounding the Alkali Creek alternative could benefit greatly from storage water. This area is presently dominated by salt brush. A consistent reservoir pool will benefit wildlife and may provide additional habitat for the sage-grouse.

Development of reservoirs often improves downstream water quality. Sediment laden waters are captured and stored in the reservoir allowing better quality water to be released downstream. In some cases, reservoirs may also have some detrimental effects to water quality. For example, concern was voiced by the FWS regarding selenium concentrations in the Alkali Creek drainage, and what impacts, if any, development of storage might have to the metal concentration in the water. These concerns are discussed in Section 10.

Some reservoirs provide infrastructure to manage flooding to downstream areas. Although flood control is not identified as a beneficial use of storage for either of the storage alternatives identified for advancement under the Project, both the Alkali Creek and Meadowlark Lake alternatives will provide infrastructure for flood management.
During times of high runoff these reservoirs provide the capacity to capture and store water so that it may be released at rates needed for beneficial use downstream.

Specific estimates of the additional economic benefits associated with the reservoir development alternatives will be developed during future phases of study as more detailed design and operations plans become available. As such, no specific demands or quantitative estimates have been produced and a cost-benefit should be completed for each supplemental benefit in future studies.

14.2 FINANCING UNDER WWDC GUIDELINES

The typical WWDC project financing standard is 67% grant with the remaining 33% of project costs to be repaid by the project sponsor. The WWDC also has the ability to grant up to 75% with the remaining 25% repaid by the project sponsor. On storage projects such as this, the WWDC and the Wyoming Legislature have the authority to approve 100% of the project cost based on the relative benefits to the State and the sponsor as estimated by the WWDC.

Statutory guidelines establish a minimum interest rate of 4% for financing plans. This interest rate is subject to change by the Wyoming Legislature. Statutes allow the WWDC to defer payment of interest for up to 5 years after completion of a project. Repayment may be financed over a maximum period of 50 years; however, the sponsor’s method of repayment and the longevity of the sponsor’s existence as a legal entity will be taken into consideration by the WWDC. The implications of applying these funding criteria to Alkali Creek and Meadowlark Lake are presented in Table 14-3.

14.3 ABILITY TO PAY ANALYSIS

The ability to pay analysis was evaluated to estimate the amount users could pay for the storage projects (including operation, maintenance, [O&M] and replacement costs) and to provide information for the development of a financing plan. The ability to pay considers the ability of local irrigators to pay for a portion of the overall project costs in return for additional water storage and supplemental irrigation water that would be made available.

As shown in Table 14-3, under the typical financing guidelines of a 67% grant and 33% loan mix, financed over a maximum of 50 years at 4% interest, the annual obligation by the sponsor would be approximately $43,000 for enlargement of Meadowlark Lake Reservoir and $241,800 for construction of Alkali Creek Reservoir. These estimates for loan repayment would be in addition to annual costs for O&M (Table 13-6). If O&M was included, an obligation ranging between $65,900 and $265,500 per year, depending on the alternative, would be required.
The sponsor’s ability to pay is estimated by comparing the estimated annual financial returns of direct irrigation benefits from the alternatives to the debt service. Table 14-2 represents an upper bound on the irrigator’s ability to pay because the values are estimates of the total additional farm income that may be generated from additional storage. If irrigators need to dedicate all of the income benefits to repay the loan obligation for construction of the project, there would be no incentive to participate in the project. However, assuming the $38.98 per acre (estimated in the benefit-cost analysis [Table 14-1]) of additional farm income that would accrue to irrigators for each ac-ft of additional irrigation water means that irrigators could gain an average (average between upper and lower range) between $126,900 and $156,900 (direct irrigation benefits [Table 14-2]) in additional income annually depending on the alternative. The ability to pay values presented in this report are based on very preliminary values for the yield and benefits analysis.

A more realistic approach is to ask the question: how much are irrigators willing to pay for additional water and keep the right to retain the water for future use? Willingness to pay investigations completed previously for the WWDC have found that typically irrigators have been willing to pay in the range of $5 to $25 per ac-ft for additional irrigation water. The higher end of this range is associated with irrigators who are able to produce high value row crops, as opposed to hay crops. Because irrigated alfalfa hay is likely to be the primary crop produced in the Watershed, a preliminary willingness-to-pay analysis was performed based on the assumption irrigators might be willing to pay $15 per ac-ft released from a reservoir. Storage water is typically assessed on the basis of water delivered; however, given the speculative nature of this preliminary analysis, conveyance losses are not incorporated as part of the calculation.

Results of an irrigators willingness-to-pay based on water sold for $15 per ac-ft are presented in Table 14-4. The estimated storage available for irrigation at Alkali Creek was assumed to be the full 5,550 ac-ft. This results in annual revenue of approximately $83,300 for water from the Alkali Creek alternative. The loan for this amount would result in the sponsor paying approximately 11% of the total project capital cost under the 50 year loan (9% for a 30 year loan). The Meadowlark Lake analysis estimated the available storage for irrigation based on the water available from a 5-foot raise in water surface elevation or approximately 1,360 ac-ft. Assuming irrigators would only be paying for the increased storage amount that would occur from an enlargement and not the full irrigation storage potential of the reservoir generates annual revenue of approximately $20,400. As presented in Table 14-4, this would result in the sponsor paying approximately 16% of the total project capital cost under the 50 year loan (13% for a 30 year loan). This analysis predicts that the revenue generated from water sales for storage in the Alkali Creek or Meadowlark Lake alternatives will likely be insufficient to offset the sponsor’s annual obligation to repay a loan from the WWDC, unless the grant covers approximately 90% of the capital cost of the alternatives.
14.4 POTENTIAL FUNDING SOURCES

A majority of potential sources of funding for the preferred storage alternatives were identified during the Level I Study and discussion of each source can be found in the Level I Study Final Report (ACE 2010). The level of funding available from the WWDC will be dependent upon the sponsor’s method of repayment, the longevity of the sponsor’s existence as a legal entity, and the potential of the Project to have multiple beneficial uses. The potential funding sources identified in this report are not necessarily exhaustive of the resources that may be available. Existing programs change and sometimes disappear over time, new programs may arise, funding levels may vary annually, and competition for many of the programs is significant. Potential funding sources identified at the local, state, and federal levels in the Level I Study Final Report (ACE 2010) are listed below by agency, and provided in Table 14-5. The agencies or organizations listed below in bold text were not identified in the Level I Study, but may provide opportunity for additional funding.

Local Agencies
- Big Horn County Weed and Pest District
- South Big Horn County Conservation District
- Washakie County Conservation District
- Washakie County Weed and Pest District
- Worland Grazing District

State Agencies
- Wyoming Department of Environmental Quality
- Wyoming Game and Fish Department
- Wyoming Office of State Lands and Investments
- Wyoming Water Development Commission
- Wyoming Wildlife and Natural Resource Trust

Federal Agencies
- Bureau of Land Management
- Bureau of Reclamation
- Environmental Protection Agency
- Farm Service Agency
- Fish and Wildlife Service
- National Fish and Wildlife Foundation
- Natural Resources Conservation Service

**Non-Profit and other organizations**

- Ducks Unlimited
- **Mule Deer Foundation**
- National Fish and Wildlife Foundation
- **Rocky Mountain Elk Foundation (RMEF)**
- Trout Unlimited
- **Wildlife Heritage Foundation of Wyoming**
15.0 CONCLUSIONS AND RECOMMENDATIONS

15.1 CONCLUSIONS

In 2007, a group of landowners in the Watershed raised concerns with late season water shortages as well as the potential benefits to water users, and others, in the Watershed if it is feasible to develop reservoir storage. These landowners requested the WWDC’s assistance in completing a Watershed study to evaluate the shortages in the Watershed, the availability of early season flows for storage, and other management approaches that could benefit the overall health and productivity of the Watershed. Based on recommendations in the Level I Study, this Project was undertaken to further evaluate the timing, location, and magnitude of shortages and available flows in the Watershed, and to evaluate potential storage alternatives.

A StateMOD watershed hydrologic model was developed to simulate flows in the Watershed. This model incorporates historical data about water resources and use, timing, and degree of water shortages, as well as water that may be physically and legally available for development in the Watershed. A Baseline Model Scenario was calibrated to establish natural flow with water rights and demands to quantify available flows and shortages during a 36-year study period from 1973 to 2008, which takes in a broad range of hydrologic condition, including drought years and years with abundant water supplies. Based on the Baseline Model Scenario, the total Watershed demand for water during the irrigation season (April-October) in a year with average hydrologic condition is approximately 146,000 ac-ft. Of this total demand, the average annual shortage is estimated to be approximately 10% (15,151 ac-ft). In a dry year, the model estimates a water shortage of 12% (16,990 ac-ft) of the demand in the Watershed. Shortages are concentrated in the upper portions of the Watershed above Tensleep Creek (an estimated shortage of approximately 6,471 ac-ft or 43% of the total shortage) and along Paint Rock Creek (5,647 ac-ft or 37% of the total shortage). The Baseline Model Scenario also identified available flows (meaning flows that are not currently put to beneficial use under existing water rights) for development or storage throughout the Watershed (Figure 6-4). The available flows were primarily associated with runoff from snow melt during the early part of the irrigation season that is not currently diverted. This surplus water flows out of the Watershed before it can be put to beneficial use. The StateMOD Model simulations support the assertions of the local landowners; there does appear to be a shortage in later season water and there is water available for storage.

Work completed as part of the Project also expanded the evaluation of potential reservoir sites suited for storing available flows in the Watershed so that the flows could be released at times to meet late season shortages. The Level I Study identified 35 potential storage sites. Five additional sites (Cherry Creek, Upper Luman Creek, Lower Luman Creek, Cornell Gulch, and Willow Creek [an alternative to West Fork Willow Creek]) were identified during this
Project. The characteristics of the 5 sites identified during the Level II Study and the 35 sites identified during the Level I Study were compared in a Matrix (Table 9-3) to evaluate which sites might provide the most benefits to the Watershed with the least impact (economic, environmental, or otherwise). More detailed investigations, including site visits to evaluate geotechnical and geological conditions, evaluation of environmental considerations, discussions with landowners and agencies, and development of conceptual level designs and cost estimates were completed for a short list of sites that appeared to provide the most overall value to the Watershed.

Based on evaluation of the characteristics, benefits, and impacts of the 40 identified potential storage sites, two sites are recommended for further evaluation: an expansion to Meadowlark Lake and construction of a new reservoir on Alkali Creek. Meadowlark Lake is located on the Bighorn National Forest near the headwaters of Tensleep Creek. Alkali Creek is a small tributary to Paint Rock Creek, which is a primary tributary to the lower Nowood River. Other potentially viable sites (i.e., sites where a reservoir could be constructed, flows are available for storage, and the stored water could be applied to meet shortages) also exist in the Watershed. Alternative sites will continue to be evaluated to establish purpose and need for water storage facilities best suited for benefiting residents in the Watershed and the State of Wyoming.

### 15.1.1 MEADOWLARK LAKE ENLARGEMENT

Meadowlark Lake (permitted as Tensleep Reservoir) is an existing reservoir located on East Tensleep Creek in the Bighorn National Forest, above the confluence with Tensleep Creek. One of the permitted uses for this site is irrigation. However, current operating practices at the reservoir do not typically provide for releases to meet irrigation demands. Changing the operations of the reservoir to incorporate releases for irrigation could satisfy a portion of the shortages experienced by downstream irrigators.

Raising the water level in the reservoir was evaluated as a means to provide additional relief of late season irrigation shortages. Raises ranging from 5 to 15 feet were evaluated. For the purposes of this study, conceptual designs and StateMOD model simulations were completed for a 5-foot raise in the operating high-water line. This raise in water level would increase the reservoir storage from approximately 3,316 ac-ft to 4,676 ac-ft, an increase of 1,360 ac-ft. Review of the simulation results for this reservoir enlargement suggest that the Baseline shortage for the entire Watershed could be reduced to 14,103 ac-ft or a 9.7% shortage; a reduction of 1,048 ac-ft or 7% reduction.

### 15.1.2 ALKALI CREEK

The Alkali Creek alternative includes development of a reservoir on Alkali Creek above the confluence with Paint Rock Creek. While this alternative would impound Alkali Creek, the site would function as an off-channel reservoir
filled with available flows diverted from Paint Rock Creek and Medicine Lodge Creek by enlargement of the Anita Supplemental Ditch and the Anita Ditch. Improvements to these existing ditches would likely be required to allow for conveyance of reservoir-supply flows and irrigation flows.

The proposed reservoir would provide 7,400 ac-ft of storage. Review of the simulation results suggest that storage in this reservoir could reduce the Baseline shortage for the entire Watershed to 12,002 ac-ft or an 8.2% shortage; a reduction of 3,149 ac-ft or 21% reduction. Water stored in this reservoir could benefit irrigators, directly and through exchange, on Paint Rock Creek, downstream of Paint Rock Creek on the Nowood River, upstream along the Nowood River to Ten Sleep, and along Tensleep Creek.

15.2 RECOMMENDATIONS
Based on the results of this Project, continued evaluation of storage alternatives in the Watershed is warranted. A potential new reservoir on Alkali Creek and enlargement and/or changes in the operations practices of Meadowlark Lake are recommended for more detailed investigations. Both of these alternatives appear to meet a portion of the needs documented in the Watershed. Recommended additional investigations and evaluations for these sites include:

- Subsurface geotechnical investigations to document overburden and foundation conditions as well as potential sources of borrow materials
- Wetland delineations to quantify potential wetland impacts associated with the alternatives
- Topographic surveying to allow for more detailed designs and to confirm or refine storage estimates
- Class III archeological investigations over the Alkali Creek project area
- More detailed evaluation of a 10-foot raise of the water level in Meadowlark Lake
- Continued temporary stream gaging to provide more data regarding diversions and hydrology throughout the Watershed
- Temporary stream gaging along reaches of East Tensleep Creek and Tensleep Creek to assess conveyance losses/gains below Meadowlark lake
- Continued data collection and refinement of the StateMOD model
- Refinement of conceptual designs and cost estimates
- Further economic analysis, including local stakeholder’s willingness to pay for storage water
- Continued coordination with interested or affected agencies to assess potential benefits and impacts, as well as to better define permitting and NEPA requirements and processes
Due to the nature of the Watershed geography and geology, and location of shortages, one storage alternative will not fully satisfy all shortages in the Watershed. Instead several storage sites throughout the Watershed will be needed to satisfy shortages. While Alkali Creek and the Meadowlark Lake enlargement alternatives are recommended for further study, other sites considered during this Project should not be completely discounted from consideration in the future. The two preferred alternatives assist in addressing shortages in the lower portion of the Watershed, but do not offset shortages in the upper Watershed to the degree that other alternatives may. Several viable alternatives were withdrawn from further evaluation based on the input of landowners or on concerns with available water for storage. Should ownership change or landowner views of storage change, these sites (particularly Deep Creek, Taylor Draw, or Big Trails) may warrant additional evaluation. Likewise, as additional data becomes available and the StateMOD model is refined, sites such as Cornell Gulch may become more viable.
16.0 REFERENCES


TABLES
### TABLE 2-1. RESULTS OF THE LEVEL I STUDY WATERSHED AVAILABLE FLOW ANALYSIS
**NOWOOD RIVER STORAGE, LEVEL II STUDY**

<table>
<thead>
<tr>
<th>Reach</th>
<th>Reach Name</th>
<th>Dry Year (ac-ft)</th>
<th>Normal Year (ac-ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>600</td>
<td>Nowood River above Tensleep Creek</td>
<td>5,874</td>
<td>9,760</td>
</tr>
<tr>
<td>610</td>
<td>Lone Tree Creek</td>
<td>1,646</td>
<td>3,424</td>
</tr>
<tr>
<td>620</td>
<td>Bear Creek</td>
<td>2,547</td>
<td>5,631</td>
</tr>
<tr>
<td>630</td>
<td>Deep Creek</td>
<td>5,874</td>
<td>9,760</td>
</tr>
<tr>
<td>640</td>
<td>Box Elder Creek</td>
<td>4,213</td>
<td>8,081</td>
</tr>
<tr>
<td>642</td>
<td>Red Bank Creek</td>
<td>3,718</td>
<td>7,135</td>
</tr>
<tr>
<td>650</td>
<td>Little Canyon Creek</td>
<td>2,409</td>
<td>6,001</td>
</tr>
<tr>
<td>655</td>
<td>South Fork Little Canyon Creek</td>
<td>110</td>
<td>246</td>
</tr>
<tr>
<td>660</td>
<td>Crooked Creek</td>
<td>835</td>
<td>2,220</td>
</tr>
<tr>
<td>670</td>
<td>Otter Creek</td>
<td>5,689</td>
<td>9,545</td>
</tr>
<tr>
<td>675</td>
<td>South Fork Otter Creek</td>
<td>5,101</td>
<td>8,988</td>
</tr>
<tr>
<td>680</td>
<td>Spring Creek</td>
<td>3,540</td>
<td>6,984</td>
</tr>
<tr>
<td>684</td>
<td>North Fork Spring Creek</td>
<td>749</td>
<td>2,058</td>
</tr>
<tr>
<td>690</td>
<td>Tensleep Creek</td>
<td>1,831</td>
<td>5,972</td>
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<tr>
<td>692</td>
<td>East Fork Tensleep Creek</td>
<td>1,831</td>
<td>5,972</td>
</tr>
<tr>
<td>694</td>
<td>West Fork Tensleep Creek</td>
<td>1,831</td>
<td>5,972</td>
</tr>
<tr>
<td>698</td>
<td>Big Canyon Creek</td>
<td>1,831</td>
<td>5,931</td>
</tr>
<tr>
<td>700</td>
<td>Nowood River from Tensleep Creek to Paint Rock Creek</td>
<td>157,247</td>
<td>188,298</td>
</tr>
<tr>
<td>740</td>
<td>Broken Back Creek</td>
<td>1,970</td>
<td>8,024</td>
</tr>
<tr>
<td>750</td>
<td>Buffalo Flat Creek</td>
<td>992</td>
<td>3,696</td>
</tr>
<tr>
<td>790</td>
<td>Paint Rock Creek</td>
<td>69,055</td>
<td>90,108</td>
</tr>
<tr>
<td>794</td>
<td>Medicine Lodge Creek</td>
<td>9,517</td>
<td>12,071</td>
</tr>
<tr>
<td>798</td>
<td>Alkali Creek</td>
<td>1,875</td>
<td>5,389</td>
</tr>
<tr>
<td>800</td>
<td>Nowood River from Paint Rock Creek to Bighorn River</td>
<td>248,963</td>
<td>316,886</td>
</tr>
</tbody>
</table>

ac-ft = acre-feet
<table>
<thead>
<tr>
<th>Reach</th>
<th>Reach Name</th>
<th>Dry Year (ac-ft)</th>
<th>Normal Year (ac-ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>600</td>
<td>Nowood River above Tensleep Creek</td>
<td>365</td>
<td>176</td>
</tr>
<tr>
<td>610</td>
<td>Lone Tree Creek</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>620</td>
<td>Bear Creek</td>
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<td>-</td>
</tr>
<tr>
<td>630</td>
<td>Deep Creek</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>640</td>
<td>Box Elder Creek</td>
<td>17</td>
<td>-</td>
</tr>
<tr>
<td>642</td>
<td>Red Bank Creek</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>650</td>
<td>Little Canyon Creek</td>
<td>2,028</td>
<td>1,459</td>
</tr>
<tr>
<td>655</td>
<td>South Fork Little Canyon Creek</td>
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<td>-</td>
</tr>
<tr>
<td>660</td>
<td>Crooked Creek</td>
<td>1,105</td>
<td>758</td>
</tr>
<tr>
<td>670</td>
<td>Otter Creek</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>675</td>
<td>South Fork Otter Creek</td>
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<td>-</td>
</tr>
<tr>
<td>680</td>
<td>Spring Creek</td>
<td>564</td>
<td>384</td>
</tr>
<tr>
<td>684</td>
<td>North Fork Spring Creek</td>
<td>204</td>
<td>135</td>
</tr>
<tr>
<td>690</td>
<td>Tensleep Creek</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>692</td>
<td>East Fork Tensleep Creek</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>694</td>
<td>West Fork Tensleep Creek</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>698</td>
<td>Big Canyon Creek</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>700</td>
<td>Nowood River from Tensleep Creek to Paint Rock Creek</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>740</td>
<td>Broken Back Creek</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>750</td>
<td>Buffalo Flat Creek</td>
<td>2,990</td>
<td>1,950</td>
</tr>
<tr>
<td>790</td>
<td>Paint Rock Creek</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>794</td>
<td>Medicine Lodge Creek</td>
<td>2,876</td>
<td>1,584</td>
</tr>
<tr>
<td>798</td>
<td>Alkali Creek</td>
<td>55</td>
<td>11</td>
</tr>
<tr>
<td>800</td>
<td>Nowood River from Paint Rock Creek to Bighorn River</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

`ac-ft` = acre-feet
### TABLE 2-3. LEVEL I STUDY PRIORITY 3 POTENTIAL STORAGE SITES

**NOWOOD RIVER STORAGE, LEVEL II STUDY**

<table>
<thead>
<tr>
<th>Site No.</th>
<th>Site Name</th>
<th>Priority</th>
<th>Site Constraints and Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Little Canyon Creek</td>
<td>3</td>
<td>Ownership and access limitations</td>
</tr>
<tr>
<td>6</td>
<td>County Line</td>
<td>3</td>
<td>Insufficient hydrologic potential</td>
</tr>
<tr>
<td>8</td>
<td>Lower Nowood</td>
<td>3</td>
<td>Impacts upon private residences, permitting constraints, wetlands and fisheries impacts</td>
</tr>
<tr>
<td>11</td>
<td>Medicine Lodge</td>
<td>3</td>
<td>Poor geologic conditions, fisheries and wildlife impacts, permitting constraints</td>
</tr>
<tr>
<td>13</td>
<td>Paint Rock Creek</td>
<td>3</td>
<td>Unsuitable geologic conditions</td>
</tr>
<tr>
<td>15</td>
<td>Pete</td>
<td>3</td>
<td>Insufficient hydrologic potential for large reservoir</td>
</tr>
<tr>
<td>16</td>
<td>Solitude</td>
<td>3</td>
<td>Wilderness area</td>
</tr>
<tr>
<td>17</td>
<td>Summit</td>
<td>3</td>
<td>Wilderness area</td>
</tr>
<tr>
<td>20</td>
<td>West Fork Willow Creek</td>
<td>3</td>
<td>Insufficient hydrologic potential for large reservoir</td>
</tr>
<tr>
<td>21</td>
<td>West Tensleep Lake</td>
<td>3</td>
<td>Wilderness area</td>
</tr>
<tr>
<td>23</td>
<td>Nowood - Mahogany Butte 1</td>
<td>3</td>
<td>Unsuitable geologic conditions</td>
</tr>
<tr>
<td>24</td>
<td>Nowood - Mahogany Butte 2</td>
<td>3</td>
<td>Unsuitable geologic conditions</td>
</tr>
<tr>
<td>28</td>
<td>Upper Brokenback</td>
<td>3</td>
<td>Small storage capacity, high cost per acre foot of storage</td>
</tr>
<tr>
<td>29</td>
<td>Woods Gulch</td>
<td>3</td>
<td>Small storage capacity, high cost per acre foot of storage</td>
</tr>
<tr>
<td>31</td>
<td>South Fork Otter (Lower)</td>
<td>3</td>
<td>Unsuitable geologic conditions</td>
</tr>
<tr>
<td>32</td>
<td>South Fork Otter (Upper)</td>
<td>3</td>
<td>Unsuitable geologic conditions, irrigated acres inundated</td>
</tr>
<tr>
<td>35</td>
<td>North Brokenback</td>
<td>3</td>
<td>Unsuitable geologic conditions</td>
</tr>
<tr>
<td>Site No.</td>
<td>Site Name</td>
<td>Priority</td>
<td></td>
</tr>
<tr>
<td>---------</td>
<td>------------------------</td>
<td>----------</td>
<td></td>
</tr>
<tr>
<td>Priority 1 Sites</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Big Trails</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Bruner Gulch</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Meadowlark Lake</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Taylor Draw</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Upper Nowood</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Deep Creek</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Nowood – Crawford</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Priority 2 Sites</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Alkali Creek</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Cottonwood Creek</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Lower Brokenback</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>McDermott Draw</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Otter Creek</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Lower Trout Creek</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Little Cottonwood Creek</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>Weintz Draw</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Alkali Creek South</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>Canyon Creek</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>Lone Tree</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Question 1</td>
<td>Which portion of the Watershed best defines your location?</td>
<td>Response Count</td>
<td>Response Percent</td>
</tr>
<tr>
<td>------------</td>
<td>----------------------------------------------------------</td>
<td>----------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Main stem of Nowood River downstream of Paint Rock Creek</td>
<td>3</td>
<td>17%</td>
<td></td>
</tr>
<tr>
<td>Paint Rock Creek / Medicine Lodge Creek / Alkali Creek watershed (or other tributary) above confluence with Nowood</td>
<td>1</td>
<td>6%</td>
<td></td>
</tr>
<tr>
<td>East of Nowood River upstream of Paint Rock Creek and downstream of Ten Sleep Creek</td>
<td>2</td>
<td>11%</td>
<td></td>
</tr>
<tr>
<td>West of Nowood River upstream of Paint Rock Creek and downstream of Ten Sleep Creek</td>
<td>3</td>
<td>17%</td>
<td></td>
</tr>
<tr>
<td>Ten Sleep Creek watershed above Nowood River</td>
<td>3</td>
<td>17%</td>
<td></td>
</tr>
<tr>
<td>Nowood River upstream of Ten Sleep Creek and downstream of Mahogany Buttes</td>
<td>2</td>
<td>11%</td>
<td></td>
</tr>
<tr>
<td>Nowood River upstream of Mahogany Buttes</td>
<td>2</td>
<td>11%</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>11%</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>18</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question 2</th>
<th>What type of operation or land use best describe your land use? (Please include consideration of leased lands in addition to deeded property)</th>
<th>Response Count</th>
<th>Response Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>No operation / in-town residential</td>
<td>0</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Residential / non-farmed / non-ranched 2 to 20 acres</td>
<td>0</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Livestock / range uses (less than 100 acres)</td>
<td>0</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Livestock / range uses (greater than 100 acres)</td>
<td>9</td>
<td>39%</td>
<td></td>
</tr>
<tr>
<td>10 to 100 acres irrigated</td>
<td>1</td>
<td>4%</td>
<td></td>
</tr>
<tr>
<td>100 to 500 acres irrigated</td>
<td>7</td>
<td>30%</td>
<td></td>
</tr>
<tr>
<td>500 or more acres irrigated</td>
<td>5</td>
<td>22%</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>4%</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question 3</th>
<th>Do you believe additional storage is needed within the Nowood watershed?</th>
<th>Response Count</th>
<th>Response Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>More storage</td>
<td>11</td>
<td>69%</td>
<td></td>
</tr>
<tr>
<td>Sufficient storage</td>
<td>4</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td>Don't know</td>
<td>1</td>
<td>6%</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>16</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question 4</th>
<th>If you believe more storage is needed, for what purpose would the stored water be used?</th>
<th>Response Count</th>
<th>Response Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation</td>
<td>12</td>
<td>39%</td>
<td></td>
</tr>
<tr>
<td>Flood Protection</td>
<td>9</td>
<td>29%</td>
<td></td>
</tr>
<tr>
<td>Fisheries</td>
<td>5</td>
<td>16%</td>
<td></td>
</tr>
<tr>
<td>Water Quality</td>
<td>3</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>6%</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>31</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question 5</th>
<th>How many acres are you entitled to irrigate?</th>
<th>Response Count</th>
<th>Average Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>352</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question 6</th>
<th>On average, how many acres do you actually irrigate?</th>
<th>Response Count</th>
<th>Average Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>315</td>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Question 7</th>
<th>On average, what dates do you start and stop irrigating?</th>
<th>Response Count</th>
<th>Response Percent</th>
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<tbody>
<tr>
<td>Start before April 15</td>
<td>3</td>
<td>21%</td>
<td></td>
</tr>
<tr>
<td>Start April 16 - April 30</td>
<td>3</td>
<td>21%</td>
<td></td>
</tr>
<tr>
<td>Start May 1 - May 15</td>
<td>4</td>
<td>29%</td>
<td></td>
</tr>
<tr>
<td>Start May 16 - May 31</td>
<td>4</td>
<td>29%</td>
<td></td>
</tr>
<tr>
<td>Start June 1 - June 15</td>
<td>0</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Start June 16 - June 30</td>
<td>0</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Start after July 1</td>
<td>0</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>14</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Stop before June 30</td>
<td>0</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Stop June 30 - July 15</td>
<td>0</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Stop July 16 - July 31</td>
<td>0</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Stop August 1 - August 15</td>
<td>9</td>
<td>56%</td>
<td></td>
</tr>
<tr>
<td>Stop August 16 - August 31</td>
<td>1</td>
<td>8%</td>
<td></td>
</tr>
<tr>
<td>Stop September 1 - September 15</td>
<td>2</td>
<td>15%</td>
<td></td>
</tr>
<tr>
<td>Stop September 16 - September 30</td>
<td>4</td>
<td>31%</td>
<td></td>
</tr>
<tr>
<td>Stop after October 1</td>
<td>6</td>
<td>46%</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>13</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Question 8 - How many years during the last 20 years have you been unable to irrigate the acres you typically irrigate, for a portion of the season?</td>
<td>Response Count</td>
<td>Response Percent</td>
<td></td>
</tr>
<tr>
<td>---------------------------------------------------------------</td>
<td>----------------</td>
<td>-----------------</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>3</td>
<td>21%</td>
<td></td>
</tr>
<tr>
<td>1 - 5 years</td>
<td>7</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>5 - 10 years</td>
<td>3</td>
<td>21%</td>
<td></td>
</tr>
<tr>
<td>10 - 15 years</td>
<td>1</td>
<td>7%</td>
<td></td>
</tr>
<tr>
<td>15 or more years</td>
<td>0</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>14</strong></td>
<td><strong>100%</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question 9 - What best describes the reason you’ve been unable to irrigate?</th>
<th>Response Count</th>
<th>Response Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does not apply to me</td>
<td>1</td>
<td>7%</td>
</tr>
<tr>
<td>My water rights are junior / calls placed on the river</td>
<td>6</td>
<td>43%</td>
</tr>
<tr>
<td>There was not water physically available</td>
<td>6</td>
<td>43%</td>
</tr>
<tr>
<td>My diversion structure(s) could not divert at low flow</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>7%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>14</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question 10 - Which months during the irrigation season have you had problems irrigating?</th>
<th>Response Count</th>
<th>Response Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>May</td>
<td>2</td>
<td>8%</td>
</tr>
<tr>
<td>June</td>
<td>1</td>
<td>4%</td>
</tr>
<tr>
<td>July</td>
<td>5</td>
<td>23%</td>
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<tr>
<td>August</td>
<td>12</td>
<td>46%</td>
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<tr>
<td>September</td>
<td>4</td>
<td>15%</td>
</tr>
<tr>
<td>October</td>
<td>1</td>
<td>4%</td>
</tr>
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<td><strong>Total</strong></td>
<td><strong>26</strong></td>
<td><strong>100%</strong></td>
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</table>

<table>
<thead>
<tr>
<th>Question 11 - How much additional water would you need to overcome the shortages you have experienced on the acres you typically irrigate?</th>
<th>Response Count</th>
<th>Response Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>No additional water / not supply-limited</td>
<td>1</td>
<td>14%</td>
</tr>
<tr>
<td>0 to 0.5 feet per acre</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>0.5 to 1.0 feet per acre</td>
<td>1</td>
<td>14%</td>
</tr>
<tr>
<td>1.0 to 1.5 feet per acre</td>
<td>4</td>
<td>57%</td>
</tr>
<tr>
<td>1.5 to 2.0 feet per acre</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>More than 2.0 feet per acre</td>
<td>1</td>
<td>14%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>7</strong></td>
<td><strong>100%</strong></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Question 12 - How much additional water would you need to fully irrigate all the acres you are entitled to irrigate?</th>
<th>Response Count</th>
<th>Response Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>No additional water / not supply-limited</td>
<td>4</td>
<td>57%</td>
</tr>
<tr>
<td>0 to 0.5 feet per acre</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>0.5 to 1.0 feet per acre</td>
<td>1</td>
<td>14%</td>
</tr>
<tr>
<td>1.0 to 1.5 feet per acre</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>1.5 to 2.0 feet per acre</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>More than 2.0 feet per acre</td>
<td>2</td>
<td>29%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>7</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question 13 - What crops(s) do you typically grow and on average, what are your yields per acre for each? (Multiple answers)</th>
<th>Response Count</th>
<th>Response Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa - yield</td>
<td>11</td>
<td>38%</td>
</tr>
<tr>
<td>Grass hay - yield</td>
<td>8</td>
<td>28%</td>
</tr>
<tr>
<td>Corn - yield</td>
<td>2</td>
<td>7%</td>
</tr>
<tr>
<td>Oats - yield</td>
<td>4</td>
<td>14%</td>
</tr>
<tr>
<td>Barley - yield</td>
<td>2</td>
<td>7%</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>7%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>29</strong></td>
<td><strong>100%</strong></td>
</tr>
<tr>
<td>Question 14 - What do you think are the most important water issues in the Nowood Watershed? (Multiple answers)</td>
<td>Response Count</td>
<td>Response Percent</td>
</tr>
<tr>
<td>---------------------------------------------------------------</td>
<td>----------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Water Conservation / saving supplies</td>
<td>6</td>
<td>9%</td>
</tr>
<tr>
<td>Water shortage</td>
<td>7</td>
<td>10%</td>
</tr>
<tr>
<td>Water quality</td>
<td>2</td>
<td>3%</td>
</tr>
<tr>
<td>More storage is needed</td>
<td>6</td>
<td>9%</td>
</tr>
<tr>
<td>Water for agriculture</td>
<td>9</td>
<td>13%</td>
</tr>
<tr>
<td>No need for dams</td>
<td>3</td>
<td>4%</td>
</tr>
<tr>
<td>Flooding and flood-related damages</td>
<td>4</td>
<td>6%</td>
</tr>
<tr>
<td>Streambank erosion and loss of riparian lands</td>
<td>6</td>
<td>9%</td>
</tr>
<tr>
<td>Habitat for fisheries</td>
<td>5</td>
<td>7%</td>
</tr>
<tr>
<td>Habitat for wildlife</td>
<td>5</td>
<td>7%</td>
</tr>
<tr>
<td>Maintaining agriculture</td>
<td>9</td>
<td>13%</td>
</tr>
<tr>
<td>Too much water</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>Runoff occurring too early to use</td>
<td>4</td>
<td>6%</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>1%</td>
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<tr>
<td>Total</td>
<td>68</td>
<td>100%</td>
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<table>
<thead>
<tr>
<th>Question 15 - How much would you be willing to pay for additional water</th>
<th>Response Count</th>
<th>Response Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not willing to pay for additional water</td>
<td>4</td>
<td>40%</td>
</tr>
<tr>
<td>less than $5 / acre-ft</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>$5 - $10 / acre-ft</td>
<td>3</td>
<td>30%</td>
</tr>
<tr>
<td>$10 - $15 / acre-ft</td>
<td>2</td>
<td>20%</td>
</tr>
<tr>
<td>$15 - $20 / acre-ft</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>$20 - $25 / acre-ft</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>More</td>
<td>1</td>
<td>10%</td>
</tr>
<tr>
<td>Total</td>
<td>10</td>
<td>100%</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Question 16 - Would you be willing to be contacted to provide input on the Nowood River Storage, Level II Study?</th>
<th>Response Count</th>
<th>Response Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes - phone</td>
<td>8</td>
<td>47%</td>
</tr>
<tr>
<td>Yes - email</td>
<td>6</td>
<td>35%</td>
</tr>
<tr>
<td>No</td>
<td>2</td>
<td>12%</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>6%</td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>100%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question 17 - Would you like to receive future information regarding the project (update flyers / meeting notices)?</th>
<th>Response Count</th>
<th>Response Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes - by mail</td>
<td>5</td>
<td>36%</td>
</tr>
<tr>
<td>Yes - by email</td>
<td>6</td>
<td>43%</td>
</tr>
<tr>
<td>No</td>
<td>3</td>
<td>21%</td>
</tr>
<tr>
<td>Total</td>
<td>14</td>
<td>100%</td>
</tr>
</tbody>
</table>

Additional Comments / Input

1. Need more wildlife and places to go for hunting and water fowl for duck and ice fishing
2. A dam will cost a lot of money to construct, but when you have no water to irrigate, it also costs you money. When I have to repair flood damage from spring flooding - this costs more money. We build a dam - I’ll pay my share.
TABLE 4-1. GIS CONTENTS  
NOWOOD RIVER STORAGE, LEVEL II STUDY

<table>
<thead>
<tr>
<th>General Type</th>
<th>Description</th>
<th>Added During Level I Study</th>
<th>Updated During Level II Study</th>
<th>Added During Level II Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background</td>
<td>USGS 30 meter DEM</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>USGS 10 meter DEM (in select areas)</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td>USGS Topographic Mapping Tiled Mosaic</td>
<td>Yes</td>
<td>No</td>
<td></td>
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<tr>
<td></td>
<td>USGS 1:100K Topographic Mapping</td>
<td>Yes</td>
<td>No</td>
<td></td>
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<tr>
<td></td>
<td>USGS 1:250K Topographic Mapping</td>
<td>Yes</td>
<td>No</td>
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<tr>
<td></td>
<td>Bing Maps layers</td>
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<tr>
<td></td>
<td>2009 NAIP County Mosaic 1 meter Pixel Resolution</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>2006 NAIP County Mosaic 1 meter Pixel Resolution</td>
<td>Yes</td>
<td>No</td>
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</tr>
<tr>
<td></td>
<td>2001 CIR Imagery 1 meter Pixel Resolution</td>
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<td>No</td>
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<tr>
<td>Climate</td>
<td>Weather station locations</td>
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<td>No</td>
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<td></td>
<td>CoCoRaHS stations</td>
<td>Yes</td>
<td>No</td>
<td></td>
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<tr>
<td></td>
<td>Precipitation Isohyetal Lines (PRISM)</td>
<td>Yes</td>
<td>No</td>
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<tr>
<td>Cultural/Historical</td>
<td>Cultural sites eligible for the National Register of Historic Places per PLSS</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
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<tr>
<td></td>
<td>Previously Recorded Cultural Sites and Inventory Areas Eligible for the National Register of Historic Places for Meadowlark Lake, Alkali Creek, and Taylor Draw</td>
<td>Yes</td>
<td>No</td>
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<tr>
<td>Environmental</td>
<td>Aquatic priority areas both crucial and enhancement areas</td>
<td>Yes</td>
<td>No</td>
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<tr>
<td></td>
<td>Terrestrial priority areas both crucial and enhancement areas</td>
<td>Yes</td>
<td>No</td>
<td></td>
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<tr>
<td></td>
<td>Invasive species</td>
<td>Yes</td>
<td>No</td>
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<tr>
<td></td>
<td>National Wetland Inventory</td>
<td>Yes</td>
<td>Yes</td>
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<td></td>
<td>Combined priority areas (both crucial and enhancement)</td>
<td>Yes</td>
<td>No</td>
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<tr>
<td></td>
<td>Big game crucial areas (All Species)</td>
<td>Yes</td>
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<td>Big game migration routes (All Species)</td>
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<td>No</td>
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<td>Big game habitats</td>
<td>Yes</td>
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<tr>
<td></td>
<td>Bison hunt area herd unit boundaries</td>
<td>Yes</td>
<td>No</td>
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<tr>
<td></td>
<td>Black bear hunt area herd unit boundaries</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mountain lion hunt area herd unit boundaries</td>
<td>Yes</td>
<td>Yes</td>
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</tr>
<tr>
<td></td>
<td>Sage Grouse Lek locations and Core Population Areas</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td></td>
<td>Fish species identified as Species of Greatest Conservation Need</td>
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<td>Geology</td>
<td>1:500K Bedrock Geology Layer</td>
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<td>1:500K Extraction of Bedrock Geology Layer containing Limestone Formations</td>
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<td>1:500K Surficial Geology Layer</td>
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<td>Statewide Geologic Formation Layer</td>
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<td></td>
<td>Landslides</td>
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<td>Existing wells</td>
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<td>Stream gage locations</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>Existing water quality monitoring</td>
<td>Yes</td>
<td>No</td>
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<td></td>
<td>Surface hydrography</td>
<td>Yes</td>
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<td></td>
<td>Stream names</td>
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<td>Yes</td>
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<tr>
<td></td>
<td>Subbasins</td>
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<td></td>
<td>HUC 5th Order Watersheds</td>
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<td>Temporary stream gage locations</td>
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<td>Georeferenced NOAA Atlas 2 Isopluvial Figures</td>
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<td>StateMOD model inputs and results</td>
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<td>Updated During Level II Study</td>
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<tr>
<td>--------------</td>
<td>-------------</td>
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<td>Infrastructure</td>
<td>Electric transmission corridors</td>
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<td>Major roads</td>
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<td>Roads of importance and names</td>
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<td>Minor/secondary roads</td>
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<td>Water transmission</td>
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<tr>
<td>Railroads</td>
<td>Yes</td>
<td>Yes</td>
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<td></td>
</tr>
<tr>
<td>Fiber optics, cell towers, microwave towers</td>
<td>Yes</td>
<td>No</td>
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<tr>
<td>Cities</td>
<td>Yes</td>
<td>No</td>
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<tr>
<td>Irrigation</td>
<td>Digitized irrigated acres</td>
<td>Yes</td>
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<tr>
<td>Ditch inventory locations</td>
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</tr>
<tr>
<td>Digitized irrigation ditches</td>
<td>Yes</td>
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<tr>
<td>Mining</td>
<td>Coal mining activity</td>
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<tr>
<td>Bentonite mining activity</td>
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<tr>
<td>Mine Permit Boundaries</td>
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<td>Oil and Gas</td>
<td>Oil and Gas wells</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Oil fields</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wyoming Oil and Gas Conservation Commission Server</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
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<tr>
<td>Ownership</td>
<td>Parcel ownership</td>
<td>Yes</td>
<td>No</td>
<td></td>
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<tr>
<td>County subdivisions</td>
<td>Yes</td>
<td>No</td>
<td></td>
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<tr>
<td>Land owner database</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
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<tr>
<td>Political Boundaries</td>
<td>County Boundaries</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>UTM Coordinate zones</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
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<tr>
<td>Public Land Survey: Townships</td>
<td>Yes</td>
<td>No</td>
<td></td>
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<tr>
<td>Public Land Survey: Quarter Sections</td>
<td>Yes</td>
<td>No</td>
<td></td>
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<td>Wilderness Study Areas (Statewide)</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>State Conservation Districts (Statewide)</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
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<td>State Improvement Districts (Statewide)</td>
<td>Yes</td>
<td>No</td>
<td></td>
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<td>BLM Field Office Boundaries</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
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<td>Range Management</td>
<td>BLM Rights of Way</td>
<td>Yes</td>
<td>No</td>
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<td>BLM allotment boundaries</td>
<td>Yes</td>
<td>Yes</td>
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<td>Viable stock pond evaluation</td>
<td>Yes</td>
<td>No</td>
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<td>Existing stock ponds</td>
<td>Yes</td>
<td>No</td>
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<td>Springs</td>
<td>Yes</td>
<td>No</td>
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<td>Guzzlers</td>
<td>Yes</td>
<td>No</td>
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<td>Stock ponds</td>
<td>Yes</td>
<td>No</td>
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<td>Range pipeline projects</td>
<td>Yes</td>
<td>No</td>
<td></td>
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<tr>
<td>Range fences</td>
<td>Yes</td>
<td>No</td>
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<tr>
<td>Ecological Site Description</td>
<td>Yes</td>
<td>No</td>
<td></td>
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<tr>
<td>Soils</td>
<td>SSURGO Soils Mapping: Carbon County</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>SSURGO Soils Mapping: Washakie County</td>
<td>Yes</td>
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<td></td>
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<tr>
<td>SSURGO Soils Mapping: Johnson County</td>
<td>Yes</td>
<td>No</td>
<td></td>
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<tr>
<td>SSURGO Soils Mapping: Fremont County</td>
<td>Yes</td>
<td>No</td>
<td></td>
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<tr>
<td>Soils: Big Horn County Planning Department</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
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<tr>
<td>General Soils Data: 1:250,000</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>General Type</td>
<td>Description</td>
<td>Added During Level I Study</td>
<td>Updated During Level II Study</td>
<td>Added During Level II Study</td>
</tr>
<tr>
<td>------------------------------------</td>
<td>--------------------------------------------------</td>
<td>-----------------------------</td>
<td>-------------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Watershed Management Plan</td>
<td>Irrigation System</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Ditch rehabilitation sites</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ditch alignment</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Point of diversions</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Potential Upland Projects</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Proposed project locations and components</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Proposed project locations - one mile buffers</td>
<td>Yes</td>
<td>No</td>
<td></td>
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<tr>
<td></td>
<td>Potential Storage Projects</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Priority 1, 2, and 3 locations</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Storage site contributing watershed</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Potential supply canal alignments</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

BLM - Bureau of Land Management
CIR - Color Infrared
CoCoRaHS - Community Collaborative Rain, Hail, & Snow Network
DEM - digital elevation model
HMR - Hydrometeorological Report
HUC - Hydrologic Unit Code
NAIP - National Agriculture Imagery Program
NOAA - National Oceanic and Atmospheric Administration
PFC - Process for Assessing Proper Functioning Condition
PLSS - Public Land Survey System
SSURGO - Soil Survey Geographic
StateMOD - State of Colorado's Water Supply Model
USGS - United States Geologic Survey
UTM - Universal Transverse Mercator
### TABLE 6-2. TEMPORARY STREAM GAGES
NOWOOD RIVER STORAGE, LEVEL II STUDY

<table>
<thead>
<tr>
<th>Site</th>
<th>Field Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkali Creek Temporary Stream Gage</td>
<td>Temporary Stream Gaging 2010 and 2011 Field Seasons</td>
</tr>
<tr>
<td>Anita Ditch Temporary Stream Gage</td>
<td>Temporary Stream Gaging 2011 Field Season</td>
</tr>
<tr>
<td>Avent Ditch Temporary Stream Gage</td>
<td>Temporary Stream Gaging 2011 Field Season</td>
</tr>
<tr>
<td>Brokenback Creek Temporary Stream Gage</td>
<td>Temporary Stream Gaging 2010 Field Season</td>
</tr>
<tr>
<td>Bruner Gulch Temporary Stream Gage</td>
<td>Temporary Stream Gaging 2010 Field Season</td>
</tr>
<tr>
<td>Lower Deep Creek Temporary Stream Gage</td>
<td>Temporary Stream Gaging 2010 and 2011 Field Seasons</td>
</tr>
<tr>
<td>Nowood Crawford Temporary Stream Gage</td>
<td>Temporary Stream Gaging 2010 and 2011 Field Seasons</td>
</tr>
<tr>
<td>Otter Creek Temporary Stream Gage</td>
<td>Temporary Stream Gaging 2011 Field Season</td>
</tr>
<tr>
<td>Paint Rock Creek Temporary Stream Gage</td>
<td>Temporary Stream Gaging 2011 Field Season</td>
</tr>
<tr>
<td>Spring Creek Temporary Stream Gage</td>
<td>Temporary Stream Gaging 2010 and 2011 Field Seasons</td>
</tr>
<tr>
<td>Upper Deep Creek Temporary Stream Gage</td>
<td>Temporary Stream Gaging 2010 and 2011 Field Seasons</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site</th>
<th>Site Level I Study Site Number</th>
<th>USDA, 1971&lt;sup&gt;a&lt;/sup&gt;</th>
<th>WSEO, Oct 1972&lt;sup&gt;b&lt;/sup&gt;</th>
<th>WWPP, 1972&lt;sup&gt;c&lt;/sup&gt;</th>
<th>USDA/WSEO, 1974&lt;sup&gt;d&lt;/sup&gt;</th>
<th>WWDC 2003&lt;sup&gt;e&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big Trails</td>
<td>2</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Nowood River</td>
<td>8</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Upper Cloud Creek</td>
<td>NA</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Middle Cloud Creek</td>
<td>NA</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>West Tensleep Lake</td>
<td>21</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tensleep Meadows</td>
<td>10</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
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<tr>
<td>Pete’s Lake</td>
<td>15</td>
<td></td>
<td>X</td>
<td></td>
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<tr>
<td>Medicine Lodge</td>
<td>11</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Paint Rock</td>
<td>13</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Buffalo Creek</td>
<td>3</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lone Tree</td>
<td>34</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mahogany Buttes</td>
<td>23/24</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Little Canyon Creek</td>
<td>22</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Big Canyon Creek</td>
<td>33</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North Brokenback</td>
<td>35</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brokenback</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Aikali Creek (South)</td>
<td>30</td>
<td></td>
<td></td>
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<td></td>
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<td>Summit</td>
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<td>Solitude</td>
<td>16</td>
<td></td>
<td></td>
<td>X</td>
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</tbody>
</table>

<sup>a</sup> May 1971 Nowood River Drainage Investigation Report, Type IV River Basin Survey, completed by the United States Department of Agriculture (USDA)
<sup>b</sup> October 1972 Water and Related Land Resources of the Bighorn River Basin, completed by the Wyoming Water Planning Program (WWPP)
<sup>c</sup> October 1972 Water and Related Land Resources of the Bighorn River Basin, completed by the Wyoming State Engineer's Office (WSEO)
<sup>d</sup> December 1974 Wind-Bighorn-Clarks Fork River Basin, Type IV Survey, completed by the USDA and WSEO
<sup>e</sup> 2003 Wind/Bighorn River Basin Planning Report, completed on behalf of the Wyoming Water Development Commission (WWDC)
<table>
<thead>
<tr>
<th>Drainage</th>
<th>Number of Sites Identified</th>
<th>Site</th>
<th>Feasible</th>
<th>Site Number</th>
<th>Feasibility Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paint Rock</td>
<td>2</td>
<td>Upper Luman Creek</td>
<td>Yes</td>
<td>37</td>
<td>Low elevation, not expected to yield significant water annually, but possible to divert from S. Fork Paint Rock Creek. Upstream of irrigated acreage. Favorable geologic conditions. Could combined with Lower Luman Creek for additional storage.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower Luman Creek</td>
<td>Yes</td>
<td>36</td>
<td>Low elevation, not expected to yield significant water annually, but possible to divert from S. Fork Paint Rock Creek. Upstream of irrigated acreage. Favorable geologic conditions. Could combined with Upper Luman Creek for additional storage.</td>
</tr>
<tr>
<td>Nowood River</td>
<td>10</td>
<td>Cornell Gulch</td>
<td>Yes</td>
<td>38</td>
<td>Ephemeral drainage providing little direct flows, would require difficult diversion from Nowood River. Topography favorable for medium-sized reservoir development. Questionable geologic conditions would require field verification.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Homestead Gulch</td>
<td>No</td>
<td>-</td>
<td>Topography does not allow for reasonable storage capacity. Poor geologic conditions.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Telephone Draw</td>
<td>No</td>
<td>-</td>
<td>Topography does not allow for reasonable storage capacity.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>North of Mahogany Butte (Un-named)</td>
<td>No</td>
<td>-</td>
<td>Topography does not allow for reasonable storage capacity. Difficulty of conveying water to this off-channel site from the Nowood River.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SV Draw</td>
<td>No</td>
<td>-</td>
<td>Topography does not allow for reasonable storage capacity.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>North of Section Line 6 (Un-named)</td>
<td>No</td>
<td>-</td>
<td>Topography does not allow for reasonable storage capacity.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Willow Creek</td>
<td>Yes</td>
<td>40</td>
<td>Not recommended initially based on limited direct flow and difficulty of conveying diverted flows from Nowood River. Ultimately investigated further due to favorable topography for storage.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Horton Draw</td>
<td>No</td>
<td>-</td>
<td>Topography does not allow for reasonable storage capacity.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mud Gulch</td>
<td>No</td>
<td>-</td>
<td>Construction of a supply conveyance at needed elevation does not appear to be feasible.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bud Kimball Creek</td>
<td>No</td>
<td>-</td>
<td>Topography appears to support reasonable storage. Diversion does not appear practical due to the length of the conveyance and number of landowners impacted to provide indirect flow from the Nowood River. High potential for sedimentation.</td>
</tr>
<tr>
<td>Little Creek and Box Elder/Redbank Creek</td>
<td>4</td>
<td>Little Canyon Creek</td>
<td>No</td>
<td>-</td>
<td>Prohibited site access during Level I field reconnaissance by landowner. Other potential sites were not identified.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Redbank Drainage</td>
<td>No</td>
<td>-</td>
<td>No site identified with notable storage capacity.</td>
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<tr>
<td></td>
<td></td>
<td>Box Elder Drainage</td>
<td>No</td>
<td>-</td>
<td>Hydrology of sites of the site does not appear to support significant storage.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cherry Creek Drainage</td>
<td>Yes</td>
<td>39</td>
<td>Small storage site requiring diversion from Box Elder Creek.</td>
</tr>
</tbody>
</table>
TABLE 9-3. LEVEL II SITE EVALUATION MATRIX
NOWOOD RIVER STORAGE, LEVEL II STUDY

Site #

10

1

36

18

38

40

13

2

25

30

12

22

20

7

Site Name

Meadowlark Lake
Enlargement

Alkali Creek

Lower Luman Creek

Taylor Draw

Cornell Gulch

Willow Creek

Paint Rock Creek

Big Trails

Deep Creek

Alkali Creek South

Otter Creek

Little Cottonwood Creek

West Fork Willow Creek

Lower Brokenback

Ranked Priority

1

1

2

2

2

2

2

2

2

2

3

3

3

3

Latitude (dd.dddddd)
Longitude (ddd.dddddd)

44.165157
-107.232061

44.263196
-107.645974

44.26011031
-107.4920134

43.919142
-107.379389

43.59117702
-107.4443058

43.790051
-107.365292

44.285345
-107.489633

43.705095
-107.330069

43.554334
-107.343234

43.994251
-107.401154

43.875655
-107.345908

44.076659
-107.529189

43.790051
-107.365292

44.085502
-107.516432

Category A: Reservoir Description
On-Channel / Off-Channel

On Channel

Off Channel

Off Channel

Off Channel

Off Channel

On Channel

On Channel

On Channel

On Channel

On Channel

On Channel

Off Channel

Off Channel

On Channel

Ten Sleep Creek

Alkali Creek

Luman Creek

Taylor Draw

Cornell Gulch

West Fork Willow Creek

Paint Rock Creek

Nowood River

Deep Creek

Alkali Creek South

Otter Creek

Little Cottonwood Creek

West Fork Willow Creek

Brokenback Creek

NA

Medicine Lodge Creek
and Paint Rock Creek

Laddie Creek/South Paint
Rock Creek

Otter Creek

Nowood River

Nowood River

NA

NA

NA

NA

NA

Nowood River

Nowood River

NA

Dam Enlargement

New Diversion and Anita
Ditch

New Diversion

New Diversion

New Diversion

Tributary Dam

Tributary Dam

Mainstem Dam

Tributary Dam

Tributary Dam

Tributary Dam

New Diversion

New Diversion

Tributary Dam

36.28
NA
12,287
8,465
37.55
3,822
28.6

40.43
285.02
7,265
4,404
42.39
2,861
15.5

10.56
31.5
7,809
5,177
18.03
2,632
20.9

6.94
89.35
5,275
4,540
16.32
735
13.0

4.87
36.15
6,407
5,452
13.1
955
16.0

20.5
247.19
5,209
4,753
16.06
456
13.6

155.19
NA
13,148
5,141
84.43
8,007
28.5

247.19
NA
9,053
4,875
109.65
4,178
19.2

41.8
NA
9,053
6,395
38.57
2,658
24.1

13.28
NA
5,570
4,486
22.12
1,084
13.4

96.41
NA
8,650
4,667
69.92
3,983
19.3

26.03
1092.25
5,447
4,321
37.64
1,126
12.1

4.76
NA
5,209
4,753
16.06
456
13.0

54.94
NA
9,334
4,319
54.89
5,015
20.0

4,677 / 1,168
279
32
18.2

7,401
288
69
35.0

2,421
57
120
73.0

2,435
103
64
35.8

2,661
79
85
42.0

42,915
1,039
140
70.0

5,850
126
165
46.5

16,850
623
75
27.1

9,600
147
95
65.3

1,461
89
65
16.4

15,300
443
80
34.5

8,400
336
85
25.0

9,600
577
65
16.6

4,200
167
60
25.2

Earthen

Earthen

Earthen

Earthen

Earthen

Earthen

Earthen

Earthen or Concrete Arch

Earthen

Earthen

Earthen

Earthen

Earthen

84

150

85

110

145

170

80

100

70

85

90

70

65

4,677 / 1,168

7,401

2,421

2,435

2,661

42,915

5,850

16,850

9,600

1,461

15,300

8,400

9,600

4,200

400
9,758
119.7

2,384
692,305
10.7

861
627,816
3.9

1,193
499,063
4.9

1,400
697,786
3.8

1,372
1,609,061
26.7

720
1,443,854
4.1

765
650,000
25.9

1,085
672,000
14.3

980
607,509
2.4

3,500
1,779,113
8.6

1,775
1,824,978
4.6

1,325
859,444
11.2

1,400
695,640
6.0

None / On channel

Diversion via exist.
irrigation ditch

Diversion Structure/ pipe

Diversion Structure /
canal

Diversion Structure /
canal

Diversion Structure/ pipe

None / On channel

None / On channel

None / On channel

None / On channel

None / On channel

Diversion Structure / canal

None / On channel

None / On channel

NA

Medicine Lodge Creek /
Paint Rock Creek via
Anita Ditch

South Paint Rock Creek
Diversion Pipeline with
tunnel diversion from
Laddie Creek

Otter Creek Diversion
Pipeline

New diversion off
Nowood River

Nowood River Diversion
Pipeline with tunnel
diversion to Willow Creek

NA

NA

NA

NA

NA

Small

Medium

Medium

Small

Medium

Large

Medium

Medium

Medium

Medium

Large

Large

Medium

Medium

Level II Nowood River
StateMOD Model

Level II Nowood River
StateMOD Model

Level II Nowood River
StateMOD Model

Miselis / Level II Nowood
River StateMOD Model

Level II Nowood River
StateMOD Model

Level II Nowood River
StateMOD Model

Level II Nowood River
StateMOD Model

Level II Nowood River
StateMOD Model

Level II Nowood River
StateMOD Model

Level II Nowood River
StateMOD Model

Level II Nowood River
StateMOD Model

Level II Nowood River
StateMOD Model

Nowater Comparison

Level II Nowood River
StateMOD Model

Normal Year (ac-ft) - Physically in the stream

15,667

832

288

2,075

552

90,712

31,391

7,175

1,955

12,212

1,280

99

9,671

Dry Year (ac-ft) - Physically in the stream

14,316

936

329

1,096

348

77,496

19,007

4,519

1,468

7,584

2,354

97

14,223

Normal Year (ac-ft) - Available in the stream

11,527

827

288

2,075

524

99 on West Fork Willow.
NA on Willow Creek

65,291

29,860

6,517

1,883

9,505

1,280

99

9,054

Dry Year (ac-ft) - Available in the stream

9,972

927

329

1,096

320

97 on West Fork Willow.
NA on Willow Creek

54,630

17,229

3,795

1,410

4,995

2,354

97

13,374

Medicine Lodge Creek /
Paint Rock Creek via
Anita Ditch
15,546 / 86,074
12,972 / 72,761
13,360 / 66,042
11,062 / 55,384

South Paint Rock Creek
& tunnel from Laddie
Creek
17,054
14,569
16,345
13,688

Otter Creek

Upper Nowood River

Nowood River

None

None

None

None

None

Middle Nowood River at
Reach 700

None

None

12,212
7,584
9,505
4,995

5,284
3,311
4,464
2,515

4,231
2,666
3,829
2,228

NA
NA
NA
NA

NA
NA
NA
NA

NA
NA
NA
NA

NA
NA
NA
NA

NA
NA
NA
NA

166,413
122,642
152,893
114,220

NA
NA

NA
NA
NA
NA

Direct Supply Source

Indirect Supply Source

Supply Mechanism
Category B: Watershed
Contributing Drainage Area - Direct (square miles)
Contributing Drainage Area - Indirect (square miles)
Maximum Elevation (feet MSL)
Minimum Elevation (feet MSL)
Basin perimeter (miles)
Maximum basin relief (feet)
Mean annual precipitation (inches)
Category C: Reservoir Statistics
Capacity / Enlargement (acre-feet)
Surface Area (acres)
Maximum Water Depth (feet)
Average Water Depth (feet)
Category D: Dam Description
Dam Statistics

Roller Compacted
Concrete Enlargement
46

Proposed Type
Dam Height (feet)
Capacity (acre-feet)
Embankment Length (feet)
Total Dam Fill Volume (cy)
Storage Efficiency (ac-ft/1000 cy fill)

Method of Reservoir Fill

Appurtenances

Size Class
(<500,000 Small, < 1,500,000 Medium, > 1,500,000 Large)

New diversion off Nowood New diversion off Nowood
River
River

NA

Category E: Hydrology

Hydrology Method

Storage Availability

Indirect Supply Source
(Indirect) Normal Year (ac-ft) - Physically in the stream
(Indirect) Dry Year (ac-ft) - Physically in the stream
(Indirect) Normal Year (ac-ft) - Available in the stream
(Indirect) Dry Year (ac-ft) - Available in the stream

None
NA
NA
NA
NA

M:\GovState\WyoWaterDvlpComm\ProjectDocs\NowoodRiverWatershed\StorageLevelIIStudy\Reports\201311_FinalSummary_RPT\2_Tables\201312_Section9_TBL

99.008 on West Fork
Willow. NA on Willow
Creek
96.628on West Fork
Willow. NA on Willow
Creek

1 of 9


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<th>Site No</th>
<th>Median Creek Lake Expansion</th>
<th>Antelope Creek</th>
<th>Lower Laramie Creek</th>
<th>Taylor Draw</th>
<th>Cones Gulch</th>
<th>Willow Creek</th>
<th>Paint Rock Creek</th>
<th>Big Thunder</th>
<th>Deep Creek</th>
<th>Antelope Creek South</th>
<th>Ether Creek</th>
<th>Little Conclamation Creek</th>
<th>West Fork Willow Creek</th>
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<td>Seasonal Range</td>
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<td>Seasonal Range</td>
<td>Seasonal Range</td>
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<td>Reservoir pool area</td>
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<td>B</td>
<td>C</td>
<td>B</td>
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**TABLE 9.3: LEVEL II SITE EVALUATION MATRIX**

**NOWOOD RANK STORAGE, LEVEL II STUDY**

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</tr>
</tbody>
</table>

**Category F: Geology**

**Site Name**

**Site #**

**Table 9.3: Level II Site Evaluation Matrix**

**Nowood Rank Storage, Level II Study**

**Seasonal Range**

**Contributing watershed**

**Reservoir pool area**

**Fisheries**

**WDEQ Stream Classification**

**Sage Grouse Leks**

**Inside Core Areas:**

- Within 4 miles of Project Disturbance
- Site within 0.6 miles

**Game:**

- White Tailed Deer
- Mule Deer
- Moose
- Elk
- Antelope

**Wetlands (acres impacted):**

From NWI data

**Dam embankment foundation**

**Reference:**

- Trihydro memo dated 11/24/10
- HAI memo dated 11/24/10
- Reference: HAI memo dated 11/24/10
- Reference: Trihydro memo dated 11/24/10
- Reference: Trihydro memo dated 11/24/10
- Reference: Trihydro memo dated 11/24/10
- Reference: Trihydro memo dated 11/24/10
- Reference: Trihydro memo dated 11/24/10
<table>
<thead>
<tr>
<th>Site Name</th>
<th>Meadowlark Lake Enlargement</th>
<th>Albright Creek</th>
<th>Lower Lusso Creek</th>
<th>Taylor Draw</th>
<th>Comal Creek</th>
<th>Willow Creek</th>
<th>Paint Rock Creek</th>
<th>Big Toad Creek</th>
<th>Deep Creek</th>
<th>Attla Creek South</th>
<th>Otter Creek</th>
<th>Little Comanche Creek</th>
<th>West Fork Willow Creek</th>
<th>Lower Bridgerback</th>
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<tr>
<td>Ranked Priority</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
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<td>2</td>
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<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Irrigated Average (cubic ac-ft)</td>
<td>8</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>260</td>
<td>0</td>
<td>0</td>
<td>130.5</td>
<td>0</td>
<td>0</td>
<td>2</td>
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<tr>
<td>Infrastructure</td>
<td>None Identified</td>
<td>None Identified</td>
<td>None Identified</td>
<td>None Identified</td>
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<td>None Identified</td>
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<td>None Identified</td>
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<tr>
<td>Transportation</td>
<td>0.1 miles dirt road and part of a parking lot</td>
<td>1.2 miles dirt rd</td>
<td>0.6 miles dirt rd</td>
<td>2 miles diversion pipeline and dirt road (would require additional excavation)</td>
<td>1 mile dirt rd</td>
<td>0.6 miles dirt rd</td>
<td>1.19 miles dirt rd</td>
<td>1.2 miles improved rd</td>
<td>0.2 miles improved rd</td>
<td>0.4 miles improved rd</td>
<td>0.6 miles improved rd</td>
<td>0.6 miles improved rd</td>
<td>0.6 miles improved rd</td>
<td>1.7 miles dirt rd</td>
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<tr>
<td>Other</td>
<td>Fiber Optics (0.5 miles)</td>
<td>Would require that a small diversion dike be built southeast of site to recognize additional impoundment. Would dam the Anita Ditch rather than build the diversion dike.</td>
<td>Should require improvements to Anita Ditch</td>
<td>Would require improvements/enlargement to Anita Ditch. Would impact the Anita Ditch siphon. Would require improvements/enlargement to Anita Ditch</td>
<td>Would require improvements/enlargement to Anita Ditch. Would require 6.3 miles diversion pipeline and 2,000 ft tunnel to gravity flow water to the site from South Fork Paint Rock Creek</td>
<td>Would require improvements/enlargement to Anita Ditch. Would require 6.5 miles of canal or pipe to gravity flow water to the site from Otter Creek</td>
<td>Would require improvements/enlargement to Anita Ditch. Would require 6.5 miles of canal and 1,961 feet of tunnel to gravity flow water to the site from the Nowood River</td>
<td>Fiber Optics (3.5 miles)</td>
<td>None Identified</td>
<td>None Identified</td>
<td>None Identified</td>
<td>None Identified</td>
<td>None Identified</td>
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<tr>
<td>Estimated Construction Cost (budgetary-level)</td>
<td>$2,796,692</td>
<td>$15,741,569</td>
<td>$14,976,690</td>
<td>$15,605,863</td>
<td>$12,930,000</td>
<td>$25,773,098</td>
<td>$27,017,244</td>
<td>$13,800,000</td>
<td>$13,000,000</td>
<td>$10,148,834</td>
<td>$22,119,394</td>
<td>$21,165,017</td>
<td>$12,748,445</td>
<td>$11,274,437</td>
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<td>Total Project per cubic yard of fill</td>
<td>$287,360</td>
<td>$5,741,569</td>
<td>$14,976,690</td>
<td>$15,605,863</td>
<td>$12,930,000</td>
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<td>$21,165,017</td>
<td>$12,748,445</td>
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<tr>
<td>Total Project per ac-ft of storage</td>
<td>$128,736</td>
<td>$83,819</td>
<td>$117,127</td>
<td>$156,006</td>
<td>$151,552</td>
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<td>NA</td>
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<td>Infrastructure Considerations</td>
<td>Diversion</td>
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<td>BLT / Private</td>
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<td>Location Relative to Demand (Irrigated Acres downstream)</td>
<td>6,871</td>
<td>4,370</td>
<td>5,835</td>
<td>6,380</td>
<td>6,354</td>
<td>7,189</td>
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<td>Demand Potential (downstream shortages; dry/normal)</td>
<td>1,099 / 957</td>
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<td>6,872 / 6,164</td>
<td>562 / 548</td>
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<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>Estimated Construction Cost (budgetary-level)</td>
<td>$2,796,692</td>
<td>$15,741,569</td>
<td>$14,976,690</td>
<td>$15,605,863</td>
<td>$12,930,000</td>
<td>$25,773,098</td>
<td>$27,017,244</td>
<td>$13,800,000</td>
<td>$13,000,000</td>
<td>$10,148,834</td>
<td>$22,119,394</td>
<td>$21,165,017</td>
<td>$12,748,445</td>
</tr>
<tr>
<td></td>
<td>Total Project per cubic yard of fill</td>
<td>$287,360</td>
<td>$5,741,569</td>
<td>$14,976,690</td>
<td>$15,605,863</td>
<td>$12,930,000</td>
<td>$25,773,098</td>
<td>$27,017,244</td>
<td>$13,800,000</td>
<td>$13,000,000</td>
<td>$10,148,834</td>
<td>$22,119,394</td>
<td>$21,165,017</td>
<td>$12,748,445</td>
</tr>
<tr>
<td></td>
<td>Total Project per ac-ft of storage</td>
<td>$128,736</td>
<td>$83,819</td>
<td>$117,127</td>
<td>$156,006</td>
<td>$151,552</td>
<td>$130,291</td>
<td>$155,509</td>
<td>$130,291</td>
<td>$130,291</td>
<td>$109,247</td>
<td>$113,520</td>
<td>$170,734</td>
<td>$127,099</td>
</tr>
<tr>
<td></td>
<td>Estimation Methodology</td>
<td>Total Project per ac-ft of storage</td>
<td>Total Project per ac-ft of storage</td>
<td>Total Project per ac-ft of storage</td>
<td>Total Project per ac-ft of storage</td>
<td>Total Project per ac-ft of storage</td>
<td>Total Project per ac-ft of storage</td>
<td>Total Project per ac-ft of storage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Site Name</td>
<td>Meadowlark Lake Enlargement</td>
<td>Albright Creek</td>
<td>Lower Lusso Creek</td>
<td>Taylor Draw</td>
<td>Comal Creek</td>
<td>Willow Creek</td>
<td>Paint Rock Creek</td>
<td>Big Toad Creek</td>
<td>Deep Creek</td>
<td>Attla Creek South</td>
<td>Otter Creek</td>
<td>Little Comanche Creek</td>
<td>West Fork Willow Creek</td>
</tr>
</tbody>
</table>
## TABLE 9-3. LEVEL II SITE EVALUATION MATRIX

### NOWOOD RIVER STORAGE, LEVEL II STUDY

### Category A: Site Priorities

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Upper Laran Creek</th>
<th>Callowhoo Creek</th>
<th>Mulberry Draw</th>
<th>Mead Creek</th>
<th>Lower Lyman</th>
<th>Medicine Lodge</th>
<th>West Tonkay Lake</th>
<th>Woodlands Quail</th>
<th>North Breakneck</th>
<th>Nowood - Crawford</th>
<th>Cherry Creek</th>
<th>Briar Guth</th>
<th>Upper Renewal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rating (1-4)</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Indirect (ac-ft)</td>
<td>17,565</td>
<td>17,565</td>
<td>17,565</td>
<td>17,565</td>
<td>17,565</td>
<td>17,565</td>
<td>17,565</td>
<td>17,565</td>
<td>17,565</td>
<td>17,565</td>
<td>17,565</td>
<td>17,565</td>
<td>17,565</td>
</tr>
<tr>
<td>Direct Supply Source</td>
<td>Laramie Creek</td>
<td>Callowhoo Creek</td>
<td>Mulberry Draw</td>
<td>Mead Creek</td>
<td>Nowood River</td>
<td>Medicine Lodge</td>
<td>West Tonkay Lake</td>
<td>Woodlands Quail</td>
<td>North Breakneck</td>
<td>Nowood - Crawford</td>
<td>Cherry Creek</td>
<td>Briar Guth</td>
<td>Upper Renewal</td>
</tr>
<tr>
<td>Supply Mechanism</td>
<td>New Diversion</td>
<td>New Diversion</td>
<td>New Diversion</td>
<td>Ams Ditch</td>
<td>Tributary Dam</td>
<td>Mainstem Dam</td>
<td>Tributary Dam</td>
<td>Mainstem Dam</td>
<td>Mainstem Dam</td>
<td>New Diversion</td>
<td>New Diversion</td>
<td>Nowood River</td>
<td></td>
</tr>
</tbody>
</table>

### Category B: Environmental Descriptions

#### Contributing Drainage Area (A, in acres - available in the stream)

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Site #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nowood Diversion, canal</td>
<td>137,176</td>
</tr>
<tr>
<td>Paint Rock Creek via Anita Ditch</td>
<td>167,910</td>
</tr>
<tr>
<td>Lower Nowood River</td>
<td>144,813</td>
</tr>
</tbody>
</table>

#### Contributing Drainage Area (B, in acres - physically in the stream)

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Site #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nowood Diversion, canal</td>
<td>57,128</td>
</tr>
<tr>
<td>Paint Rock Creek via Anita Ditch</td>
<td>68,020</td>
</tr>
<tr>
<td>Lower Nowood River</td>
<td>71,566</td>
</tr>
</tbody>
</table>

#### Diversion Structure / filling method

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Site #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Nowood River</td>
<td>11.3</td>
</tr>
<tr>
<td>Paint Rock Creek via Anita Ditch</td>
<td>12.6</td>
</tr>
<tr>
<td>Lower Nowood River</td>
<td>9.9</td>
</tr>
</tbody>
</table>

#### Indirect Supply Source

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Site #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Nowood River</td>
<td>220</td>
</tr>
<tr>
<td>Paint Rock Creek via Anita Ditch</td>
<td>4,238</td>
</tr>
<tr>
<td>Lower Nowood River</td>
<td>2,333</td>
</tr>
</tbody>
</table>

### Category C: Reservoir Statistics

#### Category D: Dam Description

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Site #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Nowood River</td>
<td>250</td>
</tr>
<tr>
<td>Paint Rock Creek via Anita Ditch</td>
<td>7,792</td>
</tr>
<tr>
<td>Lower Nowood River</td>
<td>17,054</td>
</tr>
</tbody>
</table>

#### Size Class

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Site #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Nowood River</td>
<td>Small</td>
</tr>
<tr>
<td>Paint Rock Creek via Anita Ditch</td>
<td>Small</td>
</tr>
<tr>
<td>Lower Nowood River</td>
<td>Small</td>
</tr>
</tbody>
</table>

#### Indirect Supply Source

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Site #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Nowood River</td>
<td>1,983</td>
</tr>
<tr>
<td>Paint Rock Creek via Anita Ditch</td>
<td>2,193</td>
</tr>
<tr>
<td>Lower Nowood River</td>
<td>2,515</td>
</tr>
</tbody>
</table>

#### Direct Supply Source

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Site #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Nowood River</td>
<td>2,228</td>
</tr>
<tr>
<td>Paint Rock Creek via Anita Ditch</td>
<td>3,873</td>
</tr>
<tr>
<td>Lower Nowood River</td>
<td>3,829</td>
</tr>
</tbody>
</table>

#### On-Channel / Off-Channel

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Site #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Nowood River</td>
<td>Off Channel</td>
</tr>
<tr>
<td>Paint Rock Creek via Anita Ditch</td>
<td>Off Channel</td>
</tr>
<tr>
<td>Lower Nowood River</td>
<td>Off Channel</td>
</tr>
</tbody>
</table>

### Category E: Hydrology

#### Hydrology Method

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Site #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Nowood River</td>
<td>Level 1 Normal</td>
</tr>
<tr>
<td>Paint Rock Creek via Anita Ditch</td>
<td>Level 1 Normal</td>
</tr>
<tr>
<td>Lower Nowood River</td>
<td>Level 1 Normal</td>
</tr>
</tbody>
</table>

#### Storage Availability

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Site #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Nowood River</td>
<td>Normal Year (ac-ft)</td>
</tr>
<tr>
<td>Paint Rock Creek via Anita Ditch</td>
<td>Normal Year (ac-ft)</td>
</tr>
<tr>
<td>Lower Nowood River</td>
<td>Normal Year (ac-ft)</td>
</tr>
</tbody>
</table>

#### Direct Supply Source

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Site #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Nowood River</td>
<td>17,565</td>
</tr>
<tr>
<td>Paint Rock Creek via Anita Ditch</td>
<td>17,565</td>
</tr>
<tr>
<td>Lower Nowood River</td>
<td>17,565</td>
</tr>
</tbody>
</table>

#### Indirect Supply Source

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Site #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Nowood River</td>
<td>17,565</td>
</tr>
<tr>
<td>Paint Rock Creek via Anita Ditch</td>
<td>17,565</td>
</tr>
<tr>
<td>Lower Nowood River</td>
<td>17,565</td>
</tr>
<tr>
<td>Site #</td>
<td>Site Name</td>
</tr>
<tr>
<td>-------</td>
<td>--------------------</td>
</tr>
<tr>
<td>27</td>
<td>Upper Laramie Creek</td>
</tr>
<tr>
<td>29</td>
<td>Colchester Creek</td>
</tr>
<tr>
<td>10</td>
<td>McDermott Draw</td>
</tr>
<tr>
<td>12</td>
<td>Mesa Creek</td>
</tr>
<tr>
<td>14</td>
<td>Carpen Creek</td>
</tr>
<tr>
<td>21</td>
<td>Laramie Pool</td>
</tr>
<tr>
<td>25</td>
<td>Medicine Lodge</td>
</tr>
<tr>
<td>3</td>
<td>West Tensleep Lake</td>
</tr>
<tr>
<td>9</td>
<td>Woods Gulch</td>
</tr>
<tr>
<td>18</td>
<td>North Brokenback</td>
</tr>
<tr>
<td>6</td>
<td>Wseud - Crawford</td>
</tr>
<tr>
<td>15</td>
<td>Cherry Creek</td>
</tr>
<tr>
<td>27</td>
<td>Bruner Gulch</td>
</tr>
<tr>
<td>3</td>
<td>Upper Nowood</td>
</tr>
<tr>
<td>Site Name</td>
<td>Upper Lomas Creek</td>
</tr>
<tr>
<td>----------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>Ranked Priority</td>
<td>3</td>
</tr>
<tr>
<td>Infrastructure Considerations</td>
<td></td>
</tr>
<tr>
<td>Irrigated Acreage Inundated</td>
<td>0</td>
</tr>
<tr>
<td>Residences</td>
<td>None identified</td>
</tr>
<tr>
<td>Transportation</td>
<td>0.07 miles dir1</td>
</tr>
<tr>
<td>Other</td>
<td>Would require 6.3 miles diversion pipeline and 2,000 ft tunnel diversion to gravity flow water to the site from Paint Rock Creek</td>
</tr>
<tr>
<td>Ownership</td>
<td>Private</td>
</tr>
<tr>
<td>Need to Deliver Water</td>
<td>Yes</td>
</tr>
<tr>
<td>Potential for Flood Protection</td>
<td>Low</td>
</tr>
<tr>
<td>Site Name</td>
<td>Lower Trout Creek</td>
</tr>
<tr>
<td>---------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>Ranked Priority</td>
<td>3</td>
</tr>
<tr>
<td>Latitude (dd.dddddd)</td>
<td>44.373927</td>
</tr>
<tr>
<td>Direct Supply Source</td>
<td>Paint Rock Canyon</td>
</tr>
<tr>
<td>Indirect Supply Source</td>
<td>NA</td>
</tr>
<tr>
<td>Supply Mechanism</td>
<td>Tributary Dam</td>
</tr>
<tr>
<td>Category A: Reservoir Description</td>
<td></td>
</tr>
<tr>
<td>Contributing Drainage Area - Direct (square miles)</td>
<td>6.67</td>
</tr>
<tr>
<td>Contributing Drainage Area - Indirect (square miles)</td>
<td>NA</td>
</tr>
<tr>
<td>Basin perimeter (miles)</td>
<td>10,793</td>
</tr>
<tr>
<td>Maximum basin relief (feet)</td>
<td>8,716</td>
</tr>
<tr>
<td>Mean annual precipitation (inches)</td>
<td>17.14</td>
</tr>
<tr>
<td>Category B: Watershed Description</td>
<td></td>
</tr>
<tr>
<td>Proposed Type</td>
<td>Earthen</td>
</tr>
<tr>
<td>Size (height in feet)</td>
<td>80</td>
</tr>
<tr>
<td>Spaqacity (cubic yards)</td>
<td>Medium</td>
</tr>
<tr>
<td>Embankment Length (feet)</td>
<td>1,700</td>
</tr>
<tr>
<td>Storage Efficiency (cf/1000 cy ft)</td>
<td>593,185</td>
</tr>
<tr>
<td>Method of Recharge F10</td>
<td>None / On channel</td>
</tr>
<tr>
<td>Appurtenance</td>
<td>NA</td>
</tr>
<tr>
<td>Dam Class</td>
<td>Medium</td>
</tr>
<tr>
<td>Category C: Reservoir Statistics</td>
<td></td>
</tr>
<tr>
<td>Hydrolgy Method</td>
<td>Static</td>
</tr>
<tr>
<td>Storage Availability</td>
<td>1.3</td>
</tr>
<tr>
<td>Normal Year (ac ft)</td>
<td>5,544</td>
</tr>
<tr>
<td>Dry Year (ac ft)</td>
<td>2,589</td>
</tr>
<tr>
<td>Normal Year (ac ft)</td>
<td>5,544</td>
</tr>
<tr>
<td>Dry Year (ac ft)</td>
<td>2,589</td>
</tr>
<tr>
<td>Indirect Supply Source</td>
<td>None</td>
</tr>
<tr>
<td>Indirect Normal Year (ac ft)</td>
<td>None</td>
</tr>
<tr>
<td>Indirect Dry Year (ac ft)</td>
<td>None</td>
</tr>
</tbody>
</table>
### TABLE 9-3: LEVEL II SITE EVALUATION MATRIX

**NOWOOD RIVER STORAGE, LEVEL II STUDY**

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Lower Trout Creek</th>
<th>Little Canyon Creek</th>
<th>County Line</th>
<th>Lower Riverton</th>
<th>Pole</th>
<th>Softside</th>
<th>Summit</th>
<th>Nowood- Managing Rule</th>
<th>Total</th>
<th>Nowood - Managing Rule 1</th>
<th>Total</th>
<th>Nowood - Managing Rule 2</th>
<th>Total</th>
<th>Upper Breakback</th>
<th>South Fork Other (Lower)</th>
<th>South Fork Other (Upper)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ranked Priority</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

**Category C: Dam Health**

- Dam embankment foundation
- Reservoir pool area
- Foundation Seawall

**Category G: Environmental Issues / Infrastructure**

- Wetlands (acres impacted) From NWI data
- Game: Antelope
- Game: Elk
- Game: Mule Deer
- Game: White Tailed Deer

**Category F: Geology**

- Sage Grouse Leks
- Project Impact Analysis Area (PIAA)
- Sage Grouse Core Population Area

**WDEQ Stream Classification**

- Fishery

- Brook trout fishery - potential fishery issues to consider
- Important fishery, brook, brown, rainbow, longnose sucker, L/N Dark.
- No known fisheries concerns.
- Fisheries concerns, Brook population of chubs, Stockton, L/N Dark.
- No known Fisheries concerns.
- Fisheries concerns, other local population at risk.
- Fisheries concerns, local population at risk.
- Fisheries concerns, locally sensitive species.
- Fisheries concerns, local population at risk.

**MME 3-Species Classification**

- 2AB

- No known Fisheries concerns.
- This is an excellent wild trout population at this site.
- Fisheries concerns here.
- Fisheries concerns here.
- Fisheries concerns here.
- No known Fisheries concerns.
- Fisheries concerns here.
- Fisheries concerns here.

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Lower Trout Creek</th>
<th>Little Canyon Creek</th>
<th>County Line</th>
<th>Lower Riverton</th>
<th>Pole</th>
<th>Softside</th>
<th>Summit</th>
<th>Nowood- Managing Rule</th>
<th>Total</th>
<th>Nowood - Managing Rule 1</th>
<th>Total</th>
<th>Nowood - Managing Rule 2</th>
<th>Total</th>
<th>Upper Breakback</th>
<th>South Fork Other (Lower)</th>
<th>South Fork Other (Upper)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ranked Priority</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>3</td>
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<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

**Note:** All evaluations are based on the most recent data available.
<table>
<thead>
<tr>
<th>Site Name</th>
<th>Lower Trout Creek</th>
<th>Little Canyon Creek</th>
<th>County Line</th>
<th>Lower Nowood</th>
<th>Pete</th>
<th>Solitude</th>
<th>Summit</th>
<th>Nowood - Managing Rule 1</th>
<th>Nowood - Managing Rule 2</th>
<th>Upper Brokenback</th>
<th>South Fork Other (Lower)</th>
<th>South Fork Other (Upper)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ranked Priority</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
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<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Enbankment</td>
<td>None Identified</td>
<td>None Identified</td>
<td>None Identified</td>
<td>None Identified</td>
<td>None Identified</td>
<td>None Identified</td>
<td>None Identified</td>
<td>21 buildings (2 ranches)</td>
<td>None Identified</td>
<td>None Identified</td>
<td>None Identified</td>
<td>None Identified</td>
</tr>
<tr>
<td>Impoundment</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Landowner Interest</td>
<td>None Identified</td>
<td>None Identified</td>
<td>None Identified</td>
<td>None Identified</td>
<td>None Identified</td>
<td>None Identified</td>
<td>None Identified</td>
<td>20 buildings (2 ranches)</td>
<td>None Identified</td>
<td>None Identified</td>
<td>None Identified</td>
<td>None Identified</td>
</tr>
<tr>
<td>Location Relative to Demand (Irrigated Acres downstream)</td>
<td>0</td>
<td>4.3</td>
<td>0</td>
<td>541.4</td>
<td>0</td>
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<td>562 / 547</td>
<td>446 / 518</td>
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<td>6,872 / 6,164</td>
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<td>740 / 643</td>
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<td>1,029 / 838</td>
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<td>Moderate</td>
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<td>Low</td>
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1. (Projected to be completed on Meadowlark Lake and Alkali Creek based on September 2012 water data information compiled by Trihydro. - Acres for Meadowlark Lake based on 3-in runoff.)
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<th>Site No.</th>
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<th>Removed During Level I</th>
<th>Removed During Level II</th>
<th>Removed During Level III</th>
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<td>Insufficient supply of water and high impounded acreage impacts</td>
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</table>

**Table 9-4: Summary of Alternative Screening Process**

**Nowood River Storage, Level II Study**

- **Level 1 Screening**
  - Bruner Gulch
  - Carpen Creek
  - Little Canyon Creek
  - Lone Tree
  - Lower Nowood
  - Nowood - Mahogany Butte 1
  - Nowood - Mahogany Butte 2
  - Saltlake
  - South Fork Otter (Lower)
  - South Fork Otter (Upper)
  - Summit
  - Alvord Creek
  - Old Creek
  - Cottonwood Creek
  - County Line
  - Lower Trout Creek
  - McDermott Creek
  - Medicina Lodge
  - North Brokenback
  - Nowood - Crawford
  - Pete
  - Upper Brokenback
  - Upper Luman Creek
  - Upper Nowood
  - Willow Creek
  - West Tensleep Lake
  - West Fork Willow Creek
  - Big Creek
  - Deep Creek
  - Little Cottonwood Creek
  - Lower Brokenback
  - Ski Creek
  - Paint Rock Creek
  - Willow Creek
  - Alvord Creek
  - Grand Gulch
  - Lower Luman Creek
  - Meadowlark Lake Enlargement
  - Taylor Creek

- **Level 2 Screening**
  - Bruner Gulch
  - Carpen Creek
  - Little Canyon Creek
  - Lone Tree
  - Lower Nowood
  - Nowood - Mahogany Butte 1
  - Nowood - Mahogany Butte 2
  - Saltlake
  - South Fork Otter (Lower)
  - South Fork Otter (Upper)
  - Summit
  - Alvord Creek
  - Old Creek
  - Cottonwood Creek
  - County Line
  - Lower Trout Creek
  - McDermott Creek
  - Medicina Lodge
  - North Brokenback
  - Nowood - Crawford
  - Pete
  - Upper Brokenback
  - Upper Luman Creek
  - Upper Nowood
  - Willow Creek
  - West Tensleep Lake
  - West Fork Willow Creek
  - Big Creek
  - Deep Creek
  - Little Cottonwood Creek
  - Lower Brokenback
  - Ski Creek
  - Paint Rock Creek
  - Willow Creek
  - Alvord Creek
  - Grand Gulch
  - Lower Luman Creek
  - Meadowlark Lake Enlargement
  - Taylor Creek

- **Level 3 Screening**
  - Bruner Gulch
  - Carpen Creek
  - Little Canyon Creek
  - Lone Tree
  - Lower Nowood
  - Nowood - Mahogany Butte 1
  - Nowood - Mahogany Butte 2
  - Saltlake
  - South Fork Otter (Lower)
  - South Fork Otter (Upper)
  - Summit
  - Alvord Creek
  - Old Creek
  - Cottonwood Creek
  - County Line
  - Lower Trout Creek
  - McDermott Creek
  - Medicina Lodge
  - North Brokenback
  - Nowood - Crawford
  - Pete
  - Upper Brokenback
  - Upper Luman Creek
  - Upper Nowood
  - Willow Creek
  - West Tensleep Lake
  - West Fork Willow Creek
  - Big Creek
  - Deep Creek
  - Little Cottonwood Creek
  - Lower Brokenback
  - Ski Creek
  - Paint Rock Creek
  - Willow Creek
  - Alvord Creek
  - Grand Gulch
  - Lower Luman Creek
  - Meadowlark Lake Enlargement
  - Taylor Creek
### TABLE 11-1. SUMMARY OF PREVIOUSLY RECORDED SITES IN THE MEADOWLARK LAKE AREA

**Nowood River Storage, Level II Study**

<table>
<thead>
<tr>
<th>Site #</th>
<th>Description</th>
<th>Eligibility Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>48BH264</td>
<td>Firefighters memorial</td>
<td>Undetermined</td>
</tr>
<tr>
<td>48BH746/48WA382*</td>
<td>Lithic scatter, features</td>
<td>Eligible, SHPO concurrence</td>
</tr>
<tr>
<td>48BH1143</td>
<td>Bridge</td>
<td>Not eligible, consultant</td>
</tr>
<tr>
<td>48BH1799/48WA1220</td>
<td>Black and Yellow Road</td>
<td>Eligible, SHPO concurrence</td>
</tr>
<tr>
<td>48BH3108/48WA1768</td>
<td>Deer haven lodge</td>
<td>Not eligible, SHPO concurrence</td>
</tr>
<tr>
<td>48BH3183</td>
<td>Allison cabin</td>
<td>Undetermined</td>
</tr>
<tr>
<td>48BH3456</td>
<td>Historic dump</td>
<td>Not eligible, consultant</td>
</tr>
<tr>
<td>48BH3503</td>
<td>Clay cabin</td>
<td>Undetermined</td>
</tr>
<tr>
<td>48BH3509</td>
<td>Landeck cabin</td>
<td>Undetermined</td>
</tr>
<tr>
<td>48BH3510</td>
<td>Lynch cabin</td>
<td>Undetermined</td>
</tr>
<tr>
<td>48BH3758</td>
<td>Historic cabin</td>
<td>Not eligible, SHPO concurrence</td>
</tr>
<tr>
<td>48BH3759</td>
<td>Historic cabin</td>
<td>Not eligible, SHPO concurrence</td>
</tr>
<tr>
<td>48BH3820*</td>
<td>Lithic scatter, feature</td>
<td>Undetermined</td>
</tr>
<tr>
<td>48BH3821*</td>
<td>Lithic scatter</td>
<td>Undetermined</td>
</tr>
<tr>
<td>48BH3822*</td>
<td>Lithic scatter</td>
<td>Not eligible, SHPO concurrence</td>
</tr>
<tr>
<td>48BH3823*</td>
<td>Lithic scatter</td>
<td>Undetermined</td>
</tr>
<tr>
<td>48BH4187*</td>
<td>Lithic scatter</td>
<td>Eligible, consultant</td>
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<tr>
<td>48BH4188*</td>
<td>Lithic scatter</td>
<td>Not eligible, consultant</td>
</tr>
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<td>48WA56</td>
<td>False Medicine Wheel</td>
<td>Not eligible, SHPO concurrence</td>
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<tr>
<td>48WA383</td>
<td>Lithic scatter</td>
<td>Undetermined</td>
</tr>
<tr>
<td>48WA384</td>
<td>Lithic scatter</td>
<td>Undetermined</td>
</tr>
<tr>
<td>48WA385</td>
<td>Lithic scatter</td>
<td>Not eligible, consultant</td>
</tr>
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<td>48WA386</td>
<td>Rock shelter, lithic scatter</td>
<td>Eligible, SHPO concurrence</td>
</tr>
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<td>48WA387</td>
<td>Lithic scatter</td>
<td>Not eligible, consultant</td>
</tr>
<tr>
<td>48WA389</td>
<td>Lithic scatter</td>
<td>Eligible, consultant</td>
</tr>
<tr>
<td>48WA531</td>
<td>Cairn</td>
<td>Undetermined</td>
</tr>
<tr>
<td>48WA927*</td>
<td>CCC Meadowlark Lake dam</td>
<td>Eligible, SHPO concurrence</td>
</tr>
<tr>
<td>48WA1934</td>
<td>Lithic scatter</td>
<td>Not eligible, consultant</td>
</tr>
<tr>
<td>48WA2055</td>
<td>Lithic scatter</td>
<td>Not eligible, SHPO concurrence</td>
</tr>
<tr>
<td>48WA2167*</td>
<td>Leigh Creek Archaeological District</td>
<td>Eligible, consultant</td>
</tr>
</tbody>
</table>

* Within the Meadowlark Lake project area

SHPO - State Historic Preservation Office
## TABLE 11-2. SUMMARY OF PREVIOUSLY RECORDED SITES IN THE ALKALI CREEK AREA
### NOWOOD RIVER STORAGE, LEVEL II STUDY

<table>
<thead>
<tr>
<th>Site #</th>
<th>Description</th>
<th>Eligibility Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>48BH1914*</td>
<td>Highland Ditch</td>
<td>Undetermined</td>
</tr>
<tr>
<td>48BH1915*</td>
<td>Anita Ditch</td>
<td>Not eligible, SHPO concurrence</td>
</tr>
<tr>
<td>48BH1927</td>
<td>Homestead</td>
<td>Undetermined</td>
</tr>
<tr>
<td>48BH3428</td>
<td>Lithic scatter</td>
<td>Not eligible, SHPO concurrence</td>
</tr>
<tr>
<td>48BH3887</td>
<td>Eagle trap</td>
<td>Eligible, SHPO concurrence</td>
</tr>
<tr>
<td>48BH4033</td>
<td>Cairn</td>
<td>Eligible, SHPO concurrence</td>
</tr>
<tr>
<td>48BH4034</td>
<td>Cairn</td>
<td>Eligible, SHPO concurrence</td>
</tr>
</tbody>
</table>

* Within the Alkali Creek project area

SHPO - State Historic Preservation Office
<table>
<thead>
<tr>
<th>Year</th>
<th>Name</th>
<th>Township</th>
<th>Range</th>
<th>Section</th>
<th>Qtr/Qtr</th>
</tr>
</thead>
<tbody>
<tr>
<td>1883</td>
<td>Unnamed road</td>
<td>T49N</td>
<td>R90W</td>
<td>2</td>
<td>---</td>
</tr>
<tr>
<td>1920</td>
<td>Mercer Bros Bldgs</td>
<td>T49N</td>
<td>R90W</td>
<td>2</td>
<td>NWNW</td>
</tr>
<tr>
<td>1920</td>
<td>Ranch House</td>
<td>T49N</td>
<td>R90W</td>
<td>2</td>
<td>SWSE</td>
</tr>
<tr>
<td>1920</td>
<td>Ditches and Fences</td>
<td>T49N</td>
<td>R90W</td>
<td>2</td>
<td>---</td>
</tr>
<tr>
<td>1883</td>
<td>Unnamed road</td>
<td>T50N</td>
<td>R89W</td>
<td>31</td>
<td>----</td>
</tr>
<tr>
<td>1918</td>
<td>Unnamed road, ditches, &amp; fences</td>
<td>T50N</td>
<td>R89W</td>
<td>31</td>
<td>----</td>
</tr>
<tr>
<td>1883</td>
<td>Unnamed road</td>
<td>T50N</td>
<td>R90W</td>
<td>25 &amp; 36</td>
<td>----</td>
</tr>
<tr>
<td>1914</td>
<td>Unnamed road, ditches, &amp; fences</td>
<td>T50N</td>
<td>R90W</td>
<td>27, 33, &amp;35</td>
<td>----</td>
</tr>
</tbody>
</table>

T - Township  
R - Range  
N - North  
W - West
<table>
<thead>
<tr>
<th>Year</th>
<th>Name</th>
<th>Township</th>
<th>Range</th>
<th>Section</th>
<th>Qtr/Qtr</th>
</tr>
</thead>
<tbody>
<tr>
<td>1885</td>
<td>No sites or structures identified</td>
<td>T45N</td>
<td>R88W</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>1928</td>
<td>Unnamed road, ditches, a utility line, &amp; fences</td>
<td>T45N</td>
<td>R88W</td>
<td>1</td>
<td>----</td>
</tr>
<tr>
<td>1885</td>
<td>Unnamed road</td>
<td>T45N</td>
<td>R87W</td>
<td>16</td>
<td>----</td>
</tr>
<tr>
<td>1932</td>
<td>Bigtrails to Tensleep road</td>
<td>T45N</td>
<td>R87W</td>
<td>7 &amp; 16</td>
<td>----</td>
</tr>
<tr>
<td>1932</td>
<td>Unnamed road</td>
<td>T45N</td>
<td>R87W</td>
<td>6, 7, 8, 16, &amp; 17</td>
<td>----</td>
</tr>
<tr>
<td>1932</td>
<td>Utility line</td>
<td>T45N</td>
<td>R87W</td>
<td>16 &amp; 17</td>
<td>----</td>
</tr>
<tr>
<td>1885</td>
<td>No sites or structures identified</td>
<td>T46N</td>
<td>R87W</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>1937</td>
<td>Unnamed road</td>
<td>T46N</td>
<td>R87W</td>
<td>30 &amp; 31</td>
<td>----</td>
</tr>
<tr>
<td>1885</td>
<td>No sites or structures identified</td>
<td>T46N</td>
<td>R88W</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>1927</td>
<td>Utility line, fences, &amp; Tensleep - Nowood road</td>
<td>T46N</td>
<td>R88W</td>
<td>25 &amp; 26</td>
<td>----</td>
</tr>
</tbody>
</table>

T - Township  
R - Range  
N - North  
W - West
TABLE 12-1. STATEMOD SIMULATED SHORTAGES
MEADOWLARK LAKE OPERATION SCENARIOS
NOWOOD RIVER STORAGE, LEVEL II STUDY

AVERAGE STATEMOD SIMULATED SHORTAGES FOR THE ENTIRE BASIN

<table>
<thead>
<tr>
<th></th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
<th>October</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entire Basin Shortage for Baseline Model (acre-feet)</td>
<td>39</td>
<td>532</td>
<td>2,160</td>
<td>4,069</td>
<td>5,521</td>
<td>2,666</td>
<td>164</td>
<td>15,151</td>
</tr>
<tr>
<td>Entire Basin Shortage for Scenario 4 (acre-feet)</td>
<td>39</td>
<td>520</td>
<td>2,101</td>
<td>3,856</td>
<td>4,840</td>
<td>2,616</td>
<td>162</td>
<td>14,135</td>
</tr>
<tr>
<td>Difference (acre-feet)</td>
<td>0</td>
<td>12</td>
<td>59</td>
<td>213</td>
<td>681</td>
<td>50</td>
<td>2</td>
<td>1,016</td>
</tr>
<tr>
<td>Percent Shortage Reduction</td>
<td>0%</td>
<td>2%</td>
<td>3%</td>
<td>5%</td>
<td>12%</td>
<td>2%</td>
<td>1%</td>
<td>7%</td>
</tr>
</tbody>
</table>

AVERAGE STATEMOD SIMULATED SHORTAGES BELOW THE RESERVOIR DOWNSTREAM TO THE CONFLUENCE WITH THE BIG HORN RIVER

<table>
<thead>
<tr>
<th></th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
<th>October</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shortage for Baseline Model (acre-feet)</td>
<td>5</td>
<td>196</td>
<td>548</td>
<td>496</td>
<td>1,269</td>
<td>440</td>
<td>80</td>
<td>3,034</td>
</tr>
<tr>
<td>Shortage for Scenario 4 (acre-feet)</td>
<td>5</td>
<td>186</td>
<td>500</td>
<td>283</td>
<td>595</td>
<td>391</td>
<td>78</td>
<td>2,038</td>
</tr>
<tr>
<td>Difference (acre-feet)</td>
<td>0</td>
<td>10</td>
<td>47</td>
<td>212</td>
<td>674</td>
<td>50</td>
<td>2</td>
<td>996</td>
</tr>
<tr>
<td>Percent Shortage Reduction</td>
<td>0%</td>
<td>5%</td>
<td>9%</td>
<td>43%</td>
<td>53%</td>
<td>11%</td>
<td>3%</td>
<td>33%</td>
</tr>
</tbody>
</table>

Notes:

a) Downstream of the Reservoir refers to all irrigators downstream of the Reservoir along Tensleep Creek and Nowood River to the confluence with the Bighorn River.
b) Values are a calculation of the summed shortage values of the following nodes in the StateMOD Baseline and Scenario 4 outputs (Tables 2 and 3): Tensleep Creek Shortage, Between Tensleep and Paint Rock Shortage, and Below Paint Rock Shortage.
### TABLE 12-2. STATEMOD SIMULATED DEMAND AND SHORTAGES

#### MEADOWLARK LAKE 5-FOOT ENLARGEMENT

#### NOWOOD RIVER STORAGE, LEVEL II STUDY

<table>
<thead>
<tr>
<th>Reach</th>
<th>Year Type</th>
<th>January</th>
<th>February</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
<th>October</th>
<th>November</th>
<th>December</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entire Basin Demand</td>
<td>AVG</td>
<td>4,758</td>
<td>22,407</td>
<td>34,921</td>
<td>32,981</td>
<td>27,517</td>
<td>19,513</td>
<td>3,566</td>
<td></td>
<td>145,752</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>DRY</td>
<td></td>
<td>6,884</td>
<td>23,930</td>
<td>33,368</td>
<td>32,481</td>
<td>26,777</td>
<td>19,251</td>
<td>2,930</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>145,621</td>
</tr>
<tr>
<td>Entire Basin Shortage</td>
<td>AVG</td>
<td>39</td>
<td>520</td>
<td>2,101</td>
<td>3,856</td>
<td>4,809</td>
<td>2,616</td>
<td>162</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>14,103</td>
</tr>
<tr>
<td></td>
<td>DRY</td>
<td>164</td>
<td>592</td>
<td>2,416</td>
<td>4,431</td>
<td>5,430</td>
<td>2,866</td>
<td>152</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>15,788</td>
</tr>
<tr>
<td>Entire Basin Percent Short</td>
<td>AVG</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>1%</td>
<td>2%</td>
<td>12%</td>
<td>17%</td>
<td>13%</td>
<td>5%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>9.7%</td>
</tr>
<tr>
<td></td>
<td>DRY</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>2%</td>
<td>3%</td>
<td>7%</td>
<td>14%</td>
<td>16%</td>
<td>14%</td>
<td>5%</td>
<td>5%</td>
<td>0%</td>
<td>10.8%</td>
</tr>
<tr>
<td>Nowood River above Tensleep Creek</td>
<td>AVG</td>
<td>1,567</td>
<td>5,828</td>
<td>8,442</td>
<td>7,862</td>
<td>6,806</td>
<td>5,036</td>
<td>1,145</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>36,887</td>
</tr>
<tr>
<td>Demand</td>
<td>DRY</td>
<td>2,245</td>
<td>6,147</td>
<td>8,037</td>
<td>7,759</td>
<td>6,660</td>
<td>4,982</td>
<td>963</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>36,793</td>
</tr>
<tr>
<td>Nowood River above Tensleep Creek</td>
<td>AVG</td>
<td>14</td>
<td>90</td>
<td>996</td>
<td>2,069</td>
<td>2,055</td>
<td>1,197</td>
<td>34</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>6,454</td>
</tr>
<tr>
<td>Shortage</td>
<td>DRY</td>
<td>34</td>
<td>373</td>
<td>1,492</td>
<td>2,407</td>
<td>2,799</td>
<td>1,364</td>
<td>57</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>8,005</td>
</tr>
<tr>
<td>Nowood River above Tensleep Creek</td>
<td>AVG</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>1%</td>
<td>2%</td>
<td>12%</td>
<td>26%</td>
<td>30%</td>
<td>24%</td>
<td>3%</td>
<td>0%</td>
<td>0%</td>
<td>17.6%</td>
</tr>
<tr>
<td>Percent Short</td>
<td>DRY</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>2%</td>
<td>6%</td>
<td>19%</td>
<td>31%</td>
<td>34%</td>
<td>27%</td>
<td>6%</td>
<td>0%</td>
<td>0%</td>
<td>21.8%</td>
</tr>
<tr>
<td>Tensleep Creek Demand</td>
<td>AVG</td>
<td>545</td>
<td>2,980</td>
<td>4,581</td>
<td>4,205</td>
<td>3,452</td>
<td>2,459</td>
<td>419</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>18,640</td>
</tr>
<tr>
<td>DRY</td>
<td>790</td>
<td>3,177</td>
<td>4,362</td>
<td>4,140</td>
<td>3,357</td>
<td>3,200</td>
<td>336</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>18,601</td>
</tr>
<tr>
<td>Tensleep Creek Shortage</td>
<td>AVG</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>DRY</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
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<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Nowood River between Tensleep Creek and Paint Rock Creek Demand</td>
<td>AVG</td>
<td>705</td>
<td>3,848</td>
<td>5,924</td>
<td>5,441</td>
<td>4,466</td>
<td>3,178</td>
<td>541</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>24,103</td>
</tr>
<tr>
<td>Paint Rock Creek Demand</td>
<td>DRY</td>
<td>1,022</td>
<td>4,101</td>
<td>5,666</td>
<td>5,357</td>
<td>4,345</td>
<td>3,128</td>
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<td>-</td>
<td>24,051</td>
</tr>
<tr>
<td>Nowood River between Tensleep Creek and Paint Rock Creek Shortage</td>
<td>AVG</td>
<td>5</td>
<td>186</td>
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<td>283</td>
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<td>Paint Rock Creek Shortage</td>
<td>DRY</td>
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<td>Nowood River between Tensleep Creek and Paint Rock Creek Percent Short</td>
<td>AVG</td>
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<td>1%</td>
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<td>5%</td>
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<td>0%</td>
<td>8.2%</td>
</tr>
<tr>
<td>Paint Rock Creek Percent Short</td>
<td>DRY</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
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<td>4%</td>
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<td>13%</td>
<td>0%</td>
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<td>5.6%</td>
</tr>
<tr>
<td>Paint Rock Creek Demand</td>
<td>AVG</td>
<td>1,316</td>
<td>6,233</td>
<td>9,791</td>
<td>9,713</td>
<td>8,528</td>
<td>6,038</td>
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<td>-</td>
<td>-</td>
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</tr>
<tr>
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<td>DRY</td>
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<td>6,625</td>
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<td>9,594</td>
<td>8,333</td>
<td>5,967</td>
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<td>4%</td>
<td>6%</td>
<td>15%</td>
<td>26%</td>
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<td>5%</td>
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<td>625</td>
<td>3,607</td>
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<td>4,265</td>
<td>2,902</td>
<td>469</td>
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<td>4,082</td>
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<td>0%</td>
<td>0%</td>
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<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Percent Short</td>
<td>DRY</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
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<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

**Notes:**

Values include change to representation of Surplus Water Law - second cfs rights turned off for irrigation nodes and assigned to 19 Surplus Water Right nodes located at the bottom of tributaries (Lone Tree Ck, Bear Ck, Deep Ck, Redbank Ck, Little Canyon Ck, Otter Ck, Spring Ck, Tensleep Ck, Brokenback Ck, Buffalo Flat Ck, Medicine Lodge Ck, Upper Paint Rock Ck, Alkali Ck, lower Paint Rock Ck) and sections of Nowood River main stem (above Big Trails Res, abv Tensleep Ck confluence, abv Paint Rock Ck confluence, blw Paint Rock Ck confluence).

Demands placed on Surplus Water Right nodes equal to the portion of the calculated demand beyond the first cfs for each of the tributary nodes (e.g., 0607020, 0900740, 0900790). Shortages calculated based on sum of demand for each tributary node minus (sum of total supply for each tributary node plus total supply to Surplus Water Right node).

Values exclude approximately 2718 acre-feet per year average well demand.

Values exclude approximately 2718 acre-feet per year average well demand.
### TABLE 12-3. STATEMOD SIMULATED SHORTAGE REDUCTIONS
**MEADOWLARK LAKE 5-FOOT ENLARGEMENT**
**NOWOOD RIVER STORAGE, LEVEL II STUDY**

#### AVERAGE STATEMOD SIMULATED SHORTAGES FOR THE ENTIRE BASIN

<table>
<thead>
<tr>
<th>Description</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
<th>October</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entire Basin Shortage for Baseline Model (acre-feet)</td>
<td>39</td>
<td>532</td>
<td>2,160</td>
<td>4,069</td>
<td>5,521</td>
<td>2,666</td>
<td>164</td>
<td>15,151</td>
</tr>
<tr>
<td>Entire Basin Shortage for Enlargement (acre-feet)</td>
<td>39</td>
<td>520</td>
<td>2,101</td>
<td>3,856</td>
<td>4,809</td>
<td>2,616</td>
<td>162</td>
<td>14,103</td>
</tr>
<tr>
<td>Reduction in Shortage (Difference) (acre-feet)</td>
<td>-</td>
<td>12</td>
<td>59</td>
<td>213</td>
<td>712</td>
<td>50</td>
<td>2</td>
<td>1,048</td>
</tr>
<tr>
<td>Percent Shortage Reduction</td>
<td>0%</td>
<td>2%</td>
<td>3%</td>
<td>5%</td>
<td>13%</td>
<td>2%</td>
<td>1%</td>
<td>7%</td>
</tr>
</tbody>
</table>

#### AVERAGE STATEMOD SIMULATED REDUCTION IN SHORTAGES

<table>
<thead>
<tr>
<th>Reach</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
<th>October</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensleep Creek Reduction in Shortage (acre-feet)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>191</td>
<td>167</td>
<td>50</td>
<td>2</td>
<td>410</td>
</tr>
<tr>
<td>Paint Rock Creek Reduction in Shortage (acre-feet)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>17</td>
<td>-</td>
<td>-</td>
<td>17</td>
</tr>
<tr>
<td>Nowood River below Paint Rock Creek Reduction in Shortage (acre-feet)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>484</td>
<td>-</td>
<td>-</td>
<td>484</td>
</tr>
<tr>
<td>Nowood River above Tensleep Creek Reduction in Shortage (acre-feet)</td>
<td>-</td>
<td>2</td>
<td>12</td>
<td>0</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>17</td>
</tr>
<tr>
<td>Nowood River between Tensleep Creek and Paint Rock Creek Reduction in Shortage (acre-feet)</td>
<td>-</td>
<td>10</td>
<td>47</td>
<td>21</td>
<td>43</td>
<td>-</td>
<td>-</td>
<td>121</td>
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<tr>
<td>Percent Reduction</td>
<td>100.0%</td>
<td>0.3%</td>
<td>93.4%</td>
<td>0.3%</td>
<td>5.8%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 12-4: StateMod Simulated Available Flows and Fill Scenario

**Alkali Creek**

**Nowood River Storage, Level II Study**

<table>
<thead>
<tr>
<th>Year</th>
<th>Units</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Total (acre-ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ave Year acre-feet</td>
<td>15.9</td>
<td>9.5</td>
<td>5.3</td>
<td>2.8</td>
<td>3.7</td>
<td>32.1</td>
<td>373.5</td>
<td>61.2</td>
<td>10.3</td>
<td>3.8</td>
<td>23.6</td>
<td>917.2</td>
<td>917.2</td>
<td></td>
</tr>
<tr>
<td>Ave Year cfs</td>
<td>0.3</td>
<td>0.2</td>
<td>0.1</td>
<td>0.0</td>
<td>0.1</td>
<td>0.5</td>
<td>4.8</td>
<td>6.1</td>
<td>1.0</td>
<td>0.2</td>
<td>0.1</td>
<td>0.4</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Dry Year acre-feet</td>
<td>21.6</td>
<td>13.0</td>
<td>6.6</td>
<td>2.8</td>
<td>1.9</td>
<td>33.3</td>
<td>373.5</td>
<td>61.2</td>
<td>10.3</td>
<td>3.8</td>
<td>23.6</td>
<td>917.2</td>
<td>917.2</td>
<td></td>
</tr>
<tr>
<td>Dry Year cfs</td>
<td>0.4</td>
<td>0.2</td>
<td>0.1</td>
<td>0.0</td>
<td>0.0</td>
<td>0.5</td>
<td>6.3</td>
<td>6.6</td>
<td>0.2</td>
<td>0.2</td>
<td>0.7</td>
<td>15</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Flow Available to Fill Reservoir

- **Minimum Estimated Stream Flow (Baseflow)** - Medicine Lodge & Paint Rock Creek
- **Available Flow to Fill Reservoir**
  - Alkali Creek + Anita Ditch + Anita Supply Ditch (Diversion flow)
  - Alkali Creek + Anita Ditch + Anita Supply Ditch (Diversion flow)
- **Flow Diverted to Reservoir**

1) Average year values for 1973 through 2008 period
3) Flow values are calculated for the Alkali Creek Reservoir options.
4) These values are a rough estimate based on the October 29, 2012 StateMOD results.

**cfs** - cubic feet per second

---

**Bibliographic Details**

- Title: Table 12-4: StateMod Simulated Available Flows and Fill Scenario
- Source: Alkali Creek Nowood River Storage, Level II Study
- Date: 2013
- Institution: Wyoming Water Development Board

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**Online Availability**

- [Link to the document](http://example.com/document)
### TABLE 12-5. STATEMOD SIMULATED DEMAND AND SHORTAGES

**ALKALI CREEK**

**NOWOOD RIVER STORAGE, LEVEL II STUDY**

<table>
<thead>
<tr>
<th>Reach</th>
<th>Year Type</th>
<th>January</th>
<th>February</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
<th>October</th>
<th>November</th>
<th>December</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entire Basin Demand</td>
<td>AVG</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4,758</td>
<td>22,497</td>
<td>34,921</td>
<td>32,981</td>
<td>27,517</td>
<td>19,513</td>
<td>3,566</td>
<td>-</td>
<td>-</td>
<td>145,752</td>
</tr>
<tr>
<td>Entire Basin Shortage</td>
<td>DRY</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>6,884</td>
<td>23,930</td>
<td>33,368</td>
<td>32,481</td>
<td>26,777</td>
<td>19,251</td>
<td>2,930</td>
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<td>-</td>
<td>145,621</td>
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<tr>
<td>Entire Basin Percent Short</td>
<td>AVG</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>1%</td>
<td>1%</td>
<td>5%</td>
<td>10%</td>
<td>15%</td>
<td>12%</td>
<td>3%</td>
<td>-</td>
<td>-</td>
<td>8.2%</td>
</tr>
<tr>
<td></td>
<td>DRY</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>1%</td>
<td>2%</td>
<td>0%</td>
<td>12%</td>
<td>17%</td>
<td>13%</td>
<td>4%</td>
<td>-</td>
<td>-</td>
<td>9.3%</td>
</tr>
<tr>
<td>Nowood River above Tensleep Creek Demand</td>
<td>AVG</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1,567</td>
<td>5,828</td>
<td>5,442</td>
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<td>1,145</td>
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<td>36,687</td>
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<td>-</td>
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<td>2,245</td>
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<td>Nowood River above Tensleep Creek Percent Short</td>
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<td>-</td>
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<td>34</td>
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<td>26%</td>
<td>30%</td>
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<td>-</td>
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<tr>
<td>Tensleep Creek Demand</td>
<td>AVG</td>
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<td>545</td>
<td>2,980</td>
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<tr>
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<tr>
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<td>AVG</td>
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<td>-</td>
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<td>0</td>
<td>0</td>
<td>327</td>
<td>194</td>
<td>609</td>
<td>256</td>
<td>54</td>
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<td>1,481</td>
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<td>8.3%</td>
</tr>
<tr>
<td>Paint Rock Creek Demand</td>
<td>AVG</td>
<td>-</td>
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<td>9,713</td>
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<td>-</td>
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<td>5,967</td>
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<td>-</td>
<td>42,585</td>
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<td>-</td>
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<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>-</td>
<td>-</td>
<td>0%</td>
</tr>
<tr>
<td>Nowood River below Paint Rock Creek Demand</td>
<td>AVG</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>524</td>
<td>3,807</td>
<td>5,769</td>
<td>5,769</td>
<td>4,962</td>
<td>2,802</td>
<td>469</td>
<td>-</td>
<td>-</td>
<td>23,712</td>
</tr>
<tr>
<td>Nowood River below Paint Rock Creek Shortage</td>
<td>DRY</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>354</td>
<td>3,890</td>
<td>5,632</td>
<td>5,632</td>
<td>4,982</td>
<td>2,754</td>
<td>353</td>
<td>-</td>
<td>-</td>
<td>23,617</td>
</tr>
<tr>
<td>Nowood River below Paint Rock Creek Percent Short</td>
<td>AVG</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>34</td>
<td>0</td>
<td>40</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>74</td>
</tr>
<tr>
<td></td>
<td>DRY</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>1%</td>
<td>0%</td>
<td>1%</td>
<td>0%</td>
<td>0%</td>
<td>-</td>
<td>-</td>
<td>0.3%</td>
</tr>
</tbody>
</table>

**Notes:**

Values include change to representation of Surplus Water Law - second cfs rights turned off for irrigation nodes and assigned to 19 Surplus Water Rights nodes located at the bottom of tributaries (Lone Tree Ck, Bear Ck, Deep Ck, Redbank Ck, Little Canyon Ck, Otter Ck, Spring Ck, Tensleep Ck, Brokenback Ck, Buffalo Flat Ck, Medicine Lodge Ck, Upper Paint Rock Ck, Alkali Ck, lower Paint Rock Ck) and sections of Nowood River main stem (above Big Trails Res, abv Tensleep Ck confluence, abv Paint Rock Ck confluence, blw Paint Rock Ck confluence).

Demands placed on Surplus Water Rights nodes equal to the portion of the calculated demand beyond the first cfs for each of the tributary nodes (e.g., 0900720, 0900740, 0900790 on Redbank Ck, Tensleep Ck, Brokenback Ck, Buffalo Flat Ck, Medicine Lodge Ck, Upper Paint Rock Ck, Alkali Ck, lower Paint Rock Ck) and sections of Nowood River main stem (above Big Trails Res, abv Tensleep Ck confluence, abv Paint Rock Ck confluence, blw Paint Rock Ck confluence).

Shortages calculated based on sum of demand for each tributary node minus (sum of total supply for each tributary node plus total supply to Surplus Water Right node).

Values exclude approximately 2718 acre-feet per year average well demand.
TABLE 12-6. STATEMOD SIMULATED SHORTAGE REDUCTIONS
ALKALI CREEK
NOWOOD RIVER STORAGE, LEVEL II STUDY

AVERAGE STATEMOD SIMULATED SHORTAGES FOR THE ENTIRE BASIN

<table>
<thead>
<tr>
<th>Description</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
<th>October</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entire Basin Shortage for Baseline Model (acre-feet)</td>
<td>39</td>
<td>532</td>
<td>2,160</td>
<td>4,069</td>
<td>5,521</td>
<td>2,666</td>
<td>164</td>
<td>15,151</td>
</tr>
<tr>
<td>Entire Basin Shortage for Enlargement (acre-feet)</td>
<td>30</td>
<td>276</td>
<td>1,655</td>
<td>3,376</td>
<td>4,164</td>
<td>2,390</td>
<td>112</td>
<td>12,002</td>
</tr>
<tr>
<td>Reduction in Shortage (Difference) (acre-feet)</td>
<td>9</td>
<td>256</td>
<td>506</td>
<td>693</td>
<td>1,357</td>
<td>276</td>
<td>52</td>
<td>3,149</td>
</tr>
<tr>
<td>Percent Shortage Reduction</td>
<td>24%</td>
<td>48%</td>
<td>23%</td>
<td>17%</td>
<td>25%</td>
<td>10%</td>
<td>32%</td>
<td>21%</td>
</tr>
</tbody>
</table>

AVERAGE STATEMOD SIMULATED REDUCTION IN SHORTAGES

| Reach                                                          | April | May  | June  | July  | August | September | October | Total  | Percent Reduction |
|                                                               | -     | -    | -     | 191   | 155    | 46        | 2       | 394    | 96.2%            |
| Tensleep Creek Reduction in Shortage (acre-feet)                | -     | -    | -     | 444   | -      | 444       | -       | 444    | 85.8%            |
| Paint Rock Creek Reduction in Shortage (acre-feet)              | 9     | 244  | 447   | 480   | 740    | 230       | 50      | 2,200  | 39.0%            |
| Nowood River above Tensleep Creek Reduction in Shortage (acre-feet) | -     | 2    | 12    | 0     | 2      | -         | -       | 17     | 0.3%             |
| Nowood River between Tensleep Creek and Paint Rock Creek Reduction in Shortage (acre-feet) | -     | 10   | 47    | 21    | 15     | -         | -       | 94     | 4.5%             |
### TABLE 12-7: STATEMOD SIMULATED AVAILABLE FLOWS AND FILL SCENARIO

**NOWOOD RIVER STORAGE, LEVEL I STUDY**

#### SIMULATED FLOWS IN ACRE-Ft 1, 4, 8

<table>
<thead>
<tr>
<th>Year</th>
<th>Units</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Total (acre-ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Flow - Otter Creek</td>
<td>Ave Year</td>
<td>cfs</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Dry Year</td>
<td>acre-ft</td>
<td>2.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>12,586</td>
</tr>
<tr>
<td>Available Flow - Otter Creek</td>
<td>Ave Year</td>
<td>464.5</td>
<td>574.0</td>
<td>523.7</td>
<td>505.6</td>
<td>584.4</td>
<td>396.3</td>
<td>1,434.9</td>
<td>3,731.9</td>
<td>1,710.2</td>
<td>601.1</td>
<td>442.4</td>
<td>531.0</td>
<td>3,255.4</td>
</tr>
<tr>
<td>Dry Year</td>
<td>acre-ft</td>
<td>459.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>7,582</td>
</tr>
</tbody>
</table>

#### SIMULATED FLOWS IN CFS 1, 8

<table>
<thead>
<tr>
<th>Year</th>
<th>Units</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Total (acre-ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Flow - Otter Creek</td>
<td>Ave Year</td>
<td>cfs</td>
<td>7.77</td>
<td>7.72</td>
<td>7.01</td>
<td>6.38</td>
<td>8.75</td>
<td>11.36</td>
<td>16.05</td>
<td>23.89</td>
<td>14.89</td>
<td>8.47</td>
<td>9.99</td>
<td>7.19</td>
</tr>
<tr>
<td>Available Flow - Otter Creek</td>
<td>Ave Year</td>
<td>7.55</td>
<td>9.65</td>
<td>8.50</td>
<td>8.23</td>
<td>10.52</td>
<td>15.55</td>
<td>21.35</td>
<td>52.50</td>
<td>17.32</td>
<td>1.15</td>
<td>0.20</td>
<td>1.94</td>
<td>1.94</td>
</tr>
</tbody>
</table>

#### FLOW AVAILABLE TO FILL RESERVOIR

| Minimum Estimated Stream Flow - Otter Creek | Ave Year | cfs | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 7.77 |
| Available Flow to Fill Reservoir | Ave Year | 3.7 | 5.2 | 4.5 | 3.9 | 6.2 | 8.9 | 9.5 | 12.8 | 1.5 |

#### TABLE 12-7: STATEMOD SIMULATED AVAILABLE FLOWS AND FILL SCENARIO

- **SCENARIO 1 - DIVERT FLOWS FROM NOVEMBER 1ST THROUGH MAY 31ST**

<table>
<thead>
<tr>
<th>Year</th>
<th>Units</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Total (acre-ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Available Flow to Fill Reservoir</td>
<td>Ave Year</td>
<td>5.1</td>
<td>310.2</td>
<td>424.5</td>
<td>368.3</td>
<td>351.6</td>
<td>444.8</td>
<td>801.2</td>
<td>1,119.9</td>
<td>3,069.2</td>
<td>180.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow Diverted to Reservoir</td>
<td>Ave Year</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3,510</td>
</tr>
<tr>
<td>Estimated Stream Flow Remaining in Otter Creek</td>
<td>Ave Year</td>
<td>7.6</td>
<td>5.8</td>
<td>4.5</td>
<td>4.2</td>
<td>5.5</td>
<td>6.6</td>
<td>8.4</td>
<td>52.3</td>
<td>17.3</td>
<td>11.1</td>
<td>0.2</td>
<td>1.9</td>
<td></td>
</tr>
<tr>
<td>Available Flow to Fill Reservoir</td>
<td>Ave Year</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>9.5</td>
<td>12.8</td>
<td>1.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3,079</td>
</tr>
<tr>
<td>Flow Diverted to Reservoir</td>
<td>Ave Year</td>
<td>3.7</td>
<td>424.5</td>
<td>368.3</td>
<td>351.6</td>
<td>444.8</td>
<td>801.2</td>
<td>1,119.9</td>
<td>3,069.2</td>
<td>180.1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2,344</td>
</tr>
</tbody>
</table>

#### SCENARIO 2 - DIVERT FLOWS FROM APRIL 1ST THROUGH JUNE 30TH

<table>
<thead>
<tr>
<th>Year</th>
<th>Units</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Total (acre-ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Available Flow to Fill Reservoir</td>
<td>Ave Year</td>
<td>5.1</td>
<td>310.2</td>
<td>424.5</td>
<td>368.3</td>
<td>351.6</td>
<td>444.8</td>
<td>801.2</td>
<td>1,119.9</td>
<td>3,069.2</td>
<td>180.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow Diverted to Reservoir</td>
<td>Ave Year</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3,510</td>
</tr>
<tr>
<td>Minimum Estimated Stream Flow Remaining in Otter Creek</td>
<td>Ave Year</td>
<td>7.6</td>
<td>9.6</td>
<td>8.5</td>
<td>6.2</td>
<td>10.5</td>
<td>15.6</td>
<td>24.9</td>
<td>50.9</td>
<td>11.3</td>
<td>1.1</td>
<td>0.2</td>
<td>1.9</td>
<td></td>
</tr>
<tr>
<td>Available Flow to Fill Reservoir</td>
<td>Ave Year</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>9.5</td>
<td>12.8</td>
<td>1.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1,445</td>
</tr>
<tr>
<td>Flow Diverted to Reservoir</td>
<td>Ave Year</td>
<td>3.7</td>
<td>310.1</td>
<td>276.9</td>
<td>238.8</td>
<td>345.1</td>
<td>545.2</td>
<td>566.3</td>
<td>767.0</td>
<td>91.9</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1,445</td>
</tr>
</tbody>
</table>

#### Notes:

1. Average year values for 1973 through 2008 period
3. Flow values are calculated for the Otter Creek Reservoir option. However, discussion with Rick Parson on October 26, 2011, concluded these values will also work with Taylor Draw because the diversion ditch pulls from Otter Creek in the same location as the proposed Otter Creek Reservoir.
4. These values are a rough estimate as the Statewide model is still being refined and revised to update to efficiencies, crop demands, ditch sizes, etc.
5. Green cells indicate values accounted for in the scenario analysis.
<table>
<thead>
<tr>
<th>Year</th>
<th>Units</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Total (acre-ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ave Year</td>
<td>Acre-ft</td>
<td>24.3</td>
<td>23.2</td>
<td>21.7</td>
<td>21.6</td>
<td>25.4</td>
<td>42.0</td>
<td>65.1</td>
<td>169.3</td>
<td>81.5</td>
<td>30.1</td>
<td>22.1</td>
<td>25.5</td>
<td>552</td>
</tr>
<tr>
<td>Dry Year</td>
<td>Acre-ft</td>
<td>19.6</td>
<td>18.4</td>
<td>17.9</td>
<td>16.6</td>
<td>20.9</td>
<td>30.8</td>
<td>44.5</td>
<td>69.5</td>
<td>44.1</td>
<td>26.3</td>
<td>18.6</td>
<td>20.6</td>
<td>348</td>
</tr>
</tbody>
</table>

**Flow Available to Fill Reservoir**

<table>
<thead>
<tr>
<th>Year</th>
<th>Units</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Total (acre-ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ave Year</td>
<td>acre-ft</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Dry Year</td>
<td>acre-ft</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Notes:
1) Average year values for 1973 through 2008 period
3) Flow values are calculated for the Cornell Gulch and Nowood Crawford Reservoir options. The Nowood Crawford node was used to simulate the proposed diversion for Cornell Gulch due to its location.
4) These values are calculated based on the October 29, 2012 StateMOD results.
### TABLE 13-1. SUMMARY OF ESTIMATED COSTS FOR TOP RANKED ALTERNATIVES
NOWOOD RIVER STORAGE, LEVEL II STUDY

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Storage Capacity (acre-feet)</th>
<th>Capital Construction Costs ($)</th>
<th>Total Cost ($)</th>
<th>Cost Per Acre-Foot of Storage ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meadowlark Lake Expansion²</td>
<td>1,360</td>
<td>$1,417,343.40</td>
<td>$2,796,692.31</td>
<td>$2,056.24</td>
</tr>
<tr>
<td>Alkali Creek</td>
<td>7,401</td>
<td>$10,420,866.00</td>
<td>$15,741,568.69</td>
<td>$2,126.95</td>
</tr>
<tr>
<td>Lower Luman Creek</td>
<td>2,421</td>
<td>$10,035,044.10</td>
<td>$14,976,690.05</td>
<td>$6,186.16</td>
</tr>
<tr>
<td>Taylor Draw</td>
<td>2,435</td>
<td>$10,922,871.60</td>
<td>$15,605,863.31</td>
<td>$6,408.98</td>
</tr>
</tbody>
</table>

1 - Costs include additional items such as final design and specifications, mitigation, legal fees, access, and permitting.
2 - Costs are based on a 5-foot, upstream embankment raise.
TABLE 13-2. MEADOWLARK LAKE ENLARGEMENT CONCEPTUAL LEVEL COST ESTIMATE
NOWOOD RIVER STORAGE, LEVEL II STUDY

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Unit</th>
<th>Estimated Quantity</th>
<th>Unit Rate</th>
<th>Cost Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparation of Final Designs and Specifications</td>
<td></td>
<td></td>
<td></td>
<td>$170,081.21</td>
</tr>
<tr>
<td>Permitting and Mitigation</td>
<td></td>
<td></td>
<td></td>
<td>$708,671.70</td>
</tr>
<tr>
<td>Legal Fees</td>
<td></td>
<td></td>
<td></td>
<td>$100,000.00</td>
</tr>
<tr>
<td>Acquisition of Access and Rights-of-Way</td>
<td></td>
<td></td>
<td></td>
<td>$25,000.00</td>
</tr>
<tr>
<td>Pre-Construction Cost (Subtotal #1)</td>
<td></td>
<td></td>
<td></td>
<td>$1,003,752.91</td>
</tr>
</tbody>
</table>

**Construction Components**

<table>
<thead>
<tr>
<th>Item</th>
<th>Item Description</th>
<th>Unit</th>
<th>Estimated Quantity</th>
<th>Unit Rate</th>
<th>Cost Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mobilization/Demobilization</td>
<td>LS</td>
<td>1</td>
<td></td>
<td>$104,988.40</td>
</tr>
<tr>
<td>2</td>
<td>Clearing and Grubbing</td>
<td>AC</td>
<td>6</td>
<td>$2,500.00</td>
<td>$15,000.00</td>
</tr>
<tr>
<td>3</td>
<td>Topsoil Stripping</td>
<td>CY</td>
<td>8,100</td>
<td>$3.50</td>
<td>$28,350.00</td>
</tr>
<tr>
<td>4</td>
<td>Subsoil/Key Trench Excavation/Foundation Preparation</td>
<td>CY</td>
<td>3,500</td>
<td>$6.15</td>
<td>$21,525.00</td>
</tr>
<tr>
<td>5</td>
<td>Embankment (from onsite borrow)</td>
<td>CY</td>
<td>32,400</td>
<td>$9.60</td>
<td>$311,040.00</td>
</tr>
<tr>
<td>6</td>
<td>Embankment Riprap</td>
<td>CY</td>
<td>2,224</td>
<td>$60.00</td>
<td>$133,440.00</td>
</tr>
<tr>
<td>7</td>
<td>Spillways</td>
<td>LS</td>
<td>1</td>
<td>$291,000.00</td>
<td>$291,000.00</td>
</tr>
<tr>
<td>8</td>
<td>Outlet Works</td>
<td>LS</td>
<td>1</td>
<td>$202,000.00</td>
<td>$202,000.00</td>
</tr>
<tr>
<td>9</td>
<td>Anita Ditch Enlargement/Improvements</td>
<td>LS</td>
<td>1</td>
<td>$160,000.00</td>
<td>$160,000.00</td>
</tr>
<tr>
<td>10</td>
<td>Wetland Mitigation</td>
<td>LS</td>
<td>1</td>
<td>$100,000.00</td>
<td>$100,000.00</td>
</tr>
<tr>
<td>11</td>
<td>Miscellaneous</td>
<td>LS</td>
<td>1</td>
<td>$50,000.00</td>
<td>$50,000.00</td>
</tr>
</tbody>
</table>

**Construction Components Cost (Subtotal #2)** $1,417,343.40

**Construction Engineering Costs (10% of Subtotal #2)** $141,734.34

**Subtotal Construction Cost (Subtotal #3)** $1,559,077.74

| 15% Contingency (Subtotal #3 x 15%) | $233,861.66 |

**Total Construction Cost (Subtotal #4)** $1,792,939.40

**Total Project Costs (Subtotal #1 + Subtotal #2)** $2,796,692.31

Note: Costs are based on a 5-foot upstream embankment raise.
### TABLE 13-3. ALKALI CREEK CONCEPTUAL LEVEL COST ESTIMATE

**NOWOOD RIVER STORAGE, LEVEL II STUDY**

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Cost Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparation of Final Designs and Specifications</td>
<td>$833,669.28</td>
</tr>
<tr>
<td>Permitting and Mitigation</td>
<td>$1,250,503.92</td>
</tr>
<tr>
<td>Legal Fees</td>
<td>$100,000.00</td>
</tr>
<tr>
<td>Acquisition of Access and Rights-of-Way</td>
<td>$375,000.00</td>
</tr>
<tr>
<td>Pre-Construction Cost (Subtotal #1)</td>
<td>$2,559,173.20</td>
</tr>
</tbody>
</table>

#### Construction Components

<table>
<thead>
<tr>
<th>Item</th>
<th>Item Description</th>
<th>Unit</th>
<th>Estimated Quantity</th>
<th>Unit Rate</th>
<th>Cost Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mobilization/Demobilization</td>
<td>LS</td>
<td>1</td>
<td>-</td>
<td>$771,916.00</td>
</tr>
<tr>
<td>2</td>
<td>Clearing and Grubbing</td>
<td>AC</td>
<td>15</td>
<td>$1,200.00</td>
<td>$18,000.00</td>
</tr>
<tr>
<td>3</td>
<td>Topsoil Stripping</td>
<td>CY</td>
<td>84,700</td>
<td>$3.50</td>
<td>$296,450.00</td>
</tr>
<tr>
<td>4</td>
<td>Subsoil/Key Trench Excavation/Foundation Preparation</td>
<td>CY</td>
<td>61,000</td>
<td>$4.80</td>
<td>$292,800.00</td>
</tr>
<tr>
<td>5</td>
<td>Embankment (from onsite borrow)</td>
<td>CY</td>
<td>692,000</td>
<td>$6.10</td>
<td>$4,221,200.00</td>
</tr>
<tr>
<td>6</td>
<td>Embankment Riprap</td>
<td>CY</td>
<td>48,500</td>
<td>$43.00</td>
<td>$2,085,500.00</td>
</tr>
<tr>
<td>7</td>
<td>Spillways</td>
<td>LS</td>
<td>1</td>
<td>$875,000.00</td>
<td>$875,000.00</td>
</tr>
<tr>
<td>8</td>
<td>Outlet Works</td>
<td>LS</td>
<td>1</td>
<td>$350,000.00</td>
<td>$350,000.00</td>
</tr>
<tr>
<td>9</td>
<td>Anita Ditch Enlargement/Improvements</td>
<td>LS</td>
<td>1</td>
<td>$350,000.00</td>
<td>$350,000.00</td>
</tr>
<tr>
<td>10</td>
<td>Wetland Mitigation</td>
<td>LS</td>
<td>1</td>
<td>$50,000.00</td>
<td>$50,000.00</td>
</tr>
<tr>
<td>11</td>
<td>Miscellaneous</td>
<td>LS</td>
<td>1</td>
<td>$1,110,000.00</td>
<td>$1,110,000.00</td>
</tr>
</tbody>
</table>

**Construction Components Cost (Subtotal #2)** | $10,420,866.00

**Construction Engineering Costs (10% of Subtotal #2)** | $1,042,086.60

**Subtotal Construction Cost (Subtotal #3)** | $11,462,952.60

**15% Contingency (Subtotal #3 x 15%)** | $1,719,442.89

**Total Construction Cost (Subtotal #4)** | $13,182,395.49

**Total Project Costs (Subtotal #1 + Subtotal #2)** | $15,741,568.69
**TABLE 13-4. LOWER LUMAN CREEK CONCEPTUAL LEVEL COST ESTIMATE**

**NOWOOD RIVER STORAGE, LEVEL II STUDY**

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Unit</th>
<th>Estimated Quantity</th>
<th>Unit Rate</th>
<th>Cost Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparation of Final Designs and Specifications</td>
<td></td>
<td></td>
<td></td>
<td>$ 802,803.53</td>
</tr>
<tr>
<td>Permitting and Mitigation</td>
<td></td>
<td></td>
<td></td>
<td>$ 1,304,555.73</td>
</tr>
<tr>
<td>Legal Fees</td>
<td></td>
<td></td>
<td></td>
<td>$ 100,000.00</td>
</tr>
<tr>
<td>Acquisition of Access and Rights-of-Way</td>
<td></td>
<td></td>
<td></td>
<td>$ 75,000.00</td>
</tr>
<tr>
<td><strong>Pre-Construction Cost (Subtotal #1)</strong></td>
<td></td>
<td></td>
<td></td>
<td>$ 2,282,359.26</td>
</tr>
</tbody>
</table>

### Construction Components

<table>
<thead>
<tr>
<th>Item</th>
<th>Item Description</th>
<th>Unit</th>
<th>Estimated Quantity</th>
<th>Unit Rate</th>
<th>Cost Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mobilization/Demobilization</td>
<td>LS</td>
<td>1</td>
<td>-</td>
<td>$ 743,336.60</td>
</tr>
<tr>
<td>2</td>
<td>Clearing and Grubbing</td>
<td>AC</td>
<td>18</td>
<td>$ 1,200.00</td>
<td>$ 21,600.00</td>
</tr>
<tr>
<td>3</td>
<td>Topsoil Stripping</td>
<td>CY</td>
<td>64,500</td>
<td>$ 3.50</td>
<td>$ 225,750.00</td>
</tr>
<tr>
<td>4</td>
<td>Subsoil/Key Trench Excavation/Foundation Preparation</td>
<td>CY</td>
<td>30,370</td>
<td>$ 4.75</td>
<td>$ 144,257.50</td>
</tr>
<tr>
<td>5</td>
<td>Embankment (from onsite borrow)</td>
<td>CY</td>
<td>537,800</td>
<td>$ 6.50</td>
<td>$ 3,495,700.00</td>
</tr>
<tr>
<td>6</td>
<td>Embankment Riprap</td>
<td>CY</td>
<td>29,300</td>
<td>$ 43.00</td>
<td>$ 1,259,900.00</td>
</tr>
<tr>
<td>7</td>
<td>Spillways</td>
<td>LS</td>
<td>1</td>
<td>$ 755,000.00</td>
<td>$ 755,000.00</td>
</tr>
<tr>
<td>8</td>
<td>Outlet Works</td>
<td>LS</td>
<td>1</td>
<td>$ 459,500.00</td>
<td>$ 459,500.00</td>
</tr>
<tr>
<td>9</td>
<td>New Canal Construction</td>
<td>LS</td>
<td>1</td>
<td>$ 2,450,000.00</td>
<td>$ 2,450,000.00</td>
</tr>
<tr>
<td>10</td>
<td>Wetland Mitigation</td>
<td>LS</td>
<td>1</td>
<td>$ 50,000.00</td>
<td>$ 50,000.00</td>
</tr>
<tr>
<td>11</td>
<td>Miscellaneous</td>
<td>LS</td>
<td>1</td>
<td>$ 430,000.00</td>
<td>$ 430,000.00</td>
</tr>
</tbody>
</table>

| Construction Components Cost (Subtotal #2)                                      |         |                    |           | $ 10,035,044.10 |
| Construction Engineering Costs (10% of Subtotal #2)                               |         |                    |           | $ 1,003,504.41 |
| Subtotal Construction Cost (Subtotal #3)                                          |         |                    |           | $ 11,038,548.51 |
| 15% Contingency (Subtotal #3 x 15%)                                               |         |                    |           | $ 1,655,782.28 |
| Total Construction Cost (Subtotal #4)                                              |         |                    |           | $ 12,694,330.79 |

| Total Project Costs (Subtotal #1 + Subtotal #2)                                     |         |                    |           | $ 14,976,690.05 |
### TABLE 13-5. TAYLOR DRAW CONCEPTUAL LEVEL COST ESTIMATE
NOWOOD RIVER STORAGE, LEVEL II STUDY

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Cost Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparation of Final Designs and Specifications</td>
<td>$873,829.73</td>
</tr>
<tr>
<td>Permitting and Mitigation</td>
<td>$764,601.01</td>
</tr>
<tr>
<td>Legal Fees</td>
<td>$100,000.00</td>
</tr>
<tr>
<td>Acquisition of Access and Rights-of-Way</td>
<td>$50,000.00</td>
</tr>
<tr>
<td><strong>Pre-Construction Cost (Subtotal #1)</strong></td>
<td><strong>$1,788,430.74</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Construction Components</th>
<th>Item Description</th>
<th>Unit</th>
<th>Estimated Quantity</th>
<th>Unit Rate</th>
<th>Cost Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 Mobilization/Demobilization</td>
<td>LS</td>
<td>1</td>
<td>-</td>
<td>$809,101.60</td>
</tr>
<tr>
<td></td>
<td>2 Clearing and Grubbing</td>
<td>AC</td>
<td>19</td>
<td>$1,200.00</td>
<td>$22,800.00</td>
</tr>
<tr>
<td></td>
<td>3 Topsoil Stripping</td>
<td>CY</td>
<td>84,700</td>
<td>$3.50</td>
<td>$296,450.00</td>
</tr>
<tr>
<td></td>
<td>4 Subsoil/Key Trench Excavation/Foundation Preparation</td>
<td>CY</td>
<td>30,400</td>
<td>$4.90</td>
<td>$148,960.00</td>
</tr>
<tr>
<td></td>
<td>5 Embankment (from onsite borrow)</td>
<td>CY</td>
<td>499,100</td>
<td>$4.60</td>
<td>$2,295,860.00</td>
</tr>
<tr>
<td></td>
<td>6 Embankment Riprap</td>
<td>CY</td>
<td>39,400</td>
<td>$43.00</td>
<td>$1,694,200.00</td>
</tr>
<tr>
<td></td>
<td>7 Spillways</td>
<td>LS</td>
<td>1</td>
<td>$1,300,000.00</td>
<td>$1,300,000.00</td>
</tr>
<tr>
<td></td>
<td>8 Outlet Works</td>
<td>LS</td>
<td>1</td>
<td>$360,500.00</td>
<td>$360,500.00</td>
</tr>
<tr>
<td></td>
<td>9 New Canal Construction</td>
<td>LS</td>
<td>1</td>
<td>$2,900,000.00</td>
<td>$2,900,000.00</td>
</tr>
<tr>
<td></td>
<td>10 Wetland Mitigation</td>
<td>LS</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>1 Miscellaneous</td>
<td>LS</td>
<td>1</td>
<td>$1,095,000.00</td>
<td>$1,095,000.00</td>
</tr>
</tbody>
</table>

**Construction Components Cost (Subtotal #2)** $10,922,871.60

**Construction Engineering Costs (10% of Subtotal #2)** $1,092,287.16

**Subtotal Construction Cost (Subtotal #3)** $12,015,158.76

15% Contingency (Subtotal #3 x 15%) $1,802,273.81

**Total Construction Cost (Subtotal #4)** $13,817,432.57

**Total Project Costs (Subtotal #1 + Subtotal #2)** $15,605,863.31
<table>
<thead>
<tr>
<th>Alternative</th>
<th>Dam Tender ($1)</th>
<th>Maintenance and Repairs ($2)</th>
<th>Total Estimated Annual O&amp;M Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meadowlark Lake Expansion</td>
<td>$15,810</td>
<td>$7,100</td>
<td>$22,900</td>
</tr>
<tr>
<td>Alkali Creek</td>
<td></td>
<td>$7,900</td>
<td>$23,700</td>
</tr>
<tr>
<td>Lower Luman Creek</td>
<td></td>
<td>$18,300</td>
<td>$34,100</td>
</tr>
<tr>
<td>Taylor Draw</td>
<td></td>
<td>$22,800</td>
<td>$38,600</td>
</tr>
</tbody>
</table>

1 - Costs assume 20 hrs per week @ $18.00/hr and 250 miles per week @ $0.60/mile during the irrigation season (31 weeks)
2 - Cost based on 0.5% of capital reservoir controls and conveyance costs
TABLE 14-1. COST-BENEFIT ANALYSIS
NOWOOD RIVER STORAGE, LEVEL II STUDY

<table>
<thead>
<tr>
<th>Crop</th>
<th>Irrigation Efficiency</th>
<th>Yield Increase¹ (tons/ac-ft)</th>
<th>Gross Returns²</th>
<th>Production Costs³</th>
<th>Net Returns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>29%</td>
<td>0.49</td>
<td>$ 65.77</td>
<td>$ 26.80</td>
<td>$ 38.98</td>
</tr>
</tbody>
</table>

1. Yield increase for one acre-ft of water with an irrigation efficiency of 29%. Based on a CIR of 2.08 acre-feet/acre and an average irrigated alfalfa yield of 3.5 tons/acre.
2. Based on a selling price of $135.00/ton.
3. Based on a production cost of $55.00/ton.
### TABLE 14-2. SITE SPECIFIC COST-BENEFIT ANALYSIS
**NOWOOD RIVER STORAGE, LEVEL II STUDY**

<table>
<thead>
<tr>
<th>Range</th>
<th>Storage Alternative</th>
<th>Additional Water (acre-ft)</th>
<th>Irrigated Acres Served Downstream(^{1,2})</th>
<th>Additional Water per Acre Served (acre-ft/acre)</th>
<th>Irrigated Acres Served at Full CIR of 2.08 ac-ft/acre</th>
<th>Total Increase in Alfalfa Hay Production (Tons)</th>
<th>Gross Returns ($/year)(^{3})</th>
<th>Production Costs ($/year)(^{4})</th>
<th>Direct Irrigation Benefits Net Returns ($/year)(^{5})</th>
<th>Direct and Indirect Irrigation Benefits Net Returns ($/year)(^{6})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper</td>
<td>Alkali Creek</td>
<td>5,550</td>
<td>4,879</td>
<td>1.14</td>
<td>2,668</td>
<td>2,704</td>
<td>$365,035</td>
<td>$148,718</td>
<td>$216,317</td>
<td>$568,913</td>
</tr>
<tr>
<td></td>
<td>Meadowlark Lake</td>
<td>3,510</td>
<td>6,871</td>
<td>0.51</td>
<td>1,688</td>
<td>1,710</td>
<td>$230,860</td>
<td>$94,054</td>
<td>$136,806</td>
<td>$359,799</td>
</tr>
<tr>
<td></td>
<td>Alkali Creek</td>
<td>2,500</td>
<td>4,879</td>
<td>0.51</td>
<td>1,202</td>
<td>1,218</td>
<td>$164,430</td>
<td>$66,990</td>
<td>$97,440</td>
<td>$256,267</td>
</tr>
<tr>
<td></td>
<td>Meadowlark Lake</td>
<td>3,000</td>
<td>6,871</td>
<td>0.44</td>
<td>1,442</td>
<td>1,462</td>
<td>$197,316</td>
<td>$80,388</td>
<td>$116,928</td>
<td>$307,521</td>
</tr>
</tbody>
</table>

1. Irrigated acres served downstream is the sum of all existing irrigated lands located in the Watershed which could benefit from the storage alternative through direct release.
2. For this cost-benefit analysis it was assumed that all irrigated acreage downstream of the storage alternatives consisted of irrigated alfalfa.
3. Based on a selling price of $135.00/ton.
4. Based on a production cost of $55.00/ton.
5. Conceptually the net returns per year could be reduced if a large portion of the increased production would be used for grazing. However, for this study it was assumed that all irrigated land would be harvested as alfalfa hay.
6. Assuming an indirect irrigation benefit of $2.63.
### TABLE 14-3. FINANCING UNDER WWDC GUIDELINES
**NOWOOD RIVER STORAGE, LEVEL II STUDY**

<table>
<thead>
<tr>
<th></th>
<th>Alkali Creek $^{1}$</th>
<th>Meadowlark Lake</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>50-Year Loan</strong></td>
<td><strong>30-Year Loan</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Sponsor Cost</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33% Cost Share</td>
<td>$5,194,700.00</td>
<td>$922,900.00</td>
</tr>
<tr>
<td>25% Cost Share</td>
<td>$3,935,400.00</td>
<td>$699,200.00</td>
</tr>
<tr>
<td><strong>Annualize Debts Share of Project Costs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33% Cost Share/year</td>
<td>$241,800.00</td>
<td>$43,000.00</td>
</tr>
<tr>
<td>25% Cost Share/year</td>
<td>$183,200.00</td>
<td>$32,500.00</td>
</tr>
<tr>
<td><strong>Total Estimated O&amp;M Cost</strong></td>
<td>$23,700.00</td>
<td>$22,900.00</td>
</tr>
<tr>
<td><strong>Annualized Project Cost Plus O&amp;M</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33% Cost Share</td>
<td>$265,500.00</td>
<td>$65,900.00</td>
</tr>
<tr>
<td>25% Cost Share</td>
<td>$206,900.00</td>
<td>$55,400.00</td>
</tr>
</tbody>
</table>

---

1. Costs have been rounded to the nearest $100.
<table>
<thead>
<tr>
<th>Storage Alternative</th>
<th>Total Storage Capacity (acre-feet)</th>
<th>Estimated Storage Available for Irrigation (acre-feet)</th>
<th>Willingness-to-Pay ($/acre-foot)</th>
<th>Generated Revenue ($/year)</th>
<th>Loan Period</th>
<th>Present Worth ($)</th>
<th>% Sponsor Loan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkali Creek</td>
<td>7,400</td>
<td>5,550</td>
<td>$ 15.00</td>
<td>$ 83,300.00</td>
<td>30-Year</td>
<td>$1,440,423.60</td>
<td>9%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>50-Year</td>
<td>$1,789,467.26</td>
<td>11%</td>
</tr>
<tr>
<td>Meadowlark Lake</td>
<td>4,680</td>
<td>1,360</td>
<td>$ 15.00</td>
<td>$ 20,400.00</td>
<td>30-Year</td>
<td>$352,756.80</td>
<td>13%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>50-Year</td>
<td>$438,236.88</td>
<td>16%</td>
</tr>
</tbody>
</table>

Note:
1. All costs have been rounded to the nearest $100.
<table>
<thead>
<tr>
<th>Agency/Entity</th>
<th>Program Name</th>
<th>Project Type(s)</th>
<th>Internet Site</th>
<th>Telephone</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Local</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Washakie County Conservation District</td>
<td>n/a</td>
<td>Liaison, in-kind administrative and technical assistance, program coordination/partnering</td>
<td><a href="http://www.conservewy.com/wccd.html">http://www.conservewy.com/wccd.html</a></td>
<td>307.347.2456</td>
<td><a href="mailto:wccd@rtconnect.net">wccd@rtconnect.net</a></td>
</tr>
<tr>
<td>Washakie County Weed and Pest District</td>
<td>n/a</td>
<td>Noxious weed and undesirable plant control</td>
<td><a href="http://www.conservewy.com/wccd.html">http://www.conservewy.com/wccd.html</a></td>
<td>307.347.8852</td>
<td><a href="mailto:wcwp@rtconnect.net">wcwp@rtconnect.net</a></td>
</tr>
<tr>
<td>Worland Grazing District</td>
<td>Range Improvement Fund</td>
<td>Range and related improvements</td>
<td>n/a</td>
<td>n/a</td>
<td><a href="mailto:wsgb@wyoming.com">wsgb@wyoming.com</a></td>
</tr>
<tr>
<td>Big Horn County Weed and Pest District</td>
<td>n/a</td>
<td>Noxious weed and undesirable plant control</td>
<td><a href="http://www.wyoweed.org">www.wyoweed.org</a></td>
<td>307.765.2855</td>
<td><a href="mailto:sbhwcw@tctwest.net">sbhwcw@tctwest.net</a></td>
</tr>
<tr>
<td>South Big Horn County Conservation District</td>
<td>n/a</td>
<td>Liaison, in-kind administrative and technical assistance, program coordination/partnering</td>
<td><a href="http://www.conservewy.com/sbhcd">www.conservewy.com/sbhcd</a></td>
<td>307.765.2483</td>
<td><a href="mailto:janet.hallsted@wy.nacdnet.net">janet.hallsted@wy.nacdnet.net</a></td>
</tr>
<tr>
<td><strong>State</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wyoming Game and Fish Department</td>
<td>Riparian Habitat Improvement Grant</td>
<td>Stock water development; streambank stabilization; etc.</td>
<td><a href="http://gf.state.wy.us">http://gf.state.wy.us</a></td>
<td>307.777.4600</td>
<td>See WYGF Website for contact directories</td>
</tr>
<tr>
<td></td>
<td>Water Development/Maintenance Habitat Project Grant</td>
<td>Water developments (springs, windmills, guzzlers, pumps, etc.)</td>
<td><a href="http://gf.state.wy.us">http://gf.state.wy.us</a></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Upland Development Grant</td>
<td>Range management; prescribed burns</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fish Wyoming</td>
<td>Public fishing opportunities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wyoming Office of State Lands and Investments</td>
<td>Regular Farm Loans</td>
<td>Projects involving most agricultural purposes</td>
<td><a href="http://sfl-web.state.wy.us/admin/slfb.aspx">http://sfl-web.state.wy.us/admin/slfb.aspx</a></td>
<td>307.777.6373</td>
<td><a href="mailto:elizabeth.blackwell@wyo.gov">elizabeth.blackwell@wyo.gov</a></td>
</tr>
<tr>
<td></td>
<td>Small Water Development Project Loans</td>
<td>Conversion of dry land to irrigated land and/or water use efficiency improvements</td>
<td><a href="http://sfl-web.state.wy">http://sfl-web.state.wy</a></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wyoming Water Development Commission</td>
<td>Wyoming Water Development Program</td>
<td>Planning, design and construction of new reservoir storage and rehabilitation of existing reservoir storage projects</td>
<td><a href="http://wwdc.state.wy.us/opcrit/final_opcrit.pdf">http://wwdc.state.wy.us/opcrit/final_opcrit.pdf</a></td>
<td>307.777.7626</td>
<td><a href="mailto:mike.besson@wyo.gov">mike.besson@wyo.gov</a></td>
</tr>
<tr>
<td></td>
<td>Small Water Project Program</td>
<td>Small reservoirs and stock</td>
<td></td>
<td></td>
<td><a href="mailto:ron.vore@wyo.gov">ron.vore@wyo.gov</a></td>
</tr>
<tr>
<td>Wyoming Wildlife and Natural Resource Trust</td>
<td>n/a</td>
<td>Aquatic and wildlife habitat improvement, including water developments, prescribed burns, invasive plant control, etc.</td>
<td><a href="http://wwrtr.state.wy.us">http://wwrtr.state.wy.us</a></td>
<td>307.856.4665</td>
<td>n/a</td>
</tr>
<tr>
<td><strong>Federal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental Protection Agency</td>
<td>Targeted Watershed Grants Program</td>
<td>Riparian, wetland, aquatic and upland habitat protection and improvement</td>
<td><a href="http://www.epa.gov/owow/funding/watershedfunding.html">http://www.epa.gov/owow/funding/watershedfunding.html</a></td>
<td>202.566.1730</td>
<td><a href="mailto:center.water-resource@epa.gov">center.water-resource@epa.gov</a></td>
</tr>
<tr>
<td>Agency/Entity</td>
<td>Program Name</td>
<td>Project Type(s)</td>
<td>Internet Site</td>
<td>Telephone</td>
<td>Email</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>---------------------------------------------------</td>
<td>---------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------</td>
<td>-------------------</td>
<td>--------------------------------</td>
</tr>
<tr>
<td></td>
<td>Continuous Sign-Up for High Priority Conservation| Riparian buffers, filter strips, grass waterways, salt tolerant vegetation,| <a href="http://ecos.fws.gov/partners/viewContent.do?viewPage=home">http://ecos.fws.gov/partners/viewContent.do?viewPage=home</a></td>
<td>307.332.8719</td>
<td><a href="mailto:mark_j_hogan@mail.fws.gov">mark_j_hogan@mail.fws.gov</a></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Practices</td>
<td>shallow water areas for wildlife, etc.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Emergency Conservation Program (ECO)</td>
<td>Emergency livestock watering conservation during severe drought</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>North American Wetlands Conservation Act Program</td>
<td>Various wetlands conservation projects</td>
<td></td>
<td>307.347.2456</td>
<td><a href="mailto:rory.karhu@wy.usa.gov">rory.karhu@wy.usa.gov</a> (Worland)</td>
</tr>
<tr>
<td></td>
<td>Landowner Incentive Program (Non-Tribal)</td>
<td>Funding to WGFD to support above project types</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural Resources Conservation Service</td>
<td>Environmental Quality Incentives Program</td>
<td>Conservation planning, range management, irrigation rehabilitation, livestock| <a href="http://www.nrcs.usda.gov/PROGRAMS/EQIP">http://www.nrcs.usda.gov/PROGRAMS/EQIP</a></td>
<td>307.261-5081</td>
<td><a href="mailto:mark_j_hogan@mail.fws.gov">mark_j_hogan@mail.fws.gov</a></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Watershed Protection and Flood Prevention Program</td>
<td>Water supply, water quality control, erosion and sediment control, wetland| <a href="http://www.nrcs.usda.gov/programs/watershed/index.html">http://www.nrcs.usda.gov/programs/watershed/index.html</a></td>
<td>307.332.8719</td>
<td><a href="mailto:mark_j_hogan@mail.fws.gov">mark_j_hogan@mail.fws.gov</a></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wildlife Habitat Incentives Program (WHIP)</td>
<td>fish and wildlife habitat enhancement, flood control, public recreation, etc.</td>
<td><a href="http://www.nrcs.usda.gov/programs/wihip">http://www.nrcs.usda.gov/programs/wihip</a></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wetlands Reserve Program (WRP)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grassland Reserve Program (GRP)</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Conservation Security Program (CSP)</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Farm and Ranchlands Protection Program (FRPP)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Emergency Watershed Protection (ERP)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sage Grouse Restoration Project (SGRP)</td>
<td></td>
<td><a href="http://sgrp.usu.edu/">http://sgrp.usu.edu/</a></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bring Back the Natives Grant Program</td>
<td>Riverine habitat and aquatic species restoration projects</td>
<td><a href="http://www.nfwf.org/AM/Template.cfm?Section=Grants">http://www.nfwf.org/AM/Template.cfm?Section=Grants</a></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Five-Star Restoration Program</td>
<td>Wetland and riparian habitat restoration</td>
<td><a href="http://www.nfwf.org/AM/Template.cfm?Section=Grants">http://www.nfwf.org/AM/Template.cfm?Section=Grants</a></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# TABLE 14-5. POTENTIAL FUNDING SOURCES
NOWOOD RIVER STORAGE, LEVEL II STUDY

<table>
<thead>
<tr>
<th>Agency/Entity</th>
<th>Program Name</th>
<th>Project Type(s)</th>
<th>Internet Site</th>
<th>Telephone</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ducks Unlimited</td>
<td>n/a</td>
<td>Waterfowl aquatic and upland habitat protection, restoration and enhancement</td>
<td><a href="http://www.ducks.org/Page1856.aspx">http://www.ducks.org/Page1856.aspx</a></td>
<td>307.472.6980</td>
<td><a href="mailto:carol.m.perry@wellsfargo.com">carol.m.perry@wellsfargo.com</a></td>
</tr>
<tr>
<td>Trout Unlimited</td>
<td>Watershed Restoration</td>
<td>Erosion control, fish habitat structures, willow and other riparian plantings, etc.</td>
<td><a href="http://www.tu.org/conservation/watershed-restoration-home-rivers-initiative">http://www.tu.org/conservation/watershed-restoration-home-rivers-initiative</a></td>
<td>307.332.7700</td>
<td><a href="mailto:syates@tu.org">syates@tu.org</a></td>
</tr>
<tr>
<td>Mule Deer Foundation</td>
<td></td>
<td>Habitat enhancement on both public and private lands</td>
<td><a href="http://www.muledeer.org/">http://www.muledeer.org/</a></td>
<td>801.973.3940</td>
<td></td>
</tr>
<tr>
<td>National Fish and Wildlife Foundation</td>
<td>Keystone Initiative Grants and Special Grant Program</td>
<td>Sustain, restore, and enhance fish, wildlife, plants, and habitat.</td>
<td><a href="http://www.nfwf.org/">www.nfwf.org/</a></td>
<td>503.417.8700</td>
<td><a href="mailto:info@nfwf.org">info@nfwf.org</a></td>
</tr>
<tr>
<td>Rocky Mountain Elk Foundation (RMEF)</td>
<td>n/a</td>
<td>Habitat restoration and improvement projects, and acquires land or conservation easements for the purpose of reservation.</td>
<td><a href="http://www.rmef.org/">http://www.rmef.org/</a></td>
<td>307.867.2613 (Jill Tonn - WY Staff)</td>
<td><a href="mailto:jtonn@rmef.org">jtonn@rmef.org</a></td>
</tr>
<tr>
<td>The Nature Conservancy</td>
<td>n/a</td>
<td>Preserve habitat and protect the lands and waters wildlife need to survive.</td>
<td><a href="http://www.nature.org/">http://www.nature.org/</a></td>
<td>800.628.6860</td>
<td><a href="mailto:member@tnc.org">member@tnc.org</a></td>
</tr>
<tr>
<td>Wildlife Heritage Foundation of Wyoming</td>
<td>n/a</td>
<td>Wildlife conservation efforts through philanthropy</td>
<td><a href="http://www.whyfw.org/">http://www.whyfw.org/</a></td>
<td>307.777.4529</td>
<td><a href="mailto:WildlifeHeritage@Wyoming.com">WildlifeHeritage@Wyoming.com</a></td>
</tr>
</tbody>
</table>

**Note:**

1. Bolded agencies or organizations were not identified in the Level I Study, but may provide opportunity for additional funding.
FIGURE 2-1
LEVEL I STUDY AVERAGE YEAR WATER AVAILABILITY ANALYSIS
NOWOOD RIVER STORAGE LEVEL II STUDY
WYOMING WATER DEVELOPMENT COMMISSION
TEN SLEEP, WYOMING

Checkered By: BR
File: Nowood_LevelI_Reach.mxd
Date: 11/19/13

EXPLANATION
- CITIES
- PRIMARY US OR STATE HIGHWAY
- SECONDARY STATE OR COUNTY HIGHWAY
- LOCAL OR RURAL ROAD
- COUNTY BOUNDARY
- NOWOOD WATERSHED

WATER AVAILABILITY ANALYSIS: AVERAGE YEAR

< 2,000 af
2,000 af to 5,000 af
5,000 af to 7,500 af
7,500 af to 10,000 af
10,000 af to 50,000 af
50,000 af to 100,000 af
100,000 af to 200,000 af
> 200,000 af
FIGURE 6-1

STATEMOD MODEL NETWORK

STATEMOD MODEL NETWORK

NOWOOD RIVER STORAGE LEVEL II STUDY

WYOMING WATER DEVELOPMENT COMMISSION

TEN SLEEP, WYOMING
**EXPLANATION**
- POINT OF DIVERSION
- CITIES
- IRRIGATION DITCHES
- PRIMARY US OR STATE HIGHWAY
- SECONDARY STATE OR COUNTY HIGHWAY
- LOCAL OR RURAL ROAD
- RIVERS & STREAMS
- IRRIGATED LAND
- COUNTY BOUNDARY
- NOWOOD WATERSHED

**FIGURE 6-3**
POINTS OF DIVERSION AND IRRIGATED LANDS
NOWOOD RIVER STORAGE LEVEL II STUDY
WYOMING WATER DEVELOPMENT COMMISSION
TEN SLEEP, WYOMING

- Carothers Lake
- Meadowlark Lake
### Simulated Available Flows (acre-feet)

<table>
<thead>
<tr>
<th>Site</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkali Creek</td>
<td>18,015</td>
<td>34,463</td>
<td>8,579</td>
<td>659</td>
<td>1,643</td>
</tr>
<tr>
<td>Alkali Creek South</td>
<td>467</td>
<td>236</td>
<td>162</td>
<td>71</td>
<td>188</td>
</tr>
<tr>
<td>Big Trails</td>
<td>9,660</td>
<td>3,013</td>
<td>704</td>
<td>200</td>
<td>1,077</td>
</tr>
<tr>
<td>Canyon Creek</td>
<td>4,086</td>
<td>1,231</td>
<td>463</td>
<td>72</td>
<td>222</td>
</tr>
<tr>
<td>Cornell Gulch</td>
<td>1,604</td>
<td>702</td>
<td>118</td>
<td>20</td>
<td>149</td>
</tr>
<tr>
<td>Cottonwood Creek</td>
<td>43,483</td>
<td>34,164</td>
<td>9,493</td>
<td>1,539</td>
<td>5,389</td>
</tr>
<tr>
<td>Deep Creek</td>
<td>2,190</td>
<td>979</td>
<td>174</td>
<td>37</td>
<td>240</td>
</tr>
<tr>
<td>Little Cottonwood Creek</td>
<td>39,349</td>
<td>33,576</td>
<td>9,493</td>
<td>1,539</td>
<td>5,387</td>
</tr>
<tr>
<td>Lone Tree</td>
<td>1,504</td>
<td>622</td>
<td>98</td>
<td>22</td>
<td>124</td>
</tr>
<tr>
<td>Lower Brokenback</td>
<td>1,859</td>
<td>365</td>
<td>107</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Lower Luman Creek</td>
<td>3,793</td>
<td>6,563</td>
<td>2,929</td>
<td>385</td>
<td>767</td>
</tr>
<tr>
<td>Meadowlark Lake</td>
<td>3,200</td>
<td>5,908</td>
<td>2,074</td>
<td>78</td>
<td>4</td>
</tr>
<tr>
<td>Medicine Lodge</td>
<td>340</td>
<td>658</td>
<td>314</td>
<td>48</td>
<td>33</td>
</tr>
<tr>
<td>North Brokenback</td>
<td>646</td>
<td>157</td>
<td>96</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Nowood - Crawford</td>
<td>1,293</td>
<td>584</td>
<td>98</td>
<td>22</td>
<td>124</td>
</tr>
<tr>
<td>Otter Creek</td>
<td>3,278</td>
<td>1,078</td>
<td>90</td>
<td>7</td>
<td>127</td>
</tr>
<tr>
<td>Paint Rock Creek</td>
<td>15,105</td>
<td>29,464</td>
<td>7,817</td>
<td>655</td>
<td>1,576</td>
</tr>
<tr>
<td>Taylor Draw</td>
<td>3,278</td>
<td>1,078</td>
<td>90</td>
<td>7</td>
<td>127</td>
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<tr>
<td>Upper Brokenback</td>
<td>3,762</td>
<td>6,557</td>
<td>2,929</td>
<td>385</td>
<td>762</td>
</tr>
<tr>
<td>Weintz Draw</td>
<td>17,646</td>
<td>34,401</td>
<td>8,565</td>
<td>655</td>
<td>1,618</td>
</tr>
<tr>
<td>West Tensleep Lake</td>
<td>1,574</td>
<td>2,858</td>
<td>1,130</td>
<td>74</td>
<td>4</td>
</tr>
<tr>
<td>Woods Gulch</td>
<td>113</td>
<td>64</td>
<td>20</td>
<td>7</td>
<td>17</td>
</tr>
</tbody>
</table>

Note: Only sites evaluated in StateMOD are included. At sites with direct and indirect flows, the available flows were combined to represent the total available flow available to the reservoir.

### EXPLANATION

- **CITIES**
- **POTENTIAL STORAGE LOCATION**
- **PRIMARY US OR STATE HIGHWAY**
- **SECONDARY STATE OR COUNTY HIGHWAY**
- **LOCAL OR RURAL ROAD**
- **RIVERS & STREAMS**
- **COUNTY BOUNDARY**
- **NOWOOD WATERSHED**
- **SIMULATED AVAILABLE FLOW - AVERAGE YEAR**

### FIGURE 6-4

**Simulated Available Flows during an Average Year**

**October 29, 2012 StateMOD Results**

**Nowood River Storage Level II Study**

**Wyoming Water Development Commission**

**Ten Sleep, Wyoming**

**Drawn By: DRT**

**Checked By: BR**

**Scale: 1” = 6 MI**

**Date: 11/19/13**

**File:** Nowood_StateMOD_AvailableFlows.mxd

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**Drawn By:** DRT

**Checked By:** BR

**Scale:** 1” = 6 MI

**Date:** 11/19/13

**File:** Nowood_StateMOD_AvailableFlows.mxd

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FIGURE 6-5
SIMULATED SHORTAGES DURING AN AVERAGE YEAR
OCTOBER 29, 2012 STATEMOD RESULTS
NOWOOD RIVER STORAGE LEVEL II STUDY
WYOMING WATER DEVELOPMENT COMMISSION
TEN SLEEP, WYOMING

Simulated Shortages (acre-feet)

<table>
<thead>
<tr>
<th>Location</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above Nowood Draw-Ford</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Lone Tree Creek</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Between Lone Tree Reservoir and Big Trails Reservoir</td>
<td>0</td>
<td>2</td>
<td>50</td>
<td>43</td>
<td>2</td>
</tr>
<tr>
<td>Bear Creek</td>
<td>0</td>
<td>7</td>
<td>48</td>
<td>71</td>
<td>34</td>
</tr>
<tr>
<td>Deep Creek</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Redbank Creek</td>
<td>3</td>
<td>16</td>
<td>51</td>
<td>72</td>
<td>63</td>
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<tr>
<td>Little Canyon Creek</td>
<td>4</td>
<td>332</td>
<td>773</td>
<td>764</td>
<td>471</td>
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<tr>
<td>Crooked Creek</td>
<td>31</td>
<td>395</td>
<td>241</td>
<td>219</td>
<td>128</td>
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<tr>
<td>Otter Creek</td>
<td>0</td>
<td>14</td>
<td>110</td>
<td>145</td>
<td>21</td>
</tr>
<tr>
<td>Spring Creek</td>
<td>62</td>
<td>478</td>
<td>798</td>
<td>744</td>
<td>476</td>
</tr>
<tr>
<td>Between Big Trails Reservoir and Tensleep Creek</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Tensleep Creek</td>
<td>0</td>
<td>0</td>
<td>191</td>
<td>167</td>
<td>50</td>
</tr>
<tr>
<td>Brokenback Creek</td>
<td>141</td>
<td>377</td>
<td>213</td>
<td>399</td>
<td>270</td>
</tr>
<tr>
<td>Buffalo Flat Creek</td>
<td>55</td>
<td>136</td>
<td>92</td>
<td>191</td>
<td>121</td>
</tr>
<tr>
<td>Below Tensleep Creek and Paint Rock Creek</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>29</td>
<td>0</td>
</tr>
<tr>
<td>Paint Rock Creek above Medicine Lodge Creek</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>141</td>
<td>0</td>
</tr>
<tr>
<td>Medicine Lodge Creek</td>
<td>0</td>
<td>158</td>
<td>1,024</td>
<td>1,469</td>
<td>788</td>
</tr>
<tr>
<td>Paint Rock Creek below Medicine Lodge Creek</td>
<td>244</td>
<td>447</td>
<td>480</td>
<td>595</td>
<td>240</td>
</tr>
<tr>
<td>Below Paint Rock Creek</td>
<td>0</td>
<td>34</td>
<td>0</td>
<td>484</td>
<td>0</td>
</tr>
</tbody>
</table>

EXPLANATION
- CITIES
- POTENTIAL STORAGE LOCATION
- PRIMARY US OR STATE HIGHWAY
- SECONDARY STATE OR COUNTY HIGHWAY
- LOCAL OR RURAL ROAD
- RIVERS & STREAMS
- COUNTY BOUNDARY
- NOWOOD WATERSHED
- SIMULATED SHORTAGES - AVERAGE YEAR

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Drawn By: DRT  Checked By: BR  Scale: 1" = 6 MI  Date: 11/19/13  File: Nowood_StateMOD_Shortages.mxd
FIGURE 6-6. ALKALI CREEK TEMPORARY STREAM GAGE DATA
NOWOOD RIVER STORAGE, LEVEL II STUDY

2010 Study Period (327 ac-ft Yield)  2011 Study Period (1,327 ac-ft Yield)
FIGURE 6-7. ANITA DITCH TEMPORARY STREAM GAGE DATA
NOWOOD RIVER STORAGE, LEVEL II STUDY

Flow (cfs)

Month

Apr May Jun Jul Aug Sep Oct Nov

2011 Study Period (7,710 ac-ft Yield)
FIGURE 6-9. BRUNER GULCH TEMPORARY STREAM GAGE DATA
NOWOOD RIVER STORAGE, LEVEL II STUDY

- **2009 Study Period (1,599 ac-ft Yield)**
- **2010 Study Period (921 ac-ft Yield)**

Flow (cfs) vs. Month

- 5/26/10
  - 134 cfs
FIGURE 6-10. BROKENBACK CREEK TEMPORARY STREAM GAGE DATA
NOWOOD RIVER STORAGE, LEVEL II STUDY

2009 Study Period (1,488 ac-ft Yield)
2010 Study Period (645 ac-ft Yield)
FIGURE 6-11. LOWER DEEP CREEK TEMPORARY STREAM GAGE DATA
NOWOOD RIVER STORAGE, LEVEL II STUDY

<table>
<thead>
<tr>
<th>Month</th>
<th>2010 Study Period (11,052 ac-ft Yield)</th>
<th>2011 Study Period (30,546 ac-ft Yield)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/21/11</td>
<td>641.1 cfs</td>
<td></td>
</tr>
</tbody>
</table>

Flow (cfs) vs. Month
FIGURE 6-12. UPPER DEEP CREEK TEMPORARY STREAM GAGE DATA
NOWOOD RIVER STORAGE, LEVEL II STUDY

2010 Study Period (5,715 ac-ft Yield)
2011 Study Period (3,160 ac-ft Yield)

5/21/11
228.9 cfs
FIGURE 6-13. NOWOOD CRAWFORD TEMPORARY STREAM GAGE DATA
NOWOOD RIVER STORAGE, LEVEL II STUDY

Flow (cfs)

Month

2010 Study Period (1,145 ac-ft Yield)
2011 Study Period (1,609 ac-ft Yield)

5/21/11
82.2 cfs
FIGURE 6-14. OTTER CREEK TEMPORARY STREAM GAGE DATA
NOWOOD RIVER STORAGE, LEVEL II STUDY

2009 Study Period (10,686 ac-ft Yield)  
2010 Study Period (7,637 ac-ft Yield)  
2011 Study Period (34,328 ac-ft Yield)

Flow (cfs)

Month

Apr  May  Jun  Jul  Aug  Sep  Oct  Nov

5/21/11  
386.1 cfs
FIGURE 6-15. SPRING CREEK TEMPORARY STREAM GAGE
NOWOOD RIVER STORAGE, LEVEL II STUDY

2010 Study Period (1,683 ac-ft Yield)  2011 Study Period (2,766 ac-ft Yield)
FIGURE 7-1. SIMULATED MONTHLY WATER SHORTAGES
NOWOOD RIVER STORAGE, LEVEL II STUDY

Acre-Feet

Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep

Average Year Shortage
Dry Year Shortage
EXPLANATION

- CITIES
- PRIMARY US OR STATE HIGHWAY
- SECONDARY STATE OR COUNTY HIGHWAY
- LOCAL OR RURAL ROAD
- RIVERS & STREAMS
- COUNTY BOUNDARY

WYGISC SURFICIAL GEOLOGY (100K SCALE)
- RI - BEDROCK
- AI - ALLUVIUM
- BDI - DISSECTED BENCH
- FDI - DISSECTED ALLUVIAL FAN
- FI - ALLUVIAL FAN
- GI - GLACIAL DEPOSITS
- LI - LANDSLIDE MIXED
- MI - MESA
- OAI - GLACIAL OUTWASH
- RI - RESIDUUM
- SCI - SLOPEWASH AND COLLUVIUM
- TDI - DISSECTED TERRACE
- TI - TERRACE DEPOSITS
- UI - GRUS MIXED

NOWOOD WATERSHED

FIGURE 8-1
SURFICIAL GEOLOGY
OF THE NOWOOD WATERSHED
NOWOOD RIVER STORAGE LEVEL II STUDY
WYOMING WATER DEVELOPMENT COMMISSION
TEN SLEEP, WYOMING

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**EXPLANATION**

- **CITIES**
- **PRIMARY US OR STATE HIGHWAY**
- **SECONDARY STATE OR COUNTY HIGHWAY**
- **LOCAL OR RURAL ROAD**
- **RIVERS & STREAMS**
- **COUNTY BOUNDARY**

**NOWOOD WATERSHED**

**WYGISC BEDROCK GEOLOGY (500K SCALE)**

- CA - Gallatin Limestone, Gros Ventre Formation and equivalents, and Flathead Sandstone
- H2O - Water
- JTRgc - Gypsum Spring formation, Nugget Sandstone and Chugwater formation
- Js - Sundance formation
- Jsg - Sundance and Gypsum Spring formations
- KJ - Cloverly and Morrison formations
- KJg - Cloverly, Morrison, Sundance and Gypsum Spring formations
- KJs - Cloverly, Morrison, and Sundance formations
- Kc - Cody Shale
- Kf - Frontier formation
- Kl - Lance formation
- Klm - Lance formation, Fox Hills Sandstone, Meeteetse formation, and Bearpaw and Lewis Shales
- Km - Meeteetse formation
- Kmt - Mowry and Thermopolis Shales
- Kmv - Mesaverde Group
- MD - Madison Limestone and Darby formation
- MO - Madison Limestone and Bighorn Dolomite
- MM - Madison Limestone or group
- OCA - Bighorn Dolomite, Gallatin Limestone, Gros Ventre formation, and Flathead Sandstone
- PA - Talbot Sandstone and Ammonite formation
- Pfa - Phosphate formation or related rocks
- QTg - Terrace gravel (Pleistocene and/or Pliocene)
- Qa - Alluvium and colluvium
- Qg - Glacial deposits
- Qls - Landslide deposits
- Qt - Gravel, pediment, and fan deposits
- Qu - Undivided surficial deposits
- TRPcg - Chugwater and Goose Egg formations
- TRPg - Goose Egg formation
- TRc - Chugwater formation or group
- TRcd - Chugwater and Dinwoody formations
- Tfu - Fort Union formation
- Tml - Lower Miocene rocks, Bighorn Mountains
- Tw - Wagon Bed formation
- Twl - Intrusive igneous rocks: Thorofare Creek Group: Wiggins formation
- Twr - White River formation
- Ugn - Oldest Gneiss Complex
- WVg - Plutonic Rocks
- Wmu - Metamorphosed Mafic and Ultramafic Rocks

**FIGURE 8-2**

**BEDROCK GEOLOGY OF THE NOWOOD WATERSHED**

**NOWOOD RIVER STORAGE LEVEL II STUDY**

**WYOMING WATER DEVELOPMENT COMMISSION**

**TEN SLEEP, WYOMING**

**Checked By: BR File: Nowood_GeoBed.mxd**

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**Drawn By: DRT Scale: 1" = 6 MI Date: 11/19/13**
NOTE: PHOTOGRAPHS TAKEN ON JULY 28, 2009.
NOTE: PHOTOGRAPHS TAKEN ON SEPTEMBER 29, 2010

EXPLANATION

1 LOCATION WHERE PHOTOGRAPH WAS SHOT

FIGURE 8-7

ALKALI CREEK SITE PHOTOGRAPHS

NOWOOD RIVER STORAGE LEVEL II STUDY
WYOMING WATER DEVELOPMENT COMMISSION
TEN SLEEP, WYOMING

Drawn By: PC Checked By: DT Scale: NONE Date: 11/18/13 Rec: 09/ALKALI CREEK 20133
NOTE: PHOTOGRAPHS TAKEN ON SEPTEMBER 26, 2010

EXPLANATION

1 LOCATION WHERE PHOTOGRAPH WAS SHOT

FIGURE 8.9
LOWER LUMAN CREEK SITE PHOTOGRAPHS

NOWOOD RIVER STORAGE LEVEL II STUDY
WYOMING WATER DEVELOPMENT COMMISSION
TEN SLEEP, WYOMING

Drawn By: PC  Checked By: DT  Scale: NONE  Date: 11/29/13  File: GB\_LUMANCREEK201305
FIGURE 8-10
TAYLOR DRAW GEOLOGICAL EVALUATION
NOWOOD RIVER STORAGE LEVEL II STUDY
WYOMING WATER DEVELOPMENT COMMISSION
TEN SLEEP, WYOMING

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EXPLANATION
- PHOTO LOCATIONS
- POTENTIAL STORAGE SITE
- POTENTIAL DIVERSION SUPPLY DITCH/PIPE
- RIVERS & STREAMS
- WATER IMPOUNDMENT

WYOMIC BEDROCK GEOLOGY (500K SCALE)
- Jag: Sundance and Gypsum Spring formations
- Kc: Cody shale
- Kf: Frontier formation
- Kmt: Mowry and Thermopolis shales
- PM: Tensleep sandstone and Amsden formation
- QA: Alluvium and colluvium
- TRPcg: Chugwater and Goose Egg formations
NOTE:
PHOTOGRAPHS TAKEN ON JULY 28, 2005.

EXPLANATION

1. LOCATION WHERE PHOTOGRAPH WAS SHOT

2. VIEW OF LEFT ABUTMENT

3. DRAINAGE BOTTOM UPSTREAM OF EMBANKMENT LOCATION

3. VIEW OF RIGHT ABUTMENT
1 VIEW OF LEFT ABUTMENT

2 VIEW OF RIGHT ABUTMENT

NOTE:
PHOTOGRAPHS TAKEN ON SEPTEMBER 29, 2010

EXPLANATION
1 LOCATION WHERE PHOTOGRAPH WAS SHOT
FIGURE 9-1

LEVEL I & II POTENTIAL STORAGE SITES

NOWOOD RIVER STORAGE LEVEL II STUDY
WYOMING WATER DEVELOPMENT COMMISSION
TEN SLEEP, WYOMING

EXPLANATION

CITIES
LEVEL I POTENTIAL STORAGE SITES
LEVEL II POTENTIAL STORAGE SITES
PRIMARY US OR STATE HIGHWAY
SECONDARY STATE OR COUNTY HIGHWAY
LOCAL OR RURAL ROAD
PROPOSED DIVERSION SUPPLY DITCH/PIPE
RIVERS & STREAMS
COUNTY BOUNDARY
NOWOOD WATERSHED

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Checked By: SR
Scale: 1" = 6 MI
Date: 11/19/13
File: Nowood_StorageAll.mxd

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FIGURE 9-2
MEADOWLARK LAKE (TENSLEEP RESERVOIR) ENLARGEMENT ALTERNATIVE

NOWOOD RIVER STORAGE LEVEL II STUDY
WYOMING WATER DEVELOPMENT COMMISSION
TEN SLEEP, WYOMING

EXPLANATION
- MEADOWLARK LAKE
- U.S. AND STATE HIGHWAYS
- LOCAL OR RURAL ROAD
- RIVERS & STREAMS
- APPROX. 5 FT WSE RAISE
- WATER IMPOUNDMENT
- WETLANDS
- U.S.F.S. NATIONAL FOREST
- COUNTY BOUNDARY
FIGURE 9-4
NOWOOD RIVER STORAGE LEVEL II STUDY
WYOMING WATER DEVELOPMENT COMMISSION
TEN SLEEP, WYOMING

EXPLANATION

- POTENTIAL STORAGE SITE
- POTENTIAL DIVERSION SUPPLY DITCH/PIPE
- IRRIGATION DITCHES
- LOCAL OR RURAL ROAD
- RIVERS & STREAMS
- WATER IMPOUNDMENT
- WETLANDS (NW 2011)
- BUREAU OF LAND MANAGEMENT
- PRIVATE LANDS
- U.S.F.S. NATIONAL FOREST
- WYOMING STATE LAND

Drawn By: DRT
Checked By: BR
Scale: 1" = 3000'
Date: 11/10/13
File: Nowood_LocationLLuman.mxd
EXPLANATION

- POTENTIAL STORAGE SITE
- POTENTIAL DIVERSION SUPPLY DITCH/PIPE
- IRRIGATION DITCHES
- US AND STATE HIGHWAYS
- LOCAL OR RURAL ROAD
- RIVERS & STREAMS
- WATER IMPOUNDMENT
- WETLANDS (NWI 2011)
- BUREAU OF LAND MANAGEMENT
- PRIVATE LANDS
- WYOMING STATE LAND

FIGURE 9-5
TAYLOR DRAW STORAGE ALTERNATIVE
NOWOOD RIVER STORAGE LEVEL II STUDY
WYOMING WATER DEVELOPMENT COMMISSION
TEN SLEEP, WYOMING

Checked By: BR

File: Nowood_LocationTaylorDraw.mxd
Scale: 1" = 4000'
Date: 11/19/13
**FIGURE 9-6**

**CORNELL GULCH STORAGE ALTERNATIVE**

**NOWOOD RIVER STORAGE LEVEL II STUDY**

**WYOMING WATER DEVELOPMENT COMMISSION**

**TEN SLEEP, WYOMING**

---

**EXPLANATION**

- **POTENTIAL STORAGE SITE**
- **POTENTIAL DIVERSION SUPPLY DITCH/PIPE**
- **WATER IMPOUNDMENT**
- **LOCAL OR RURAL ROAD**
- **RIVERS & STREAMS**
- **WETLANDS (NW 2011)**
- **BUREAU OF LAND MANAGEMENT**
- **PRIVATE LANDS**
- **WYOMING STATE LAND**

---

**Drawn By:** DRT  **Checked By:** BR  **Scale:** 1" = 3000'  **Date:** 11/19/13  **File:** Nowood_LocationCornell.mxd

---

**0 3,000'**
Note: The northern project boundary was analyzed and displayed in this figure, however, after further evaluation the southern enlargement option was advanced and is discussed in the report.

Explanation:
- Cities
- Highways
- County roads
- Rivers & Streams
- Proposed project boundary
- Project disturbance
- County road buffer
- Existing buildings
- Irrigated lands
- Existing reservoir
- DDCT final boundary
- Sage-grouse leks - March 16, 2011
- Sage-grouse core area
- Version 3, June 29, 2010
- County boundary

Surface disturbance:

<table>
<thead>
<tr>
<th>Category</th>
<th>Acres</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall DDCT boundary</td>
<td>39,554.2</td>
<td>100.00</td>
</tr>
<tr>
<td>Total disturbed</td>
<td>4,677.0</td>
<td>11.9</td>
</tr>
<tr>
<td>Disturbed - project only</td>
<td>65.9</td>
<td>0.2</td>
</tr>
<tr>
<td>Disturbed - prior to project</td>
<td>4,611.1</td>
<td>11.7</td>
</tr>
</tbody>
</table>

**Executive order limit: 5% of DDCT area

**Executive order limit: average of 1 per 640 acres within DDCT area

** Table of contents:

- Cities
- Highways
- County roads
- Rivers & Streams
- Proposed project boundary
- Project disturbance
- County road buffer
- Existing buildings
- Irrigated lands
- Existing reservoir
- DDCT final boundary
- Sage-grouse leks - March 16, 2011
- Sage-grouse core area
- Version 3, June 29, 2010
- County boundary

** Figure 10-3

Alkali Creek maximum allowable disturbance of suitable sage-grouse habitat using the disturbance density calculation tool (DDCT)

Nowood River storage level II study
Wyoming Water Development Commission
TEN SLEEP, WYOMING
FIGURE 10-4
LOWER LUMAN CREEK MAXIMUM ALLOWABLE DISTURBANCE OF SUITABLE SAGE-GROUSE HABITAT USING THE DISTURBANCE DENSITY CALCULATION TOOL (DDCT)

SAGE-GROUSE LEKS - MARCH 16, 2011
SAGE-GROUSE CORE AREA
VERSION 3, JUNE 29, 2010
COUNTY BOUNDARY

NOWOOD RIVER STORAGE LEVEL II STUDY
WYOMING WATER DEVELOPMENT COMMISSION
TEN SLEEP, WYOMING

CATALOGUE

CITIES
HIGHWAYS
COUNTY ROADS
RIVERS & STREAMS
PROPOSED PROJECT BOUNDARY
COUNTY ROAD BUFFER
HIGHWAY BUFFER
EXISTING BUILDINGS
IRRIGATED LANDS
EXISTING RESERVOIR
DDCT FINAL BOUNDARY
SAGE-GROUSE LEKS - MARCH 16, 2011
SAGE-GROUSE CORE AREA
VERSION 3, JUNE 29, 2010
COUNTY BOUNDARY

SURFACE DISTURBANCE

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>ACRES</th>
<th>PERCENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>OVERALL DDCT BOUNDARY</td>
<td>41,128.96</td>
<td>100</td>
</tr>
<tr>
<td>TOTAL DISTURBED</td>
<td>895.43</td>
<td>2.18</td>
</tr>
<tr>
<td>DISTURBED - PROJECT ONLY</td>
<td>59.43</td>
<td>0.14</td>
</tr>
<tr>
<td>DISTURBED - PRIOR TO PROJECT</td>
<td>836</td>
<td>2.03</td>
</tr>
</tbody>
</table>

**EXECUTIVE ORDER LIMIT: 5% OF DDCT AREA

SURFACE DISRUPTION

TOTAL DISRUPTIONS

| NA - THIS ONLY APPLIES TO OIL AND GAS AND MINING ACTIVITIES

**EXECUTIVE ORDER LIMIT: AVERAGE OF 1 PER 640 ACRES WITHIN DDCT AREA

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Checked By: MD
Scale: 1" = 2 MI
Date: 11/20/13
File: Nowood_SageGrouse_LL_DDCT.mxd
FIGURE 10-5
TAYLOR DRAW MAXIMUM ALLOWABLE DISTURBANCE OF SUITABLE SAGE-GROUSE HABITAT USING THE DISTURBANCE DENSITY CALCULATION TOOL (DDCT)

NOWOOD RIVER STORAGE LEVEL II STUDY
WYOMING WATER DEVELOPMENT COMMISSION
TEN SLEEP, WYOMING

EXPLANATION
- HIGHWAYS
- COUNTY ROADS
- RIVERS & STREAMS
- PROPOSED PROJECT BOUNDARY
- COUNTY ROAD BUFFER
- EXISTING BUILDINGS
- IRRIGATED LANDS
- DDCT FINAL BOUNDARY
- SAGE-GROUSE LEKS - MARCH 16, 2011
- SAGE-GROUSE CORE AREA
- VERSION 3, JUNE 25, 2010

SURFACE DISTURBANCE

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>ACRES</th>
<th>PERCENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>OVERALL DDCT BOUNDARY</td>
<td>66,398.67</td>
<td>100.00</td>
</tr>
<tr>
<td>TOTAL DISTURBED</td>
<td>1,065.66</td>
<td>1.61</td>
</tr>
<tr>
<td>DISTURBED - PROJECT ONLY</td>
<td>176.81</td>
<td>0.27</td>
</tr>
<tr>
<td>DISTURBED - PRIOR TO PROJECT</td>
<td>888.87</td>
<td>1.34</td>
</tr>
</tbody>
</table>

**EXECUTIVE ORDER LIMIT: 5% OF DDCT AREA

SURFACE DISRUPTION

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>TOTAL DISRUPTIONS</th>
<th>DISRUPTION PER 640</th>
</tr>
</thead>
</table>
| NA - THIS ONLY APPLIES TO OIL AND GAS AND MINING ACTIVITIES

**EXECUTIVE ORDER LIMIT: AVERAGE OF 1 PER 640 ACRES WITHIN DDCT AREA

Washakie County
FIGURE 10-6
WILLOW CREEK MAXIMUM ALLOWABLE DISTURBANCE OF SUITABLE SAGE-GROUSE HABITAT USING THE DISTURBANCE DENSITY CALCULATION TOOL (DDCT)

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>ACRES</th>
<th>PERCENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>OVERALL DDCT BOUNDARY</td>
<td>75,313.11</td>
<td>100.00</td>
</tr>
<tr>
<td>TOTAL DISTURBED</td>
<td>1,954.91</td>
<td>2.60</td>
</tr>
<tr>
<td>DISTURBED - PROJECT ONLY</td>
<td>1,044.47</td>
<td>1.39</td>
</tr>
<tr>
<td>DISTURBED - PRIOR TO PROJECT</td>
<td>910.44</td>
<td>1.21</td>
</tr>
</tbody>
</table>

**EXECUTIVE ORDER LIMIT: 5% OF DDCT AREA

SURFACE DISRUPTION PER 640 ACRES WITHIN DDCT AREA

**EXECUTIVE ORDER LIMIT: AVERAGE OF 1 PER 640 ACRES WITHIN DDCT AREA

NA - THIS ONLY APPLIES TO OIL AND GAS AND MINING ACTIVITIES

EXPLANATION

- HIGHWAYS
- COUNTY ROADS
- RIVERS & STREAMS
- PROPOSED PROJECT BOUNDARY
- COUNTY ROAD BUFFER
- EXISTING BUILDINGS
- IRRIGATED LANDS
- DDCT FINAL BOUNDARY
- SAGE-GROUSE LEKS - MARCH 16, 2011
- SAGE-GROUSE CORE AREA
- VERSION 3, JUNE 29, 2010

WYOMING WATER DEVELOPMENT COMMISSION
TEN SLEEP, WYOMING

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Date: 11/20/13
File: Nowood_SageGrouse_WC_DDCT.mxd
FIGURE 11-1
MEADOWLARK LAKE
LITERATURE REVIEW
CULTURAL RESOURCE INVENTORY AREA
NOWOOD RIVER STORAGE LEVEL II STUDY
WYOMING WATER DEVELOPMENT COMMISSION
TEN SLEEP, WYOMING

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Drawn By: DRT Scale: 1" = 1,000' Date: 11/20/13
File: Nowood_CulturalArea_ML.mxd

EXPLANATION
CULTURAL RESOURCE INVENTORY AREA
PROJECT AREA
HIGHWAYS
COUNTY ROADS
RIVERS & STREAMS
COUNTY BOUNDARY
TOWNSHIP

Bean (2001)
1-725

Eckles (2008)
7-1672

Laurent (1990)
88-1017

Carender (1992)
91-1323

Wood (1988)
87-824

Sutton (1994)
94-915

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NOTES:
1. CONTOURS BELOW THE EXISTING HIGH WATER LEVEL, WERE DIGITIZED FROM THE 1938 JURNE TUNKLE TOWERS RESERVOIR PERMIT APPLICATION MAP. THESE CONTOURS SHOULD BE CONSIDERED APPROXIMATE AND MIGHT NOT REPRESENT CURRENT RESERVOIR BOTTOM TOPOGRAPHY.
2. CONTOURS ABOVE THE HIGH WATER LEVEL WERE GENERATED FROM THE 10 METER NATIONAL ELEVATION DATASET (NED) PRODUCED AND DISTRIBUTED BY THE USGS. AS PROVIDED BY THE USGS, THESE CONTOURS MAY BE CONSIDERED APPROXIMATE AND MAY NOT REPRESENT ACTUAL SITE TOPOGRAPHY.
3. NWI MAPPING INCLUDES THE RESERVOIR SURFACE; THIS PORTION OF THE MAPPING HAS BEEN REMOVED FOR CLARIFICATION AND IS NOT COUNTED. WETLANDS IDENTIFIED BY NWI MAPPING ARE APPROXIMATE AND SHOULD BE VERIFIED IN THE FIELD.

EXPLANATION
- US HIGHWAY AND DESIGNATION
- CAMPGROUND AND DESIGNATION
- EXISTING SURFACE CONTOUR
- CURRENT HWL
- PROPOSED HWL
- HWL AT SCENARIOS 1 AND 4
- RIVER/STREAM
- TOWNSHIP/RANGE LINE
- SECTION LINE
- SECTION QUARTER LINE
- WETLAND (FROM 2011 NWI)
- ACRE
- FT
- FEET
- FT AMSL
- FEET ABOVE MEAN SEA LEVEL
- HWL
- HIGH WATER LEVEL
- MSL
- NATIONAL WETLANDS MAPPING
- WSE
- WATER SURFACE ELEVATION

FIGURE 12-1
MEADOWLARK LAKE ANALYSIS
SITE MAP
NOWOOD RIVER STORAGE LEVEL II STUDY
WYOMING WATER DEVELOPMENT COMMISSION
TEN SLEEP, WYOMING

Drawn By: PC
Checked By: DT
Date: 3/7/13
File: 06N-AD-LDLW-PP201303
**EXISTING CONDITIONS STAGE STORAGE**

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**PROPOSED CONDITIONS STAGE STORAGE**

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**PROPOSED STAGE STORAGE CURVE**

**NOTE:**
- The yearly minimum EOM storage values estimated in scenario A are above 8461.1 FT AMSL.

**EXPLANATION**
- CURRENT HWL: FT AWL
- PROPOSED HWL: FT AWL
- MAX: MAXIMUM
- MIN: MINIMUM
- HWL AT VARIOUS SCENARIOS: FT AWL
- FT: FEET
- FEET ABOVE MEAN SEA LEVEL
- CENTER LINE: HWL
- END OF MONTH CONTENTS: WSE
- NATIONAL WETLANDS INVENTORY
- NOTE: FEET ABOVE MEAN SEA LEVEL
- HIGH WATER LEVEL
- WATER SURFACE ELEVATION
- FT: FEET
- AWL: ABOVE MEAN SEA LEVEL
- MAX: MAXIMUM
- MIN: MINIMUM
- HWL: HIGH WATER LEVEL
- WSE: WATER SURFACE ELEVATION
- FT: FEET
- CENTER LINE: HWL
- END OF MONTH CONTENTS: WSE
- NATIONAL WETLANDS INVENTORY

**FIGURE 12-2**

**MEADOWLARK LAKE ANALYSIS**

**CROSS SECTIONS**

**NOWOOD RIVER STORAGE LEVEL II STUDY**

**WYOMING WATER DEVELOPMENT COMMISSION**

**TEN SLEEP, WYOMING**

**Trishydro**

1253 Commerce Drive
Laramie, Wyoming 82070

www.trihydro.com

---

Drawn By: PC | Checked By: DT | Scale: 1" = 500' | Date: 3/7/13 | File: 06N-MEADOWLW-PP201303
FIGURE 12-3. MEADOWLARK LAKE SCENARIO 1
NOWOOD RIVER STORAGE, LEVEL II STUDY

ACRE-FEET

END-OF-MONTH CONTENTS
DEAD STORAGE (37 AC-FT)
FISH STORAGE (829 AC-FT)
FIGURE 12-4. MEADOWLARK LAKE SCENARIO 2
NOWOOD RIVER STORAGE, LEVEL II STUDY

ACRE-FEET


END-OF-MONTH CONTENTS  DEAD STORAGE (37 AC-FT)  FISH STORAGE (829 AC-FT)
FIGURE 12-6. MEADOWLARK LAKE SCENARIO 4
NOWOOD RIVER STORAGE, LEVEL II STUDY

ACRE-FEET


END-OF-MONTH CONTENTS
DEAD STORAGE (37 AC-FT)
FISH STORAGE (829 AC-FT)
FIGURE 12-7. SIMULATION OF FLOWS AVAILABLE TO FILL ALKALI CREEK NOWOOD RIVER STORAGE, LEVEL II STUDY

Flow (cfs)

Month

Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep

Flow Diverted to Reservoir
Avg Year Combined Physical Flow
Avg Year Combined Available Flow
Total Available Water to Fill Reservoir
Avg Year Available Flow Supplied By Diversion
Avg Year Available Flow Supplied by Watershed
Anita Ditch Recorded Flow 2011
Anita Ditch Recorded Flow 2012
FIGURE 12-8. SIMULATION OF FLOWS AVAILABLE TO FILL TAYLOR DRAW - WINTER DIVERSION
NOWOOD RIVER STORAGE, LEVEL II STUDY

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<th>Average Available Flow</th>
<th>Baseline Shortage</th>
<th>Available Water to Fill Taylor Draw</th>
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<td>Sep</td>
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FIGURE 12-9. SIMULATION OF FLOWS AVAILABLE TO FILL TAYLOR DRAW - SPRING DIVERSION
NOWOOD RIVER STORAGE, LEVEL II STUDY

0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0

Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep

Flow (cfs)

Month

Average Physical Flow
Average Available Flow
Baseline Shortage
Available Water to Fill Taylor Draw
FIGURE 14-1. ALFALFA HAY PRICES IN WYOMING OVER TIME
NOWOOD RIVER STORAGE, LEVEL II STUDY
MEADOWLARK LAKE EXPANSION
WASHAKIE/BIG HORN COUNTIES, WYOMING
NOVEMBER 2013

EXPLANATION

STATE OF WYOMING PARCEL
EXISTING PARCEL
PROPENDED PARCEL
EXISTING LINE (CCT4: 1 PT: 4.51'
PROPOSED LINE (1 PT: 4.51')
EXISTING DITCH
RIVER/STREAM
FISH/LANDER
B&M PARCEL
AC: ACRE
CY: CUBIC YARDS
PL: FT
PT: POST-PEET
H: MI
B: BILLION
R: RANGE
T: TOWNSHIP
N: NORTH
W: WEST

ABBREVIATIONS

PROJECT LOCATION
EXISTING SURFACE CONTOUR
PROPOSED SURFACE CONTOUR
EXISTING WATER LEVEL
EXISTING DITCH
LANDER
1 FT.
WATER LINE (HWL)
EL:
FT.
AMS
FOOT
ELEVATION
TYP.
HIGHWATER LEVEL
REINFORCED CONCRETE

INDEX OF SHEETS

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002
003

ML-1
ML-2
ML-3

EXISTING SITE AND EXPLANATION
EXISTING SLEEP DAM DETAILS
PROPOSED SLEEP DAM MODIFICATIONS

Citation:
National Agriculture Imagery Program (NAIP) Colored Orthophoto,
Forest Service Parcel

WASHAKIE/BIG HORN COUNTIES, WYOMING
TEN SLEEP, WYOMING

Sheet:
ML-1
ML-2
ML-3

Rev:
B
B
B

Scale:
1" = 7,500'
1" = 7,500'
1" = 7,500'

Drawn by:
Tribhdy Group Inc.

Prepared:
Tribhdy Group Inc.

Approved:
Tribhdy Group Inc.

Sheet:
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ML-3

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ML-1
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1" = 7,500'
1" = 7,500'

Drawn by:
Tribhdy Group Inc.

Prepared:
Tribhdy Group Inc.

Approved:
Tribhdy Group Inc.
A CROSS SECTION THROUGH OUTLET

SCALE: 1" = 10'

SECTION OF SPILLWAY ON C OF DAM (LOOKING UPSTREAM)

SCALE: 1" = 10'

PLAN OF SPILLWAY

SCALE: 1" = 30'

SECTION AT CREST OF SPILLWAY

SCALE: 1" = 2''

CONTOUR EL.

AREAS

CAPACITY

(FT AMSL)

(ACRE-FT)

8444.000

8449.015.3838.45

8454.0169.775050.32

8459.0225.841490.32

8464.0258.262700.57

8467.0 (HWL)280.653508.94

CAPACITY TABLE

EXISTING TEN SLEEP RESERVOIR DAM DETAILS

PROPOSED MEADOWLARK LAKE EXPANSION

TEN SLEEP, WYOMING

WYOMING WATER DEVELOPMENT COMMISSION

WARNING

IF THIS BAR DOES NOT MEASURE 1" IN LENGTH THEN DRAWING IS NOT AT INTENDED SCALE

REVISIONS

DESCRIPTION CHK'DBY

DATE:

REV.

FILE:

CHECKED BY:

DRAWN BY:

DATE:

REV.

NOTE: SCALE IS 3/8" = 1'-0"

2 OF 3

SHEET

NOWOOD RIVER STORAGE LEVEL II STUDY

REVISION HISTORY

GEO: 6/12/13 FINAL REPORT PC DT

NOWOOD RIVER STORAGE LEVEL II STUDY

REVISION HISTORY

GEO: 6/12/13 FINAL REPORT PC DT
PROPOSED RESERVOIR SITE PLAN

SCALE: 1" = 600'

PROPOSED SITE PLAN, CROSS SECTIONS, AND DETAILS ALKALI CREEK RESERVOIR
NOWOOD RIVER STORAGE LEVEL II STUDY
WYOMING WATER DEVELOPMENT COMMISSION
TEN SLEEP, WYOMING

REV: FILE: CHECKED BY: SCALE: DRAWN BY: DATE: REVISIONS DESCRIPTION CHK'DBYREV.

IF THIS BAR DOES NOT MEASURE 1" IN LENGTH THEN DRAWING IS NOT AT INTENDED SCALE

WARNING

AC-2

PROPOSED EMBANKMENT PROFILE
SCALE: H: 1" = 100'  V: 1" = 50'

EMBANKMENT CROSS SECTION A-A
SCALE: H: 1" = 100'  V: 1" = 50'

EMBANKMENT CROSS SECTION A-A
SCALE: H: 1" = 100'  V: 1" = 50'

RESERVOIR STAGE-STORAGE

PROPOSED STAGE STORAGE CURVE

WATER EL. STORAGE VOLUME AREA
(FT. AMSL) (AC-FT) (AC.)
4410 1.64 2.20
4415 32.19 11.40
4420 115.87 23.13
4425 254.54 32.41
4430 442.00 42.62
4435 680.49 52.91
4440 977.02 66.51
4445 1351.58 83.90
4450 1823.03 104.43
4455 2401.31 128.81
4460 3123.73 160.01
4465 4009.39 197.05
4470 5075.17 229.63
4475 6301.67 261.79
4479 7401.81 288.28

EARTHWORK QUANTITIES

ITEM CUT FILL NET TOTAL

TOTAL

3

PROPOSED RESERVOIR SITE PLAN
SCALE: 1" = 600'

PROPOSED STAGE STORAGE CURVE

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Reservoir Stage-Storage

Proposed Reservoir Site Plan

Proposed Stage Storage Curve

Elevation vs. Storage

Earthwork Quantities

Proposed Embankment Cross Section A-A

Proposed Embankment Profile

Reservoir stage-storage
