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EXECUTIVE SUMMARY
UPPER GREEN WATERSHED STUDY
LEVEL I

For

Wyoming Water Development Commission

Sublette County Conservation District

Prepared by:

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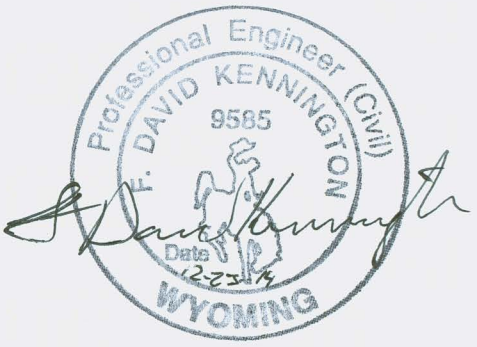

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I. INTRODUCTION

The purpose of the Upper Green River Watershed – Level I Study was to 1) assess, describe, and inventory the watershed and 2) develop management and rehabilitation plans for the watershed. The watershed study provides both practical and economical recommendations that, if implemented, will help solve issues and realize opportunities identified during the inventory and assessment of the Upper Green River Watershed. Additionally, the study analyzes the potential for developing surface water within the Upper Green River watershed with particular emphasis on small upland water projects. These small upland projects include both public and private lands and are intended to advance grazing management through public-private partnerships that develop small and under-utilized water resources. Larger scale water storage was evaluated in light of the many studies already completed and relied on the detailed analysis and concepts of earlier studies.

Figure 1.1 Location Map; outlines the location and extent of the Upper Green watershed.

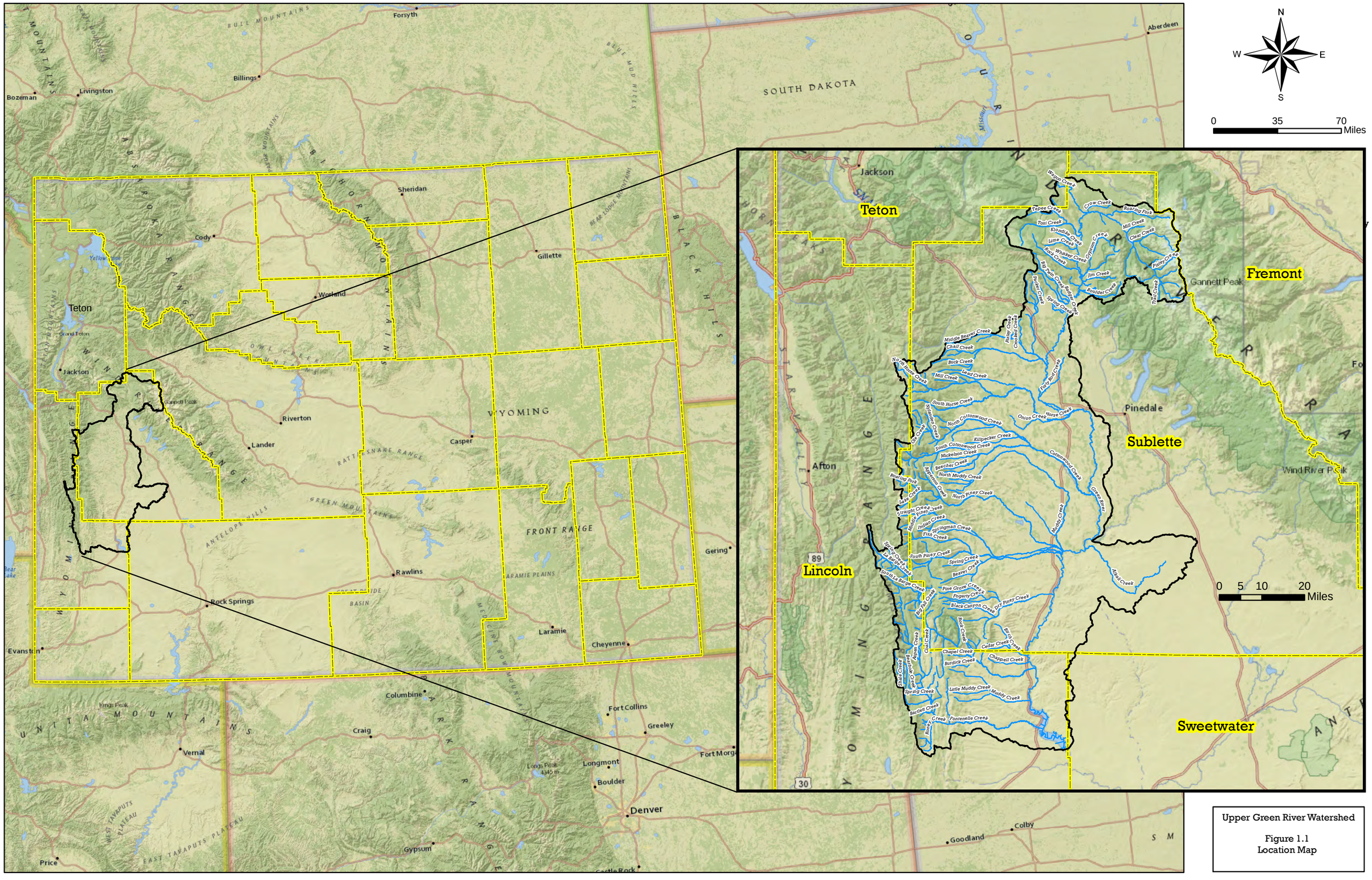
The Upper Green River watershed is approximately 1.9 million acres in size and is located primarily within Sublette County (79%), to a lesser degree in eastern Lincoln County (20%), and a combined 1% in southeastern Teton County and northwestern Sweetwater County. The watershed includes the main stem of the Green River, the primary river system; a variety of larger tributaries including Tosi Creek, Klondike Creek, Rock Creek, Gypsum Creek, Beaver Creeks, Horse Creek, Cottonwood Creek, Piney Creeks, LaBarge Creek and Fontenelle Creek; and numerous smaller tributaries. Elevations range from the 13,804' Gannett Peak down to the top of the Fontenelle Reservoir conservation pool at 6,506'.

Land ownership in the Upper Green drainage is a mixture of public (federal and state) and private land. The ownership breakdown is as follows: BLM (42%); Forest Service (30%); private land (23%); State of Wyoming (3%); The Nature Conservancy (.1%); and unknown (<1%). There are three incorporated municipalities within the project area; Big Piney and Marbleton in Sublette County, and La Barge in Lincoln County. In addition, there are 7 unincorporated towns within the project area; Daniel, Daniel Junction, Halfway, Merna, and Bronx in Sublette County, and Calpet and Viola in Lincoln County.

Administratively the study areas falls within Division IV of the State Engineers agency divisions and includes Districts 5, 10, and 11.

The watershed faces the following general challenges with regard to its land and water resources including:

- Distribution of water resources
- Energy development pressures on land and water resources
- Water quality
- Infrastructure maintenance
- Wildlife habitat preservation
- Rangeland health
- Maintenance of riparian habitat



Upper Green River Watershed

Figure 1.1
Location Map

Projection: NAD 83 - UTM Zone 12

The primary purpose of this Level I Study was to gather relevant existing information and combine that information with data generated by this study to form a comprehensive Watershed Management and Rehabilitation Plan. Specific objectives of the project include the following:

1. Conduct an evaluation and description of the watershed, including quantity and quality of surface water resources, and riparian/upland conditions.
2. Conduct an evaluation of water storage needs and opportunities to augment upland water available for livestock and wildlife.
3. Conduct an irrigation system inventory and develop a rehabilitation plan for those ditches expressing an interest to participate.
4. Promote public participation in the study.
5. Facilitate participation and consensus building with the landowners and the public at large, the Conservation District, and the Wyoming Water Development Commission.
6. Identify natural resource issues within the watershed and propose practical economic solutions.
7. Identify permits, easements and clearances necessary for plan implementation.
8. Develop a watershed management and rehabilitation plan describing and prioritizing potential alternative projects and management strategies to address water resource related issues and potential water development opportunities identified in the watershed inventory.
9. Develop conceptual-level estimates of the costs of the potential projects identified in the watershed management and rehabilitation plan.
10. Compile and collate all spatial data, relevant published and unpublished reports, and collected information into a comprehensive digital library to facilitate the completion of this project and also to be available as a resource for the District and future studies.
11. Conduct a geomorphic investigation of primary tributary channels within the watershed and identify potential mitigation measures to improve impaired channel reaches.

The Wyoming Water Development Commission's (WWDC) Level I Watershed Study is a fundamental landscape analysis confined to a hydrologically connected drainage area or watershed and is focused on two primary components. The first is an identification of the physical attributes of that analysis area. This is accomplished by conducting a comprehensive inventory of the natural resources and subsequently using that inventory to articulate a description of the current natural resource conditions. The second is a long range plan outlining management and/or rehabilitation opportunities and activities that address ecological enhancement and watershed function.

Identifying improvement opportunities for hydrologic and watershed function, including water quantity, yield and use, is an essential element of the Level I Watershed Study. Hydrologically, there are three fundamental watershed functions: (1) collection of the water from rainfall, snowmelt, and storage that becomes runoff, (2) storage of various amounts and durations, and (3) discharge of water as runoff [Black, 1997].

Implementation of BMPs and conservation practices can affect water resource quantity through improvement of plant communities, vegetative diversity, and ecological site health achieved from water development and the creation of reliable water sources in areas devoid of such allows for the establishment of grazing systems and changes in grazing distribution.

An ecological enhancement is any activity that improves an ecosystem such as stabilizing erosive soils, increasing soil quality, planting or maintaining native grasses, shrubs, or trees, removing and controlling invasive species, and improving or maintaining riparian/wetland areas. Ecological sites are complex and varied within a watershed study area as are the potential benefits achieved from project activities and implementations that influence the condition of those ecological sites and characteristics. Section 4 discusses several potential management and rehabilitation strategies.

Conjunctive to soil function is plant community diversity, health and productivity and subsequent forage diversity, production and wildlife habitat. Benefits accrued to water quality are significant as improvements to the chemical, physical, and biological constituents of a water body produce both local site enhancements and those transferred downstream. Wetland enhancement and restoration provides benefits to ecological stabilization as well as contributions to water quality and quantity. Ecologically, watersheds function by providing diverse sites and pathways along which vital chemical reactions occur and furnishing habitat for the flora and fauna that constitute the biological elements of ecosystems [Black, 1997].

Locations of conservation practices and rangeland infrastructure can have a large, indirect impact on overall vegetation change with the spatial design of infrastructure including the locations of fences, watering points, and feeders that are used to modify patterns of animal movement and forage utilization, taking into account livestock behavior and the template of topography and plant communities to which livestock respond [Laca, 2009; Natural Resources Conservation Service, 2011].

Reducing impact to riparian plant communities through the development of upland water resources can result in stream corridor benefits. Riparian plant community diversity and regeneration of desirable important woody species can help restore local water tables, trap sediments, increase wildlife habitat and migration corridors, and stabilize stream banks which can affect localized land loss. In addition, aquatic population benefits can accrue and recreation potential can be realized.

The watershed management and rehabilitation plan and components presented in the final report of a watershed study provides recommendations for improvements for the following:

- Irrigation system rehabilitation components
- Livestock/wildlife upland watering opportunities
- Grazing management opportunities
- Storage opportunities
- Stream channel condition and stability
- Wetland enhancement opportunities
- Other watershed management opportunities.

II. PROJECT MEETINGS AND PUBLIC INTERACTION

Project meetings were held by the Wyoming Water Development Office (WWDO) staff to inform the Sublette County Conservation District and the community of the WWDC's watershed study process. The meetings held were as follows:

- July 12, 2011 - SCCD Board Meeting
- October 11, 2011 - SCCD Board Meeting
- February 13, 2012 - Big Piney Landowner Meeting
- February 13, 2012 - Pinedale Landowner Meeting
- March 20, 2012 - Pre-Proposal Meeting
- May 10, 2012 - Consultant Interviews/Selection w/ Sponsor

During the course of the study, meetings were conducted on two different levels. The first level of meetings were the publicly advertised and attended meetings held at the Marbleton Town Hall, the Sublette County Library, or at the Offices of the Sublette County Conservation District. These meetings were general project meetings discussing approach and project findings. The attendanace at the meetings was between eight and twenty individuals with roughly half being land owners at the public meetings. The remaining attendees were from State and Federal agencies. The Conservation District provided an initial contact list for the first meeting. Invitations to the meetings were by postcard, email, or telephone as contact information dictated. The meetings held were as follows:

- July 17, 2012 - Project Kickoff Meeting, Marbleton
- July 17, 2012 - Project Kickoff Meeting, Pinedale
- December 5, 2012 - SCCD Board Meeting
- April 23, 2013 - Open House/Workshop, Marbleton
- July 1, 2013 - DRAFT Report Presentation, Marbleton

The second level of meetings were arranged with individual property owners to review their proposed upland water projects and irrigation improvement projects. These contacts were initially made at the public meeting, or by referrals from the Conservation District, or by word of mouth.

The meetings with individual property owners were held in the field and where practical, (favorable weather and access conditions) included a site visit. In some cases the review was made using aerial photography. A second follow-up meeting with individual landowners was accomplished via an open-house held at the Marbleton Town Hall. At the meeting, maps and project descriptions based on the initial consultation were reviewed for accuracy by the landowner.

III. WATERSHED DESCRIPTION AND INVENTORY

A considerable amount of information pertaining to the Upper Green River watershed already exists. These data span a wide variety of disciplines, including basin hydrology, water quality, wetlands, wildlife, land use and ownership, climate, geology, soils, agricultural practices and others. The data comes from Federal, State, local, corporate, and private interests and spans the previous century. Interest in the above topics began with early settlement in the basin and has since grown to the point of massive amounts of data being available to the general public at present through the use of computers and public data sets.

A primary goal of watershed planning studies conducted on behalf of the Wyoming Water Development Commission (WWDC) is to:

1. Collect, review, and compile pertinent information regarding the project area;
2. Collate the data in a single dataset; and
3. Use this information to characterize the watershed and facilitate current and future planning, permitting, and improvement efforts within the watershed.

The information collected during the course of this study primarily came from existing data sets already in existence. Many Federal, State and local governmental agencies have successfully cataloged and scanned historic paper documents into electronic data bases and have made these documents available. In addition, on-going research and more recent studies completed in electronic format are available from various contacts including the following:

U.S. Geological Survey (USGS)

U.S. Forest Service (USFS)

U.S. Department of Agriculture (USDA)

U.S. Fish and Wildlife Service (FWS)

U.S. Environmental Protection Agency (EPA)

U.S. Bureau of Land Management (BLM)

U.S. Department of the Interior Bureau of Reclamation (BOR)

USDA Natural Resources Conservation Service (NRCS)

Wyoming Water Development Office (WWDO)

Wyoming Department of Environmental Quality (WDEQ)

Wyoming State Engineers Office (SEO)

Wyoming Game and Fish Department (WGFD)

Wyoming State Geological Survey (WSGS)

Wyoming Geographic Information Science Center (WyGISC)

Wyoming State Geological Survey (WSGS)

Wyoming Oil and Gas Conservation Commission (WOGCC)

Wyoming Secretary of State's Office

Sublette County

Sublette County Conservation District

Sublette County Weed and Pest

Much of the collected data and some data generated during the preparation of the study are in GIS format. The map becomes a window into larger data sets of attributes (tables of facts, descriptions, and numbers) associated with the graphically displayed map data. The non GIS user can access the data sets through the user interface and the "geo-pdf" figures of the study. In this way, a simple

exhibit depicting various basin features can contain vast amounts of tabular data. For instance, a map of soil types can access portals to tabular data such as soil abbreviations, soil types, soil characteristics, acreage by type, etc. The interface is based on Adobe Reader or Adobe Acrobat with "TerraGo" (a free program) added. The user can interrogate the geo-pdf and also add data to the geo-pdf. The user can also manipulate the layers that are shown on the pdf.

IV. WATERSHED MANAGEMENT AND REHABILITATION PLAN

Opportunities with regard to management oand rehabilitation include the following:

- Livestock/Wildlife Upland Watering Opportunities – Potential upland water development projects were identified based on an evaluation of existing water sources, upland grazing conditions, and input from landowners.
- Stream Channel Condition and Stability – Stream channels within the watershed were characterized with respect to their condition and stability. Impaired channels were identified for further evaluation and alternative improvements developed.
- Grazing Management Opportunities – Grazing management strategies are presented based on a review of the Ecological Site Descriptions (ESDs), vegetation, and soil conditions within the watershed.
- Other Upland Management Opportunities – Additional upland management opportunities were identified.

The Upper Green River watershed study area supports numerous grazing allotments on BLM and USFS administered land. These allotments are generally adjacent to privately held ground and serve as summer and early fall range for the adjacent ranches. Extensive work has been done within the watershed to provide upland water sources for livestock and wildlife. Abundant natural water features also provide similar services; especially in the northern and western portions of the watershed.

Many of the allotments have small water improvements constructed by resource agencies or the permit holder. The facilities generally group into one or more of the following categories:

- Wells
- Springs
- Earthen Catchments (Reservoirs)
- Raintraps/Guzzlers
- Troughs
- Conveyance

In the case of springs there are both developed and undeveloped springs. In addition there are some natural features such as ponds and pits that also serve to water livestock.

Opportunities to develop additional water sources exist in many locations. Potential water sources that would provide at least seasonal water on underutilized rangelands as well as alternative water supplies to riparian corridors include development of springs, rehabilitation of existing permitted stock reservoirs, new earthen catchments and wells. Development of springs that flow in excess of 2 gallons per minute and redevelopment of former industrial wells associated with energy

development and idle or un-used domestic wells provide the greatest potential for new or expanded water sources. New or rehabilitated stock reservoirs could also provide upland water sources where wells or springs are not available, but these activities will likely require more work and are inherently more expensive to design, permit, and construct.

Individual meetings with the landowners were scheduled and completed to gain their input on the water needs of their respective geographical areas of interest. Based upon the results of these interviews and the information presented above pertaining to existing water supplies and areas in need of upland water development, numerous conceptual water development projects were identified.

V. IRRIGATION SYSTEM INVENTORY AND REHABILITATION

Agricultural Water use in the Upper Green River Basin consists primarily of irrigation and to a lesser degree stock watering. Although a few irrigation wells exist in the Upper Green River Basin, the predominant source of irrigation supply is surface water. Historically, a network of canals and ditches were constructed by producers to convey water from the natural tributaries and main stream Green River to the meadows and cultivated lands. Flood irrigation remains the principal method of applying water to the fields. In recent years, through the NRCS Environmental Quality Incentives Program (EQIP), center pivot irrigation systems have emerged as an alternative to flood irrigation. Center pivot irrigation is being utilized in the LaBarge, Big Piney, and 40 Rod Flat area(s) of the Upper Basin.

Approximately 287 diversions to ditches or pipline intakes exist in the Upper Green River watershed atudy area. The diversion priority dates range from 1882 to 1988.

Much of the project need within the upper Green River waterhed study area is associated with aging headgate structures constructed of wood; headgates being stranded as the main channel drops in elevation; and diversion revetments that are difficult to maintain.

VI. WATER SUPPLY AND STORAGE OPPORTUNITIES

A StateMod format model was developed for the Green River Basin above Fontenelle Reservoir to support the Upper Green River Level II Storage Study Model (Kleinfelder, 2005). The StateMod model incorporated the monthly variability in streamflows and demands over a 34-year study period. Unlike the spreadsheet models, the StateMod model distributes water to meet demands per Wyoming Water Law, based on user input water rights.

The study period of the Upper Green StateMod model was extended and representation of the Piney Creek tributary basin was refined to support the Upper Green River Level II Westside Storage Study Model (Short Elliott Hendrickson, 2007). The geographic extent of the Upper Green StateMod model was extended down to the Town of Green River to support the 2009 planning effort by WWC Engineering and AECOM. The 2007 and 2009 models both represented a 1971 through 2006 study period.

Although the geographic focus of the Watershed Study is the Upper Green River basin (excluding the New Fork River), the 2007 StateMod model and 2009 StateMod model were combined to develop one complete StateMod format model for use in the Watershed Study and future efforts.

The model results were utilized to estimate the available flows at the bottom of particular tributaries and main stem locations. The results of the physical flow estimates and available flow estimates are summarized in Tables 6.2.2.1a (annual) and 6.2.2.1b (monthly). Note the Available Flow values are NOT additive. The Available Flow represents the flow available for diversion at a certain location based on the minimum flow available for diversion at all downstream locations.

Table 6.2.2.1a Simulated Flows for Tributary and Main Stem Locations (ac-ft/yr)

#	Gage ID	Name	Simulated Stream Flow 1971 – 2011 Average	
			Physical Flow	Available Flow
1	09188500	Green River at Warren Bridge	347,993	292,089
2	09189000	Beaver Creek near Daniel	26,524	25,106
3	09190000	Horse Creek near Daniel	37,142	20,166
4	09191500	Cottonwood Creek near Daniel	54,126	26,086
5	09205500	North Piney Creek near Mason	39,496	10,228
6	09206000	Middle Piney Creek below South Fork	16,131	1,179
7	09207500	South Piney Ck near Big Piney	40,767	15,414
8	09205000	New Fork R near Big Piney	551,977	499,502
9	09209400	Green River near La Barge	1,202,673	852,439

Table 6.2.2.1b Simulated Flows for Tributary and Main Stem Locations (ac-ft/Month)

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
09188500	Green River at Warren Bridge	Physical Flow	6,699	6,016	8,022	17,183	56,926	104,007	73,710	29,893	17,145	12,110	8,756	7,528	347,993
		Available Flow	6,670	5,980	8,022	10,376	34,629	96,585	62,706	24,116	15,320	11,705	8,567	7,414	292,089
09189000	Beaver Creek near Daniel	Physical Flow	372	334	444	1,170	4,138	7,549	5,639	3,017	1,764	1,185	556	357	26,524
		Available Flow	372	334	444	706	3,250	7,483	5,639	3,017	1,764	1,185	556	357	25,106
09190000	Horse Creek near Daniel	Physical Flow	404	367	500	2,319	8,924	11,409	5,428	3,804	1,955	1,132	574	326	37,142
		Available Flow	404	367	500	1,827	4,973	7,219	1,145	837	861	1,132	574	326	20,166
09191500	Cottonwood Creek near Daniel	Physical Flow	734	661	891	1,990	8,416	15,938	12,167	6,698	3,465	1,670	834	664	54,126
		Available Flow	734	661	891	1,449	3,509	8,734	4,527	1,203	1,211	1,670	834	664	26,086
09205500	North Piney Creek near Mason	Physical Flow	701	633	839	1,789	6,534	12,030	8,705	3,657	1,821	1,167	845	777	39,496
		Available Flow	701	633	839	1,352	603	2,451	345	72	444	1,167	845	777	10,228
09206000	Middle Piney Creek below South Fork	Physical Flow	235	203	300	740	2,768	5,190	3,663	1,421	768	241	326	277	16,131
		Available Flow	30	21	71	404	22	346	0	0	25	90	112	59	1,179
09207500	South Piney Ck near Big Piney	Physical Flow	449	374	602	1,656	7,008	13,164	9,592	4,165	1,810	888	547	512	40,767
		Available Flow	449	374	602	1,274	2,240	5,405	2,383	196	546	888	547	512	15,414
09205000	New Fork R near Big Piney	Physical Flow	27,849	26,753	45,595	78,949	175,972	350,549	231,102	103,644	53,787	40,823	37,885	29,766	1,202,673
		Available Flow	19,262	19,874	37,229	22,985	51,764	290,332	187,369	95,810	46,303	32,057	29,124	20,329	852,439
09209400	Green River near La Barge	Physical Flow	12,627	11,704	17,390	25,238	74,979	183,176	108,480	39,969	23,872	21,620	18,356	14,568	551,977
		Available Flow	12,442	11,582	17,390	16,915	42,136	178,873	104,163	39,969	23,479	20,507	18,170	13,878	499,502

The results of the modeling were reviewed to identify the extent of shortages to demands at individual ditches and groups of ditches on tributary systems. It is recognized that almost every area of the Green River basin within Wyoming can be considered water short during severe dry years. The purpose of this investigation is to identify the extent of shortages in the basin.

The shortages were classified during dry, wet, and normal years. The wet years were defined as the highest 20 percent of annual flows recorded at the Green River near LaBarge stream gage (USGS ID 09209400) over the 1971 through 2011 study period. The dry years were defined as the lower 20 percent of annual flows recorded at the stream gage. The remaining 60 percent of years in the middle define the normal years.
The areas listed in Table 6.2.3.1 were identified based on their locations with certain water districts in the Green River basin. The table values represent total shortages on the tributaries and the Green River main stem within the Districts. Note the contribution of shortages to main stem nodes is minimal.

Table 6.2.3.1 Water Short Areas during Various Hydrologic Conditions

Water District	Location	Percent Demand is Shorted		
		Dry Year	Avg. Year	Wet Year
11	Green River above Cottonwood Ck	20%	10%	5%
10	Green River from Cottonwood Ck to below Piney Ck	49%	23%	8%
5	Green River from Piney Ck to Fontenelle Reservoir	15%	2%	0%

Dry year based on average of 1977, 1981, 1988, 1992, 1994, 2001, 2002, and 2007
Wet year based on average of 1971, 1972, 1982, 1983, 1986, 1997, 1999, and 2011
Average year based on remaining years between 1971 and 2011

Several rivers and streams in the Green River basin are permitted for instream flow water rights and several are in the process of being studied by the WGFD to determine appropriate flows.

As of the date of this report, a total of eight instream flow segments reside within the Upper Green River Basin study area, and the WWDC has completed a separate hydrologic study for each. One of these segments is located on the Green River mainstem and is fully adjudicated. The other 7 have been issued permits by the State Engineer's Office and are in the process of being proofed by Division 4 of the State's Board of Control. A summary of these eight instream flow segments is presented in Table 6.2.4.

Table 6.2.4 Instream Flow Segments within the Upper Green River Basin Study Area

Stream Name	Stream Length (mi)	Temp Filing No.	Priority Date	SEO Hearing Date	Approval Date	Permit No.	Adjudicated Date	County	Current Status
Green River	9.84	26 2/328	1/10/1989	8/7/1990	1/7/1992	6 IF	8/15/2012	Sublette County	Adjudicated
South Cottonwood Creek	2.93	26 6/383	6/27/1989	11/9/1993	1/16/2008	74 IF		Sublette County	BOC Proofing Stage
North Cottonwood Creek	8.90	26 4/388	7/12/1989	11/9/1993	1/15/2008	73 IF		Sublette County	BOC Proofing Stage
LaBarge Creek	3.30	27 3/146	12/17/1990	11/8/1993	12/3/2003	29 IF		Lincoln County	BOC Proofing Stage
North Piney Creek	7.60	27 5/185	3/11/1991	11/9/1993	2/10/2004	35 IF		Sublette County	BOC Proofing Stage
Middle Piney Creek	3.60	27 6/185	3/11/1991	11/9/1993	2/23/2004	36 IF		Sublette County	BOC Proofing Stage
South Piney Creek	7.00	27 1/186	3/11/1991	11/9/1993	12/3/2003	28 IF		Sublette County	BOC Proofing Stage
Fish Creek	4.20	27 2/186	3/11/1991	11/9/1993	12/1/2003	30 IF		Sublette County	BOC Proofing Stage

The model input includes full supply water demands to meet crop water requirements for lands identified as currently irrigated in the 2009 AECOM model. The full utilization of water rights, though, to meet demands on the permitted acreage associated with the water rights would further limit flow available for upland storage or in a new storage facility.

This study does not pursue new detailed analysis of previously identified reservoir sites or attempt to identify new sites. This study compiles the previously identified sites along with basic site information and study results.

Numerous studies have addressed storage opportunities in the Upper Green. Of the planning documents reviewed, the following studies had reservoir planning components. Table 6.3.1.1 is a matrix illustrating which studies addressed various sites and the ranking of the top sites in the respective study. Table 6.3.1.2 show the sites and various site characteristics.

	Previous Studies containing Reservoir Components*	1 Fish Creek	2 Fontenelle No. 1	3 Fontenelle Creek	4 Green River Lakes Enl.	5 Green River Supplemental Supply Project	6 Kendall	7 LaBarge Meadows	8 Lower Kendall	9 McNinch Wash	10 Middle Piney Lake	11 North Piney Cr	12 Sand Hill	13 Sixty Seven Enl.	14 Snider Basin	15 South Cottonwood	16 Warren Bridge Res.	17 Cottonwood No. 1	18 Fogarty Creek	19 Horse Creek	20 LaBarge Reservoir	21 Middle Beaver Creek	22 North Cottonwood Creek	23 South Beaver Creek	24 South Cottonwood Creek	25 South Horse Creek	26 Straight Creek	27 Cottonwood Creek	28 Fontenelle Res. #1	29 Big Piney and LaBarge	30 Horse Pasture Draw	31 Mickleson Creek Res	32 Cow Gulch Res	33 North Horse Creek	34 Haines Flat	35 North Cottonwood Creek SHE-5	36 North Cottonwood Creek SHE-7	37 Wiskey Creek	38 Fish Creek SEH-12	39 New Fork Narrows	40 Geen River Lakes Enl
1	Report on Green River Basin In Wyoming and Proposed New Project Therein, 1919 Department of the Interior, United States Reclamation Service																																								
2	Water Resources of Colorado River Basin, Feb, 1938; Workers on WPA Project 65-83-107																																								
3	142707 US Bureau of Reclamation, 1938						1																																		
4	Proposed Unit Plan, Development of Water Resources Green River Basin in Wyoming, April, 1938, State Planning Board											2						1																							
5	Appendix To The Report On Green River Basin Wyoming-Utah, May 1944; Bureau of Reclamation																																								
6	Summary of Available Information on Water Development Projects, Green River Basin in Wyoming, 1965, Bureau of Reclamation																																								
7	Report on Prelimnary Reconnaissance of Poential Reservoir Green River Basin Wyoming, July 1969; JT Banner and Associates, Inc.						1		2																																
8	Reconnaissance Geologic Report, New Fork Damsite, Upper Green River Investigations, Wyoming, Report No. G-271 , 1970 Bureau of Reclamation																																							Only dam	
9	Water and Related Land Resources of the Green river Basin, Wyoming, 1970, Wyoming wagter Planning Program						1																																	2	
10	Development of Presently Unused Water Supplies of the Green River Basin In Wyoming, 1972 Tipton and Kalmbach for State of Wyoming Department of Ecomonic Planning and Development																																								
11	Alternative Plans for Water Resource Developments Green River Basin, Wyoming, 1972, Bureau of Reclamation						1																																	2	
12	A Plan for Study of Water and its Relation to Economic Development in the Green River and Great Divide Basins in Wyoming, 1976 US Geological Survey																																								
13	Green River Basin, Wyoming, Cooperative River Basin Study, 1978, USDA											2								1																					
14	WWDC Pre-Feasibility Study of the Upper Green River Drainage Potential Reservoir Sites, January 12m 1983, ARIX												1		2	3																									
15	Green River Basin Plan 2001, States West										1			2																											
16	Green River Ground Water Recharge and Alternate Storage, Level I Project, December 2001, States West for WWDC.																																								
17	Upper Green River Storage Level II Study, February 2007; Klienfelder, Inc.																														2	3	1								
18	Kendall Reservoir, Upper and Lower Sites Near Warren Bridge, "WWDO, 2007						2		1																																
19	Middle Piney Reservoir Level II Study, 2009 States West Water Resources Corporation										1																														
20	Upper Green River Westside Storage Study, Level II, February 2009, Short Elliott Hendrickson Inc.											3				2										1						2			1			3			
21	Green River Basin Plan, December 2010 WWC Engineering												2																		3		1								
22	Green River Basin Summary of Potential Dam and Reservoir Projects Literature																																								

Table 6.3.1.1 Previous Reservoir Studies

Potential Reservoir sites

Site #	Proposed Reservoir Site Name	Comment	Status	Drainage/River	Section	Township	Range	Volume in Acre Feet	Use	Priority ranking from 2001 Basin Plan	*Previous Studies Addressing Site
1	Fish Creek		Proposed	Fish Creek, South Piney Creek	26	30	115	1,400	irr	2	13, 14, 15, 22
2	Fontenelle No. 1		Proposed	Fontenelle Creek	4	24	115	2,500	irr	2	2, 15, 22
3	Fontenelle Creek		Proposed	Fontenelle Creek	30	26	115	15,950	irr	2	13, 15, 22
4	Green River Lakes Enl.		Proposed	Green River	32	39	108	80,000 to 250,000	irr, pow	2	2, 15, 22
5	Green River Supplemental Supply Project		Proposed	Green River	4	33	110		irr	2	15
6	Kendall		Proposed	Green River	34	36	111	100,000	irr, ind, mun	3, 4	2, 3, 4, 5, 6, 7, 9, 11, 12, 15, 18, 22
7	LaBarge Meadows		Proposed	LaBarge Creek	8	29	116	4,800	irr	2	4, 13, 14, 15, 22
8	Lower Kendall		Proposed	Green River	4	35	111	77k-810k	irr, rec, wl, pow	3, 4	1, 2, 7, 18, 22
9	McNinch Wash		Proposed	North Piney Creek	10	30	113	5,600	irr	2	14, 15, 17, 21, 22
10	Middle Piney Lake		Proposed	Middle Piney Creek	8	30	115	4,200	irr	1	2, 4, 15, 19, 21, 22
11	North Piney Cr		Proposed	North Piney Creek	24	31	115	5,600	irr	2	2, 4, 13, 14, 15, 22
12	Sand Hill		Proposed	Middle Piney Creek or Middle Piney and S. Piney	36	30	113	14,100	irr	2	14, 15, 17,20, 21, 22
13	Sixty Seven Enl.		Proposed	North Piney Creek	17	30	112	5,600	irr	1	4, 14, 15, 22
14	Snider Basin		Proposed	South Piney Creek	11	29	115	4,300	irr	2	13, 14, 15, 22
15	South Cottonwood		Proposed	Cottonwood Creek	12	32	115	6,000	irr	2	14, 15, 21
16	Warren Bridge Res.		Proposed	Green River	4	35	111	33,400	irr	2	15, 22
17	Cottonwood No. 1		Proposed	South Cottonwood Creek	16	32	115	1,465	irr	2	4, 15, 22
18	Fogarty Creek		Proposed	Dry Piney Creek	24	28	114	700	irr	2	13, 15
19	Horse Creek		Proposed	Horse Creek	7	34	114	36,660	irr	2	13, 15, 22
20	LaBarge Reservoir		Proposed	LaBarge Creek	12	29	116	4,030	irr	2	2, 4, 15, 22
21	Middle Beaver Creek		Proposed	Middle Beaver Creek	29	36	112	5,905	irr	2	13, 15, 22
22	North Cottonwood Creek		Proposed	North Cottonwood Creek	24	33	115	10,805	irr	2	13, 15, 22
23	South Beaver Creek		Proposed	South Beaver Creek	24	35	114	5,905	irr	2	13, 15, 22
24	South Cottonwood Creek		Proposed	South Cottonwood Creek	11	32	115	10,805	irr	2	13, 15, 22
25	South Horse Creek		Proposed	South Horse Creek	30	34	114	36,660	irr	2	13, 15, 22
26	Straight Creek		Proposed	Straight Creek	4	30	115	4,815	irr	2	13, 15
27	Cottonwood Creek		Proposed	Cottonwood Creek		30 & 31	110 & 111	1,465	irr		2, 22
28	Fontenelle Res. #1		Proposed	Fontenelle Creek		24	115	2,507	irr		2, 22
29	Big Piney and LaBarge		Proposed			26 to 29	111 to 113				2
30	Horse Pasture Draw	North Horse Creek Drainge Off Channel Site	Proposed	North Horse Creek and South Horse Creek	16	34	113	5710 - 7,670	irr		17, 20, 21, 22
31	Mickleson Creek Res	South Cottonwood Creek Off Channel Site	Proposed	South Cottonwood Creek	11	32	114	6,010 -15,000	irr		17, 20, 21, 22
32	Cow Gulch Res	Beaver Creek Drainage Off Channel Site	Proposed	South Beaver Creek and Middle Bea ver Creek	4	35	112	13,330	irr		17, 21, 22
33	North Horse Creek		Proposed	North Horse Creek	1	34	114				20, 22
34	Haines Flat	Captures S Horse direct and North Horse Via Canal	Proposed	South Horse Creek	33	34	113	40,000	irr		20
35	North Cottonwood Creek SHE-5		Proposed	North Cottonwood Creek	14	33	114		irr		20
36	North Cottonwood Creek SHE-7		Proposed	North Cottonwood Creek	29	33	114		irr		20
37	Wiskey Creek	Off Channel	Proposed	North Piney Creek	19	31	113	20,000	irr		20
38	Fish Creek SEH-12		Proposed	Fish Creek and South Piney	35	30	110	20,000	irr		20
39	New Fork Narrows	Just Outside Basin	Proposed	New Fork	14	30	110	200,000	irr		7, 8, 9, 11, 12, 22
40	Geen River Lakes Enl		Proposed	Green River	2	39	109	100,000	irr		4,22

Table 6.3.1.2 Characteristics of Potential Reservoir Sites

Studies of the past decade have tended to rank about 12 to 13 sites high in the respective scoring. The changes in the sites studied reflect a trend toward finding permittable sites. These sites include several off channel sites and a few main channel sites:

Off Channel	On Channel
Horse Creek/Cottonwood Creek (Haines Flat Res)	Middle Piney Rehab
Cottonwood Creek (Mickelson Creek Res)	North Piney Creek
North Piney Creek (Wiskey Creek Res)	Snider Basin (South Piney Creek)
Sixty Seven Enlargement	Kendall Reservoir Sites
Beaver Creek (Cow Gulch Res)	
North Horse Creek (Horse Pasture Draw)	
McNinch Wash	
S. Piney and Middle Piney Creek (Sand Hill Res)	
Mickleson Creek	
Sand Hill	

The following Table 6.3.4 shows a short list of potential reservoir sites along with issues and features gleaned from previous studies that could impact feasibility.

Due to impacts associated with wetlands, migration corridors and conveyance ditches, instream flow, endangered species, depletion, etc., and expected permitting difficulty with mainstem sites such as the Kendall sites, and the relatively large cost of the project, the Kendall sites are not a favored alternative after reviewing the recent studies.

Table 6.3.4 Potential Reservoir Storage Sites

Site #	6	8	9	10	11	12	13
Proposed Reservoir Site Name	**Upper Kendall**	**Warren Bridge (Lower Kendall)**	**McNinch Wash**	**Middle Piney Lake**	**North Piney Cr**	**Sand Hill**	**Sixty Seven Enl.**
Location	On Channel	On Channel	Off Channel	On Channel but Existing	On Channel	Off Channel	Off Channel
Status	Proposed	Proposed	Proposed	Proposed	Proposed	Proposed	Proposed
Drainage/River	Green River	Green River	North Piney Creek	Middle Piney Creek	North Piney Creek	Middle Piney Creek or Middle Piney and S. Piney	North Piney Creek
Section	34	4	10	8	24	36	17
Township	36	35	30	30	31	30	30
Range	111	111	113	115	115	113	112
Volume in Acre Feet	340,000	77,000	5,600	4,200	5,600	14,500	5,600
Use	irr, ind, mun	irr, rec, wl, pow	irr	irr	irr	irr	irr
Priority ranking from 2001 Basin Plan	3, 4	3, 4	2	1	2	2	1
*Previous Studies Addressing Site	2, 3, 4, 5, 6, 7, 9, 11, 12, 15, 18, 22	1, 2, 7, 18, 22	14, 15, 17, 21, 22	2, 4, 15, 19, 21, 22	2, 4, 13, 14, 15, 20, 22	14, 15, 17,20, 21, 22	4, 14, 15, 22
Source	Green	Green	North Piney Creek	Middle Piney Creek	North Piney Creek	Piney Creek Drainage	North Piney Creek
Surface Elevation (NWS)	7680	7620	7230	8840	8118		
Irrigated Acres	71000[b]	71000[b]	6,000	8,827			
Average Annual Shortages							
Other Benefits	Flood Control, Recreation	Flood Control, Recreation	Recreation	Flood Control, Recreation	Flood Control, Recreation	Recreation	Recreation
Dam Type	Earth Fill	Earth Fill	Earth Fill	Earth Fill	Earth Fill	Earth Fill	Earth Fill
Conveyance	135 miles of canal and 15,000' tunnel crossing private and public land, roads, fences and other improvements.	135 miles of canal and 11,700' tunnel crossing private and public land, roads, fences and other improvements.	5 miles of canal to off channel site	Existing	None Required	3 miles of canal to off channel site	Existing
Geology	Glacial till-potentially unfavorable	Glacial till-potentially unfavorable	generally favorable	generally favorable	generally favorable	unknown	generally favorable
Land Ownership	BLM, Private	BLM, Private	BLM, Private	USFS	USFS	State- BLM-Private	Private and BLM
Inudated Acreage	9500	1100		250	264		
Inundated Infrastructure	Canyon Ditch headgate will be flooded. Service to this ditch could be lost during low water if headgate is damaged. Loss of productive meadows in pool area.	Canyon Ditch headgate will be flooded. Service to this ditch could be lost during low water if headgate is damaged. Loss of productive meadows in pool area.		None	Road innundation	Significant transportation, energy, and utility infrastructure	None
Cultural or Archaelological Impacts	One or more sites eligible for NRHP	One or more sites eligible for NRHP	No Mapped Sites	No Mapped Sites	No Mapped Sites	Lander Trail	One or more sites eligible for NRHP
Wetlands[a]	Significant impacts to riparian and wetland area along Green River; 4,700 acres	Loss of some riparian and wetland area along Green River; 75 to 120 acres	Few to None	1.5 acres innundated	Yes	minimal impact	Limited - 26 potential acreas created by lake
Threatened and Endangered	Some Sensitive Species	Some Sensitive Species	Some Sensitive Species	No impact on Whooping Crane or Canada Lynx, Potential T&E amphibians	Canada Lynx, Potential T&E amphibians	Limited Impact	Limited Impact
Sage Grouse	Core Area	Core Area	LEK in area	No impact	No Impact	LEK in area	No Mapped LEK, No mapped Core Area
Big Game Impacts	Yes; Pronghorn migration, Mule Deer Crucial Winter Habitat, Elk Winter Range, Year long Moose range	Yes; Pronghorn migration, Mule Deer Crucial Winter Habitat, Elk Winter Range, Year long Moose range	Moose Winter Range, Crucial Mule Deer Winter Range	Few to none	Moose Crucial Range	Mule Deer and Pronghorn Crucial Winter Range; Moose Winter Range	Moose Winter Range, Mule Deer Crucial Winter Range
Fish	Migration along Green, Colorado River Cutthroat, Innudation of adjudicated instream flow segment	Migration along Green, Colorado River Cutthroat, Innudation of adjudicated instream flow segment	Fish entrainment, Colorado River Cutthroat,	Fish Passage, Colorado River Cutthroat	Fish Passage, Colorado River Cutthroat	Fish entrainment, Colorado River Cutthroat, flanel Mouth Suckers, Bluehead Suckers, and Roundtail Chub	Fish entrainment,
Year of Most Recent Cost Estimate	2007	2007	2010	2009	1983	2007	1983
Cost at Date of Estimate	386,500,000[c]	247,000,000[c]	28,600,000	2,930,000	4,501,000	32,800,000	3,514,000
$ Cost in 2014 @3%/annum inflation	475,346,249	303,778,845	32,189,552	3,396,673	11,252,862	40,339,863	8,785,282
2014 $ Cost/ Acre Ft	1,398	3,945	5,748	809	2,009	2,782	1,569

Favorable for Project
Minimal Difficulty
Cost Permitting Impact
Caution Could be Potentitally Cost Prohibitive
Potential Fatal Flaw

[a] Some wetlands will be replaced at a ratio higher or lower than 1:1 such as 710 acres @30% = 210 mitigated acres

[b] These are not all existing irrigated acres but include 34,000 new potential acres that would be brought into production, which would trigger additional environmental scrutiny that may trigger additonal mitigation expense.

[c] Estimates ingnore costs of conveyance system appurtenances (farm turnouts, canal drops/energy dissapaters, inverted siphons, flumes or bridges and culverts at county or ranch road crossings), endangered species depletion fee assessment and easement and land acquisition costs.

Table 6.3.4 Potential Reservoir Storage Sites (Continued)

Site #	14	30	31	32	34	37
Proposed Reservoir Site Name	**Snider Basin**	**Horse Pasture Draw**	**Mickelson Creek Res**	**Cow Gulch Res**	**Haines Flat**	**Wiskey Creek**
Location	On Channel	North Horse Creek Drainge Off Channel Site	South Cottonwood Creek Off Channel Site	Beaver Creek Drainage Off Channel Site	Captures S Horse direct and North Horse Via Canal	Off Channel
Status	Proposed	Proposed	Proposed	Proposed	Proposed	Proposed
Drainage/River	South Piney Creek	North Horse Creek and South Horse Creek	South Cottonwood Creek	South Beaver Creek and Middle Beaver Creek	South Horse Creek	North Piney Creek
Section	11	16	11	4	33	19
Township	29	34	32	35	34	31
Range	115	113	114	112	113	113
Volume in Acre Feet	4,300	7,670	15,000	13,330	40,000	20,000
Use	irr	irr	irr	irr	irr	irr
Priority ranking from 2001 Basin Plan	2					
*Previous Studies Addressing Site	13, 14, 15, 22	17, 20, 21, 22	17, 20, 21, 22	17, 21, 22	20	20
Source	South Piney Creek	North Horse Creek	South Cottonwood Creek	Beaver Creek	Horse Creek/Cottonwood Creek	North Piney Creek
Surface Elevation (NWS)	7948	7635	7740 or 7795	7640	7659	7544
Irrigated Acres		15,151	20,200	11,500	35,100	17,900
Average Annual Shortages			7,950	2,793	21,000	11,100
Other Benefits	Flood Control, Recreation	Recreation	Recreation	Recreation	Recreation	Recreation
Dam Type	Earth Fill	Earth Fill	Earth Fill	Earth Fill	Earth Fill	Earth Fill
Conveyance	None Required	Off channel site requires canal	Canal from South Cottonwood to Reservoir Water delivered to Cottonwood Creek via 100 cfs canal	Supply canal from Beaver Creek and Supply canal from Cottonwood Creek for 5 total miles	Canals to Reservoir from Horse Ck (240 cfs) and Cottonwood (Ck 165 cfs)	None Required
Geology	unknown	Favorable but Cautious	Favorable but Cautious	Favorable but Cautious	Favorable	Marginal slope stablity surrounding pool
Land Ownership	USFS , State	State, Private	Private	Private	Private	Private
Inudated Acreage	180		576		1408	640
Inundated Infrastructure	USFS Road	Limited access two track inundated	Limited (one fence)	Shorth Access Road and Culvert Crossing	Slight to roads and some 707 acres of irrigated lands	Roads; 1.5 miles of power and phone; 403 irrigated acres
Cultural or Archaelological Impacts	One or more sites eligible for NRHP	No Mapped Sites	Few known sites	Few known sites	Few known sites	Few known sites
Wetlands[a]	Yes	Few to None	NWI = 407 acres @40%; 163 mitigated acres	92 acres	NWI = 710 acres @30%; 210 mitigated acres	NWI = 279 acres @60%; 167 mitigated acres
Threatened and Endangered	Potential T&E amphibians	Marginal Impacts to several species	Marginal Impacts to several species	Marginal Impacts to several species	Marginal Impacts to several species	Marginal Impacts to several species
Sage Grouse	No Mapped LEK, No mapped Core Area	Inside Fringe of Core Area	Core Area; one LEK at 1.4 miles	Core Area but no mapped LEK	Core Area but no mapped LEK	Core Area
Big Game Impacts	Elk Proturition	Year Long Moose Habitat, Elk Porturition	Some impacts to Moose	Potential Pronghorn Migration Issues	Few to None	Moderate impacts to Moose
Fish	Fish Passage, Colorado River Cutthroat	Fish entrainment	Fish entrainment	Fish entrainment	Fish entrainment	Fish entrainment
Year of Most Recent Cost Estimate	1983	2007	2009	2007	2009	2009
Cost at Date of Estimate	1,940,000	20,600,000	40,278,000	19,500,000	87,657,000	49,058,967
$ Cost in 2014 @3%/annum inflation	4,850,156	25,335,402	46,693,241	23,982,540	101,618,488	56,872,789
2014 $ Cost/ Acre Ft	1,128	3,303	3,113	1,799	2,540	2,844
Favorable for Project		[a] Some wetlands will be replaced at a ratio higher or lower than 1:1 such as 710 acres @30% = 210 mitigated acres				
Minimal Difficulty						
Cost Permitting Impact						
Caution Could be Potentitally Cost Prohibitiv						
Potential Fatal Flaw						

Recent studies have demonstrated off channel sites and enlargement of existing reservoirs appear most favorable, largely due to environmental and permitting difficulties associated with damming mainstem channels. In addition, the tributary storage is located on drainages where shortages exist and the supplemental water can be put to beneficial use without the additional conveyance infrastructure. The early spring flow can be stored for use later in the season, when physical water in the steams is lacking for exchanges. The sites are located in the tributary drainages of South Cottonwood Creek, Middle Piney Creek, South Piney Creek, South Horse Creek, and South and Middle Beaver Creek. Based on preliminary data, the Middle Piney Lake project actually turned out to be the lowest cost project in terms of $/acre-foot. On Table 6.3.4 the top four sites in terms of $ cost/ acre-foot are:

1) Middle Piney Lake $809/ac.ft.
2) Snider Basin $1,128/ac.ft.
3) Kendall $1,398/ac.ft.*
4) Sixty Seven Enl. $1,569/ac.ft.

Other off channel sites that should be considered further due to favorable permitting and/or the potential for beneficial yeild include:

5) Cow Gulch Res. $1,799/ac.ft.
6) Sand Hill $2,782/ac.ft.
7) Mickleson Creek $3,113/ac.ft
8) McNinch Wash $5,748/ac.ft.

**The low cost is due to an economy of scale that will likely not be realized due to a lack of purpose and need for the full volume of 340,000 acre-feet. The final size of the Kendall project will be smaller with a corresponding increase in per acre ft. cost.*

The top five sites in terms of anticipated permitting ease are:

1) Middle Piney Lake
2) Sixty Seven Enlargement (McNinch Wash)
3) Horse Pasture Draw
4) Mickleson Creek
5) Sand Hill

VIII. FUNDING OPPORTUNITIES

Multiple funding sources exist to assist with the cost of project implementation. Selection of the proper program(s) can result in a significant portion of the cost being covered by complimentary sources. Table 8.5 in Section 8 of the main study identifies County, State, Federal and non-profit oganizations, their programs and project type if projects funded.

IX. CONCLUSIONS AND RECOMMENDATIONS

"The number one resource concern associated with range management in the study area is water availability" (Pers. Comm. Karen Clause, Pinedale NRCS Field Office, 2013). There are many different types and applications of upland water developments, and the particular design that is selected is highly dependent on local needs, conditions, and available funding. Upland livestock watering systems typically include spring developments, wells, pumps, tanks, diversions, or gravity feed systems. These types of water projects can be mutually beneficial for range health, wildlife, and livestock.

Within the Upper Green River watershed study area additional opportunities exist to improve upland water availability for livestock and wildlife. The potential projects range from simple spring developments to reservoirs with piped distribution to multiple tanks and troughs. Many opportunities lie on public lands and agency involvement is required for permitting. Agencies may also present opportunity for partnering on projects that improve range and offer wildlife watering opportunities. Partnering could take the form of design and permitting support or even financial participation.

The basin-wide channel morphology classification identified numerous disequilibrium channel reaches and areas of morphologic concern based upon channel condition and valley setting. High width/depth ratio Rosgen C-type channels are prevalent within the Upper Green River watershed study area. These stream reaches may benefit from aquatic habitat enhancement projects that incorporate bank stabilization, channel narrowing, and/or width/depth ratio reduction.

Environmental conditions and constraints vary by location, but the following general BMPs for range management can be implemented in concert with the ESD state and transition models to accomplish management objectives:

1) Upland (i.e., off-site) livestock watering systems;
2) Strategic salting and/or herding;
3) Riparian fences to exclude livestock from, or manage livestock use of, riparian areas;
4) Pasture fences or cross-fences to facilitate rotational grazing systems;
5) Prescribed fire; and
6) Chemical brush control.

Potential opportunities for irrigation projects identified in this study are associated with primary conveyance systems. Identified projects included piping canal sections, combining head gates, and repairs to troubled spots on canals.

The Upper Green Watershed produces excess water that could be beneficially utilized with additional storage capability. Reservoir sites range from small sites (4,000 acre-feet) of local significance to larger sites (over 100,000 acre-feet). The smaller sites tend to be located in tributary basins and off the channel of the tributaries. The smaller off channel sites are favored in terms of permitting. Permitting of any of the sites will be rigorous with the main stem sites being the most difficult. Mitigation measures will be required for any site. In terms of cost and permitting ease, Middle Piney Lake ranks as the best opportunity with the Sixty Seven Enlargement ranking second.