RECLAMATION
Managing Water in the West

Henrys Fork Watershed Basin Study Water Needs Assessment

Technical Series No. PN-HFS-001

U.S. Department of the Interior
Bureau of Reclamation
Pacific Northwest Region
Pacific Northwest Regional Office
Snake River Area Office
Boise, Idaho

October 2012

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Photograph on front cover: View of Teton Mountain range and Henrys Fork watershed.

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1.0 INTRODUCTION

The Bureau of Reclamation (Reclamation), in cooperation with the Idaho Water Resource Board (IWRB), developed this Henrys Fork River basin water needs assessment as part of the Henrys Fork Basin Study (Basin Study) which is jointly funded by the IWRB and Reclamation's WaterSMART Program. This needs assessment report will be used by the Basin Study workgroup to develop a range of alternatives that addresses water resources issues in the basin.

The Henrys Fork of the Snake River (Henrys Fork River) basin in southeastern Idaho has experienced population growth, urban development, irrigation needs, changes in climate, and drought conditions that have the potential to deplete water resources. The Henrys Fork River basin is a major tributary to the Snake River, contributing approximately one-third of the Snake River's flow in eastern Idaho. Located in the upper reaches of the Snake River, the Henrys Fork watershed provides irrigation for over 280,000 acres and sustains a world-class trout fishery. The Henrys Fork River overlays a portion of the Eastern Snake Plain Aquifer (ESPA) and supplies groundwater recharge to two shallow aquifers and the ESPA which are tapped for municipal/industrial and agricultural water uses. The ESPA region, which includes the southwestern corner of the Henrys Fork River basin, produces approximately 21 percent of all goods and services in the State of Idaho, resulting in an estimated value of $10 billion annually (IDWR 2009). Water is the critical element for this productivity.

The Basin Study workgroup is the Henrys Fork Watershed Council, made up of State and Federal agencies, irrigation entities, conservation organizations, universities, and the farming community. The Henrys Fork Watershed Council is co-facilitated by the Fremont-Madison Irrigation District (FMID) and the Henrys Fork Foundation. The workgroup is collaborating to find alternatives that would improve the water supply reliability for irrigation water, municipal/industrial water supplies, power generation, groundwater recharge, and instream flows for fish and wildlife habitat.

The State of Idaho (State) is interested in water supplies from the Henrys Fork River and its tributaries to help improve water supply conditions in the ESPA and the Upper Snake River basin in accordance with the ESPA Comprehensive Aquifer Management Plan (CAMP). Continued conflict and litigation between groundwater and surface water users, water rationing/curtailment, increased power costs, and limited community growth resulting from depleted water supplies would adversely affect the economies of Idaho. In order to ensure certainty and sustainability of water supplies to meet current and future demands, the State identified a long-term goal to incrementally achieve a net water budget change of an additional 600,000 acre-feet annually to the aquifer water budget, with a short-term target of between 200,000 acre-feet and 300,000 acre-feet (IDWR 2009). Henrys Fork River basin may play a part in the budget change with contributions to the ESPA recharge.

The State requested assistance from Reclamation under the WaterSMART Basin Program in finding more water to meet the water needs of the State, to study the water supply in the Henrys Fork River of the Snake River, and to analyze options to help resolve in-basin and out-of-basin water supply issues. The request was elevated to the basin-level study that includes a comprehensive assessment of the water resources and hydrology of the Henrys Fork and their impacts to the ESPA. This Basin Study is intended to assist future planning efforts and provide specialized information that can be used in future decisionmaking processes at the State and local levels.

As an essential step in the WaterSMART Basin Program, this technical series report was developed and divided into four sections:

- Henrys Fork watershed hydrology (water supplies)
- Water supply and facilities (water infrastructure)
- Current water use in the Henrys Fork watershed (water demands)
- Future water needs in the Henrys Fork watershed (water demands with climate changes)

Objectives

This water supply and demand outlook for the Basin Study area provides information needed for evaluating different water resource management actions to be considered under the Basin Study. This technical series report identifies and quantifies current water supply and demands and how those water demands may likely change in the future in the face of climate change, urbanization, and other social factors. This information will be used in the Basin Study analyses when identifying opportunities for developing new water supplies and improving current water management through optimization and conservation while sustaining environmental quality. The water management issues being addressed by the Basin Study are complex and involve understanding surface/groundwater interactions and the interface with the larger ESPA.

Description of the Basin Study Area

Henrys Fork River System

The Henrys Fork River flows for 120 miles in the eastern part of Idaho, joining the upper Snake River from the north near Rexburg, Idaho (Figure 1). The Basin Study area encompasses approximately 3,300 square miles bound by high desert areas of the Eastern Snake Plain on the west and on the north by the Continental Divide along the Centennial and

Henry's Lake mountains. The Yellowstone Plateau and Teton Mountains form the eastern boundary and the southern boundary is marked by the Snake River. Elevations in the Basin Study area range from over 10,000 feet along the Continental Divide to approximately 4800 feet near Henrys Fork River's confluence with the Snake River.

Originating at Big Springs in the northern part of the basin, the mainstem of the Henrys Fork River flows generally southward, supplemented by water from tributaries flowing from the mountains to the east. The Henrys Fork watershed has four major subbasins: upper Henrys Fork, lower Henrys Fork, Fall River, and Teton River. The United States Geological Survey (USGS) identifies the upper Henrys Fork River watershed as hydrologic unit code (HUC) 17040202; the lower Henrys Fork River watershed as HUC 17040203; the Fall River is part of HUC 17040202 watershed; and Teton River watershed as HUC 17040204.

Three major storage reservoirs, six hydroelectric powerplants, and multiple irrigation diversions ranging from small pumps to large canal headworks regulate the flows in the basin. These facilities are discussed in detail later in this report.

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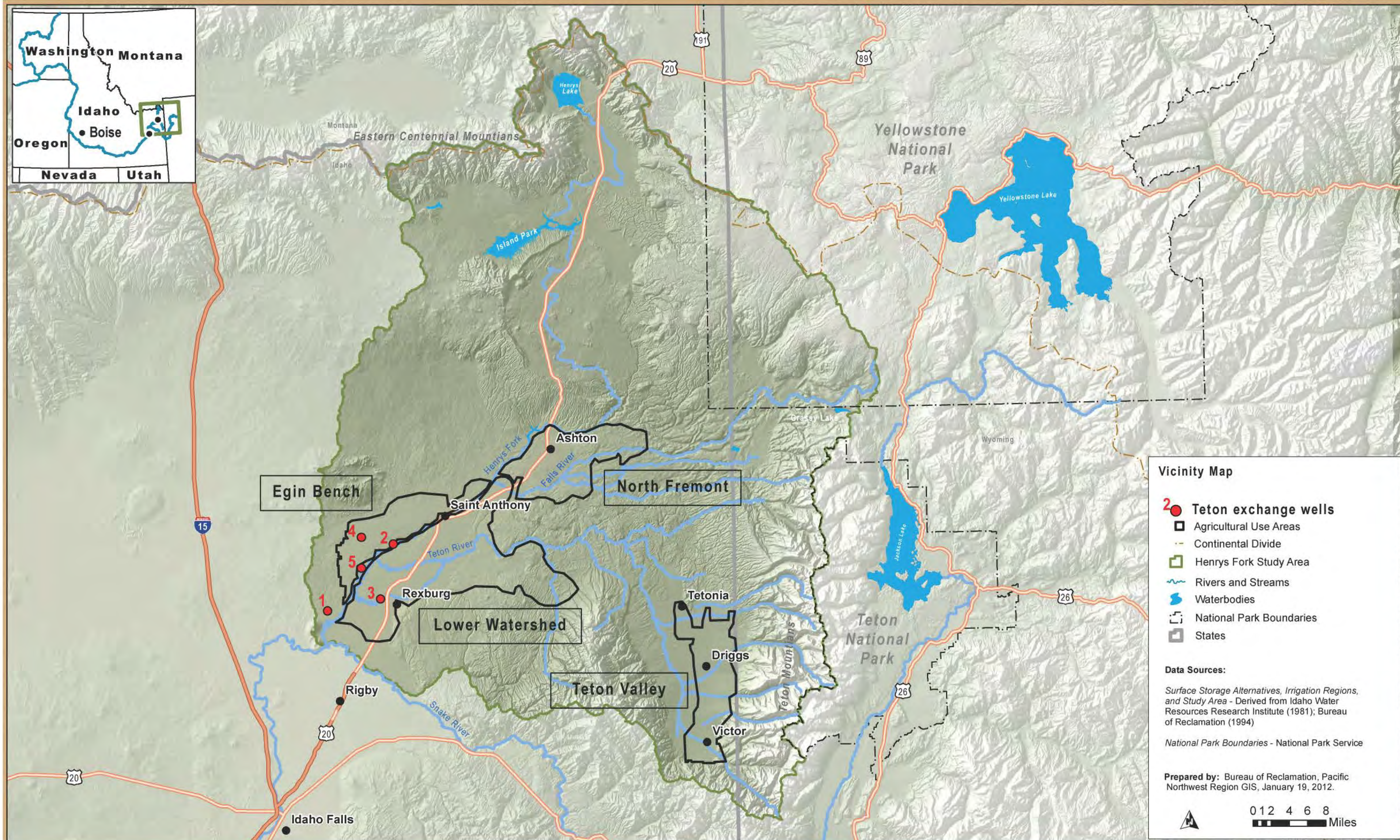
Henrys Fork Water Needs Assessment
Vicinity Map



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Historical Background

Once, only the ancestors of the Shoshone-Bannock people inhabited the Henrys Fork River watershed, using the area for hunting and fishing. Early in the 19th century, Andrew Henry, the fur trapper after whom the area is named, explored the watershed looking for beaver. Since the late 19th century when Euro-American settlers migrated to the area, water in the Henrys Fork River basin has been used for agriculture. In the early 1900s, farmers used the surface water/groundwater connection by diverting Henrys Fork River water to subirrigate on the Egin Bench which caused an increase of water in Mud Lake, a natural volcanic depression (Reclamation 1946). To increase irrigation capability in the upper Henrys Fork River basin, a dam was constructed in 1923 across the outlet of Henry's Lake to increase its storage volume.

The Minidoka Project was implemented by Reclamation to provide irrigation water in the upper Snake River and Henrys Fork River basins. Island Park Dam was constructed by Reclamation as part of the Upper Snake River Division of the Minidoka Project to provide supplemental water to irrigators who divert water from the Henrys Fork. Its construction in 1935 resulted in a water rights priority that is junior to downstream storage rights, including American Falls Reservoir and many natural flow diversion rights, including most Henrys Fork River diversion rights. As part of the upper Snake River system, Island Park is allowed to store water during the winter when its rights are priority. As American Falls Reservoir fills in late winter or during snowmelt in the spring, most of the water temporarily held in upstream reservoirs, including Island Park, can be reallocated to the reservoir where the water is held. In dry years, water may not be available for storage rights soon after April 1 when senior rights holders begin to divert surface flow.

Population

The 2010 Census recorded 13,242 people in Fremont County, 37,536 people in Madison County, and 10,170 people in Teton County (Census 2012). The average county population of the Basin Study area has increased by about 34 percent since 2000, with Fremont County population increasing 7.4 percent, Madison County increasing 39.9 percent, and Teton County increasing 55.7 percent (Census 2011). In Madison County, the expansion of Brigham Young University-Idaho has increased the population, making it the third fastest growing county in Idaho (Table 1; IDOL 2011a). Teton and Madison counties' pristine landscapes and proximity to Rexburg in Idaho and Jackson Hole and Yellowstone National Park in Wyoming have attracted many second homeowners (IDOL 2011a). To meet the needs of the growing population, farms and ranches have been subdivided into housing developments, many of which were platted on lands formerly irrigated for agriculture.

Table 1. Historic growth in the three-county area.

County	Population Growth Rate 1980-2006	Annualized Growth Rate 26 Years	Percent of Population in Henrys Fork Basin	Basin - Prorated Population Growth Rate
Fremont	14.4%	0.5%	24	0.12%
Madison	61.2%	1.85%	61	1.13%
Teton	170.6%	3.9%	15	0.59%
Estimated Basin Population – Annual Growth Rate 1980-2006				1.84%

Economy

Irrigated agriculture and its related food processing are the main economic activities in the Henrys Fork River basin (IWRB 1992), with the FMID lands generating over $100 million annually in crop sales (Reclamation 2004). The irrigated lands consist of highly productive soils which primarily produce grain, alfalfa, and potato crops (Table 2) and support dairy and beef operations (Table 3). Livestock water supplies come from irrigation canals or from livestock access to streams and springs.

Table 2. Acreages of major crops in 2010 (NASS 2012).

Crop	Fremont County (acres)	Madison County (acres)	Teton County (acres)	Estimated total of acres
Alfalfa	25,900	20,100	16,800	62,800
Barley	42,800	38,100	28,300	109,200
Potatoes	22,500	28,000	5,300	55,800
Winter Wheat	0	2,600	2,000	4,600

Table 3. Estimated number of cattle during 2010 (NASS 2012).

	Fremont County	Madison County	Teton County
Head of Cattle	13,100	11,100	8,200

In addition to agriculture, the largest employers in the Basin Study area are in the Leisure and Hospitality industry; the Trade, Utilities, and Transportation industry; the Educational and Health Services industry; and Federal, State, and local governments. Jobs in the construction industry from the Brigham Young University-Idaho expansion and the requisite trades industry have pushed economic growth in Madison County (IDOL 2011a).

The Henrys Fork River's reputation for world-class fly fishing and the National Forest lands that provide both summer and winter outdoor recreational opportunities draw tourists from all over the world, sustaining the tourism/recreation businesses in the area. In 2005, an economist at Colorado State University conducted an economic valuation of boating and fishing in the Upper Snake River (primarily Henrys Fork River, South Fork Snake River, and Upper Snake near Jackson, Wyoming) with a grant from Reclamation, Trout Unlimited, and the Henry's Fork Foundation. The valuation report stated that on the Henrys Fork River alone (Fremont and Madison Counties), angling contributed $29 million and 851 jobs to eastern Idaho's economy, and higher catch rates and larger fish would result in larger benefits to the rural communities, up to $49 million annually (Loomis 2005).[1] In 2010, wages in the tourism/recreation industries in Fremont, Madison, and Teton counties provided over 1,000 jobs and over $17 million in wages and almost $4 million in indirect wages (IDOL 2011b).

Fish and Wildlife

The Henrys Fork River basin supports wild populations of native Yellowstone cutthroat trout and nonnative rainbow trout and brown trout. The Idaho Department of Fish and Game (IDFG) operates the Henrys Lake Hatchery near the town of Island Park part of the year for egg collections from Yellowstone cutthroat trout for release into Henrys Lake. IDFG also operates the Ashton Hatchery.

Migratory Yellowstone cutthroat trout can be found in Henry's Lake, the Teton River, and the lower Henrys Fork River (DeRito 2012). Rainbow trout have displaced cutthroat trout throughout most of the main Henrys Fork River watershed and the Fall River drainage, but have not displaced cutthroat trout everywhere in the Teton River drainage. The reason for the difference is likely due to hydrology. Figure 2 illustrates the timing of rainbow and cutthroat trout spawning and fry emergence in relation to the peak flows in the Teton River at South Leigh Creek, the Henrys Fork River, and the Snake River. The Henrys Fork River hydrograph is representative of groundwater-dominated streams in the Henrys Fork basin while the Teton River at South Leigh Creek and Snake River at Heise hydrographs are representative of snowmelt-dominated streams in the Henrys Fork basin. Nonnative rainbow trout have difficulty reproducing in streams that have a high peak flow immediately before and during fry emergence because the peak flow displaces eggs and fry. The Yellowstone cutthroat trout fry generally emerge in late summer and early fall when they are not displaced by high flows. In the Henrys Fork, peak flows are low during rainbow trout egg incubation and fry emergence; consequently, rainbow trout have displaced cutthroat trout throughout most of the Henrys Fork watershed (Van Kirk and Jenkins 2005). In the Teton River drainage,

[1] Additional information can be found at in the Idaho Department of Fish and Game 2003 Economic Survey Report at https://research.idfg.idaho.gov/Fisheries%20Research%20Reports/Mgt08-129Grunder2003%20Economic%20Survey%20Report.pdf.

peak flows are high during rainbow trout egg incubation and fry emergence. It is assumed that this is why rainbow trout have been less successful in the Teton River Basin.

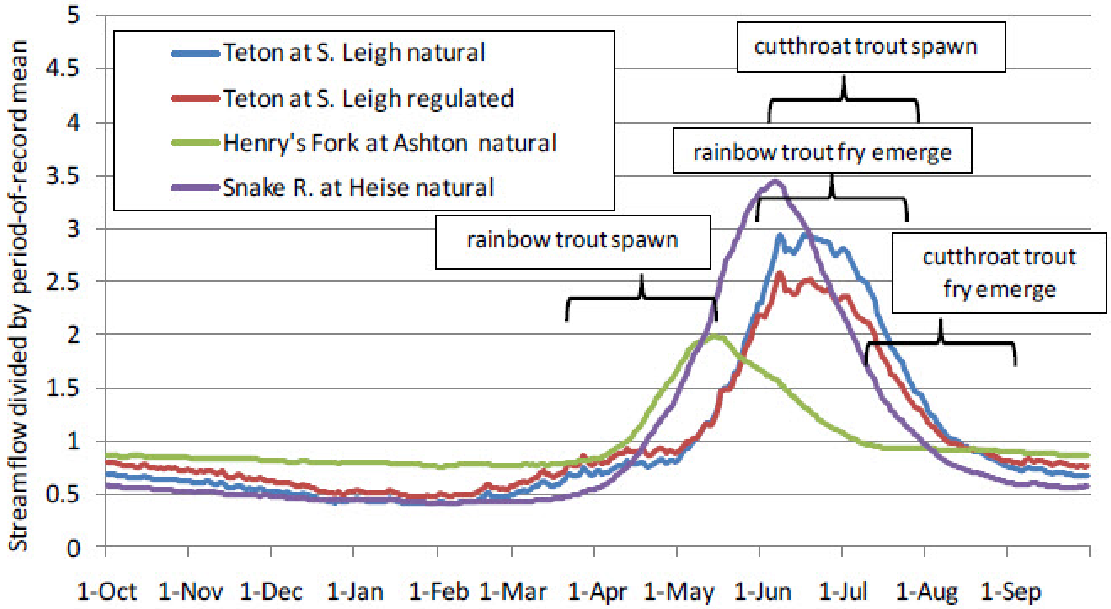


Figure 2. Mean hydrograph over water years 1972-2003 for Henrys Fork River basin streams (natural and unregulated), with spawning and fry emergence timings for rainbow trout and cutthroat trout shown (Van Kirk 2010a).

In the Teton River basin, the native Yellowstone cutthroat trout population decreased over the past 15 years while the nonnative rainbow trout population has increased (Van Kirk and Jenkins 2005); however, recent IDFG surveys suggest an increase in Yellowstone cutthroat trout populations. While the causes of the decline in Yellowstone cutthroat trout populations are unclear, human activities, the introduction of nonnative fish populations, the prevalence of whirling disease in the lower reaches, loss of habitat, and drought conditions are suspected of contributing to the decline (IDFG 2007).

The natural hydrology of the main Henrys Fork and Fall rivers is dominated by groundwater from the headwater springs on the Yellowstone Plateau. In the absence of large snowmelt freshets, there is essentially nothing in the physical or biotic environment to act negatively on rainbow trout. They have competitive advantages over cutthroat, and they hybridize with cutthroat. Without a snowmelt freshet to scour their eggs and fry during late spring, rainbow trout will displace cutthroat trout. In the Teton River watershed, the natural hydrology is driven by snowmelt, and the resulting spring freshet is large enough to limit rainbow trout spawning success. Hydrologic alteration of the rivers by the diversion of flows during the spawning times of the Yellowstone cutthroat trout may have also contributed to their reduced numbers (Van Kirk and Jenkins 2005).

As a result of the Yellowstone cutthroat trout population status, the IDFG has designated the Yellowstone cutthroat trout as a Species of Greatest Conservation Need (IDFG 2005). IDFG's Management Plan for Conservation of Yellowstone Cutthroat Trout in Idaho provides detail on Yellowstone cutthroat trout population status, distribution, habitat, history of endangered species act actions, threats, and management actions (IDFG 2007).

As part of the Greater Yellowstone Ecosystem, the Basin Study area provides habitat for a variety of large and small mammals and birds. Grizzly bears and lynx, both ESA-listed species, are found in the basin. Black bears, deer, moose, elk, and pronghorn also inhabit the forested uplands, grassland steppe, and canyons. Over 50 IDFG Species of Greatest Conservation Need are found throughout the watershed. Small mammals such as beaver, fisher, river otters, raccoons, marmots, bats, and a large variety of rodents are year-round residents across the entire Study Basin area. Fish in the rivers and creeks draw hawks, osprey, owls, kestrels, and eagles to nest in the area during the summers. Columbian sharp-tailed grouse are found throughout the watershed in suitable grassland steppe and agricultural habitats and are considered a species of concern by the U.S. Fish and Wildlife Service and a sensitive species by the U.S. Forest Service and Bureau of Land Management. Sage-grouse are found in isolated areas of the watershed and are a candidate species for Endangered Species Act listing by the U.S Fish and Wildlife Service. The northern goshawk has been seen in the Basin Study area and is considered a sensitive species by the U.S. Forest Service (Reclamation 2006).

The Henrys Fork River basin is located along a portion of the Pacific waterfowl flyway. Over a million waterfowl migrate through the area in spring and in fall, with large concentrations of ducks and geese around Island Park Reservoir and Henrys Lake. Trumpeter swans utilize the open waters of the Henrys Fork River basin, which is the primary wintering area for most of Canada's trumpeter swan population. While no longer listed as endangered or threatened under the Endangered Species Act, their populations are still rebuilding (IWRB 1992).

2.0 HENRYS FORK WATERSHED HYDROLOGY

The elements of a river's hydrologic regime are timing, frequency, magnitude, duration, and rate of change in flows. The geology of the watershed, along with climate and precipitation amounts, types, and timing, influence the hydrology of a region. In the Henrys Fork watershed, water storage and irrigation deliveries have altered river and stream hydrology in the Henrys Fork subbasin (Van Kirk and Jenkins 2005). This alteration is highest during low water years and greatest in the upper portion of the basin (Reclamation 2004).

The hydrology of the Henrys Fork watershed was studied through a U.S. Department of Agriculture grant to Humboldt State University. Modeling tools were created as part of the project to study the impacts that potential projects and water management decisions would have on the Henrys Fork River (Van Kirk 2011). These modeling tools were used in the analyses conducted for the Basin Study.

Geology

Geology in the Basin Study area was formed by volcanic cycles and flows that left the Island Park basin layered with primarily rhyolitic magma which fractured and allowed basaltic magma to erupt and flood the floor of the basin. The Island Park basin is part of a series of calderas that formed over a span of 2 million years (Christiansen 1982). The rhyolite formations are highly permeable, particularly in the upper 100 feet or in the highly fractured zones. Rainfall and snowmelt appear to rapidly infiltrate the formation so that little runoff or evapotranspiration occurs (IDWR 1978).

Outwash from glaciers during the Pleistocene scoured the highlands at the same time as basalt flows from vents south and west of the caldera covered some of the rhyolite flows. Flows from vents on the north and east of the caldera covered much of the eastern part of the study area. The alluvium fill that covers most of the basin is derived from the volcanic and sedimentary rocks from the adjacent highlands. In general, the alluvium fill is thickest in the area of Henrys Lake and thins as it goes south (Bayrd 2006).

There are three main aquifers in the Basin Study area which influence the flows in the Henrys Fork watershed, as well as a localized shallow aquifer. The Yellowstone Plateau Aquifer, formed of rhyolite, covers hundreds of square miles and is recharged by snowmelt. It discharges hundreds of thousands of acre-feet annually to the headwaters of the Henrys Fork River. The Teton Valley Aquifer, which is comprised of alluvial fan and basin-fill deposits, covers 90 square miles. Recharge to the Teton Valley Aquifer comes from stream channel, irrigation canal, and irrigation activity seepages (Bayrd 2006). The southwestern portion of the Basin Study area lies above the highest point of the ESPA, upstream from all points of use. The importance of recharge to the ESPA from the Basin Study area is described in detail later in this report.

Climate

The climate in the Basin Study area varies with elevation and proximity to the mountain ranges on the north and east. The headwaters of the Henrys Fork River are located in one of the coldest areas of Idaho, with minimum annual average temperatures of 22 °F in the winters to a maximum annual average of 52 °F in the summers. Freezing spring temperatures usually last through the first of June and start again in late August to early September, giving an average of about 60 to 70 frost-free days. Further downstream, the average temperatures around Rexburg range from an average annual maximum temperature of 57 °F to an average annual minimum temperature of 30 °F. Freezing spring temperatures usually end in May and start again in mid September to late October, giving an average of about 100 frost-free days (WRCC 2012).

Weather systems generally move across the Basin Study area traveling eastward from the Pacific Ocean. The orographic lifting of these systems as they pass over the Continental Divide causes an average of over 43 inches of precipitation in the headwaters of the Henrys Fork River above Island Park Dam. Average annual precipitation amounts decrease with distance from the mountains, with only about 14 inches falling at St. Anthony and Rexburg (WRCC 2012). Over 70 percent of the precipitation falls between November and May, mainly in the form of snow (Reclamation 1980).

Surface Water

Natural Flow Regime

River flows are described in terms of their mean annual natural discharge, which is defined as the measurement of the amount of water flowing past a specific point in a given period of time. As one of the largest tributaries to the upper Snake River basin, the Henrys Fork River is extensively measured at numerous gaging stations along the length of the river and its tributaries.

Under natural, unregulated conditions, the total watershed discharge would be around 2.5 million acre-feet per year (Table 4; Van Kirk 2011). The largest tributaries to the Henrys Fork River are the Fall River, adding about 700,000 acre-feet per year, and the Teton River which adds a natural discharge of over 600,000 acre-feet per year.

Table 4. Surface water supply, mean annual natural flows for Henrys Fork River basin (Van Kirk 2011).

Source	Segment	30-Year Mean Annual Natural Flow (acre-feet)	30-Year Mean Annual Flow (acre-feet)	Percent of Total
Upper Henrys Fork River			1,225,356	48.2%
	Henrys Lake	41,768		1.6%
	Henrys Lake to Island Park	439,072		17.3%
	Island Park to Ashton	744,516		29.3%
Fall River			699,914	27.5%
Teton River			618,863	24.3%
	Teton Above S. Leigh	304,084		12.0%
	Teton S. Leigh to St. Anthony	314,779		12.4%
Total Henrys Fork River watershed			**2,544,133**	**100.0%**

Current Flow Regime

The natural flow regime of the Henrys Fork River has been altered by irrigation diversions, increased evapotranspiration of irrigation, water storage, and canal conveyances. The mean annual basin outflow over the past 30 years is about 1.6 million acre-feet, which is probably less than the basin's outflow would be under "natural" hydrologic conditions (Figure 3). However, modeling shows that the lower Henrys Fork River would be a losing reach in the absence of irrigation return flow, so that under natural conditions, the basin outflow would still be somewhat less than the supply of 2.5 million acre-feet, due to river seepage to the regional ESPA (Van Kirk 2012a).

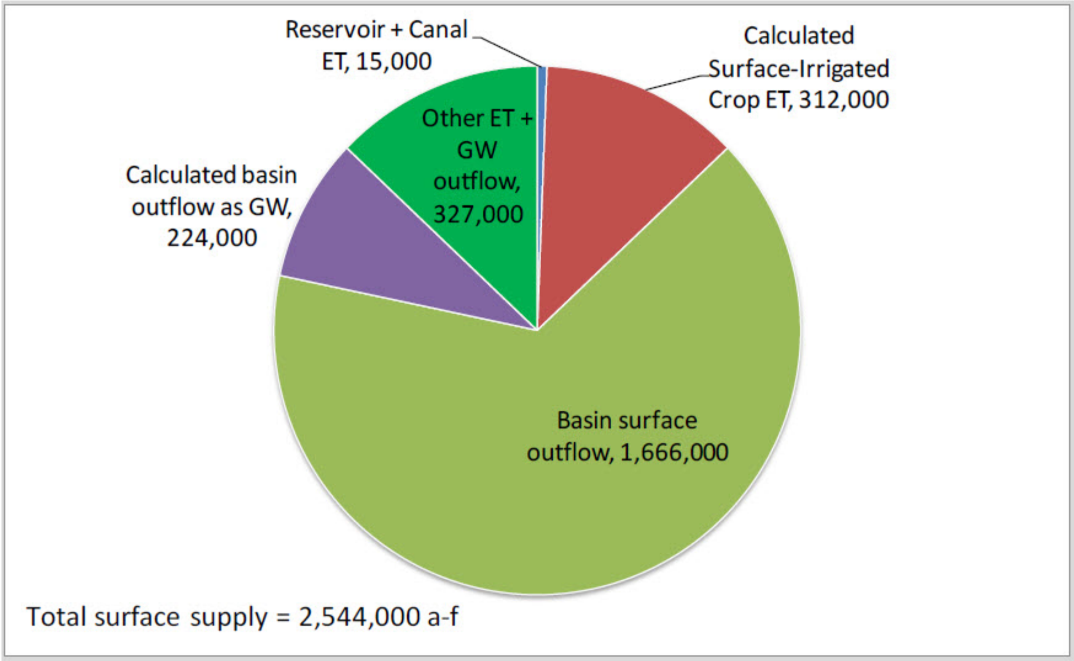


Figure 3. Water budget for Henrys Fork River basin surface supply (Van Kirk 2011). ET denotes evapotranspiration and GW denotes groundwater.

Figure 4 and Figure 5 show the average monthly flows of the Henrys Fork and Teton rivers gaging stations, and Figure 6 shows the mean annual discharge of the Henrys Fork River at Rexburg. The Henrys Fork reach between Ashton and Rexburg is a gaining reach for most of the year, with gains that range from about 500 cubic feet per second (cfs) in October to over 2,000 cfs in May. During July, August, and September, irrigation diversions exceed gains from the aquifer and tributary inflows, and the flow at Rexburg is less than at Ashton.

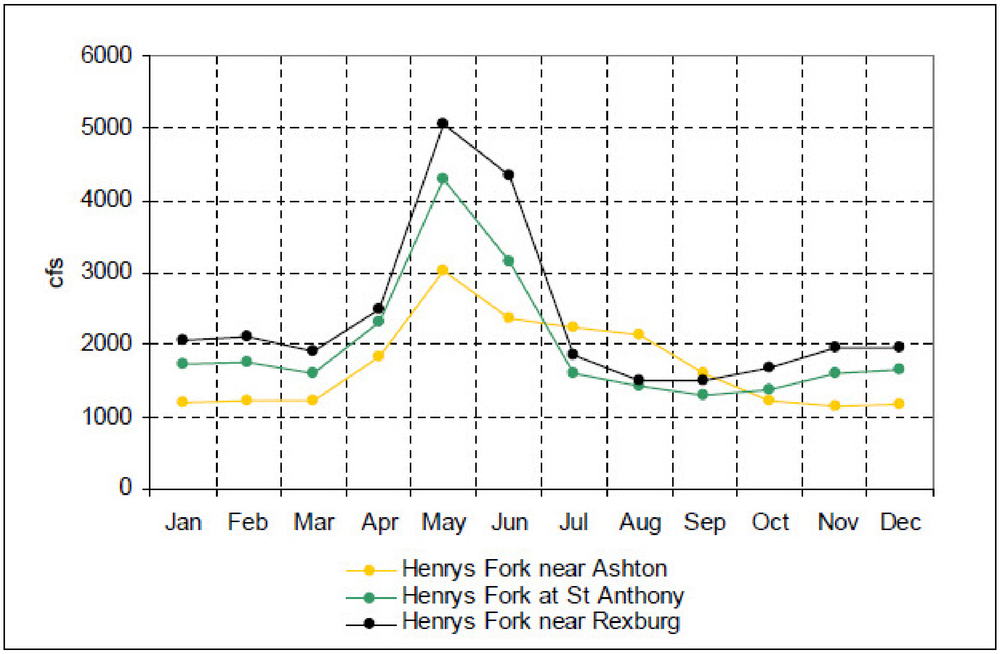


Figure 4. Average monthly flows at three gaging stations on the Henrys Fork River from 1977 to 2002 (Reclamation 2004).

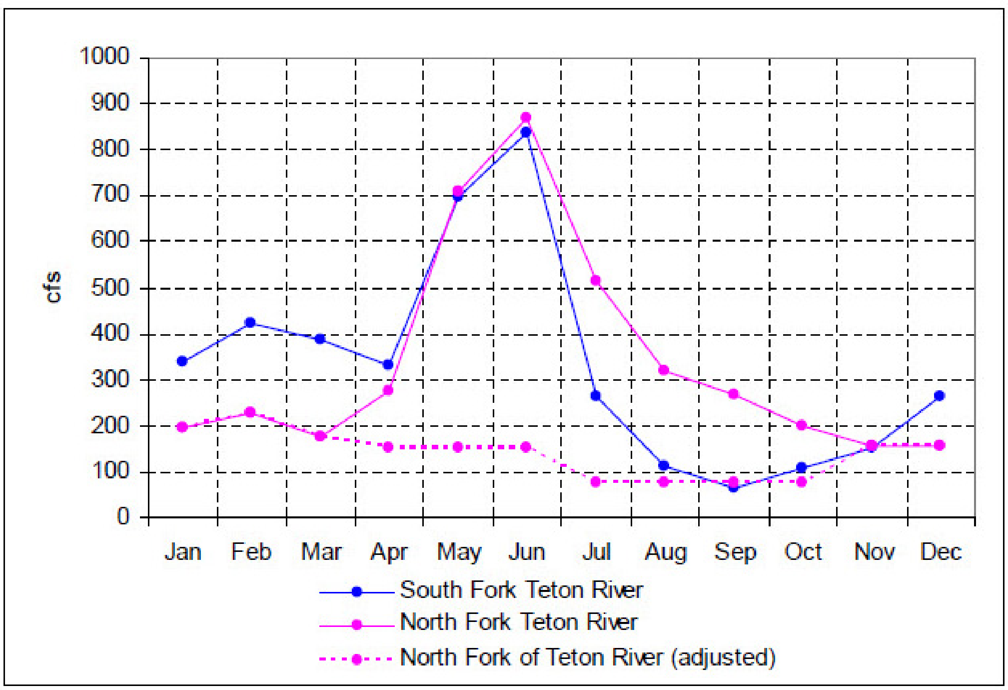


Figure 5. Average monthly flow in the Teton River (from gaging stations at Rexburg and Teton, respectively) from 1977 to 2002 (Reclamation 2004). For the North Fork of the Teton River, the diversion estimates were adjusted for the Teton Island Feeder canal and other canals downstream from the gage.

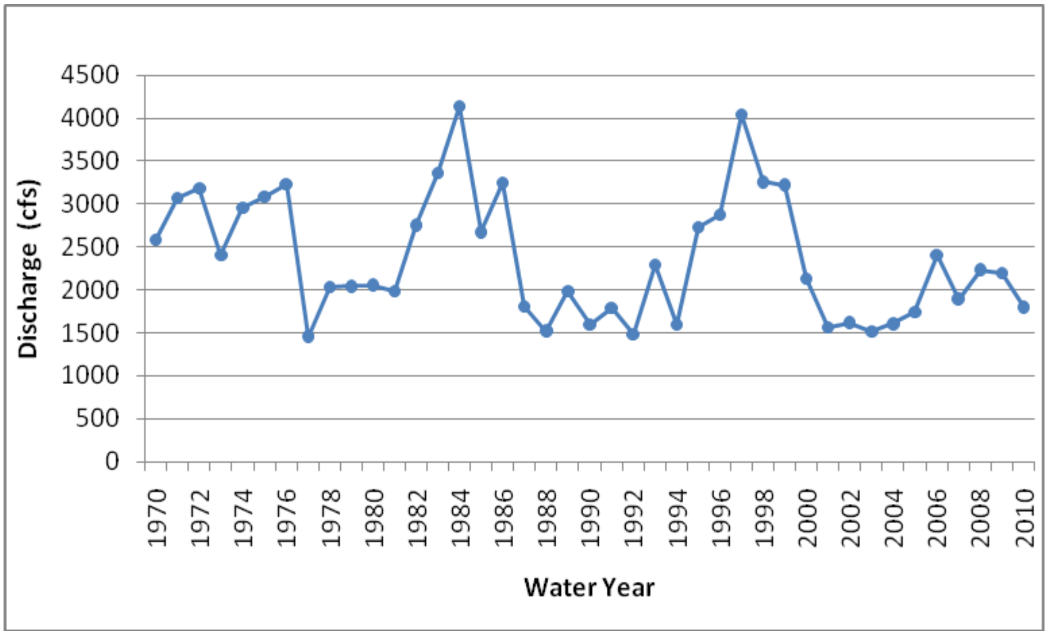


Figure 6. Mean annual discharge (cfs) in the Henrys Fork River near Rexburg (USGS 2011a).

Groundwater

The Henrys Fork River watershed exhibits a high degree of surface water and groundwater interaction both spatially and temporally. The rhyolite aquifer of the Yellowstone Plateau and the basalt aquifer of Island Park play a role in the natural flow regime of the Henrys Fork at Ashton. Because it is a groundwater dominated system, it exhibits both lower seasonal variation and greater resilience to drought than a snowmelt dominated system. Peak surface water flows generally occur in early summer as the weather warms and the snowpack melts in the higher elevations (Figure 7). Groundwater discharge that results from irrigation recharge increases river flows during the winter; however, with the advent of sprinkler irrigation practices and the conversion from flood to sprinkler irrigation methods that took place from 1980 to 1990, the winter flows have declined (Van Kirk 2012b). Aquifer recharge from irrigation system seepage is a major component to the Henrys Fork watershed hydrology. Of the amount of flows currently diverted from the rivers in the Basin Study area, almost 25 percent is converted from surface water into groundwater when seepage from reservoirs, rivers, conveyance systems, and irrigation enters the aquifers (Figure 3; Van Kirk 2011).

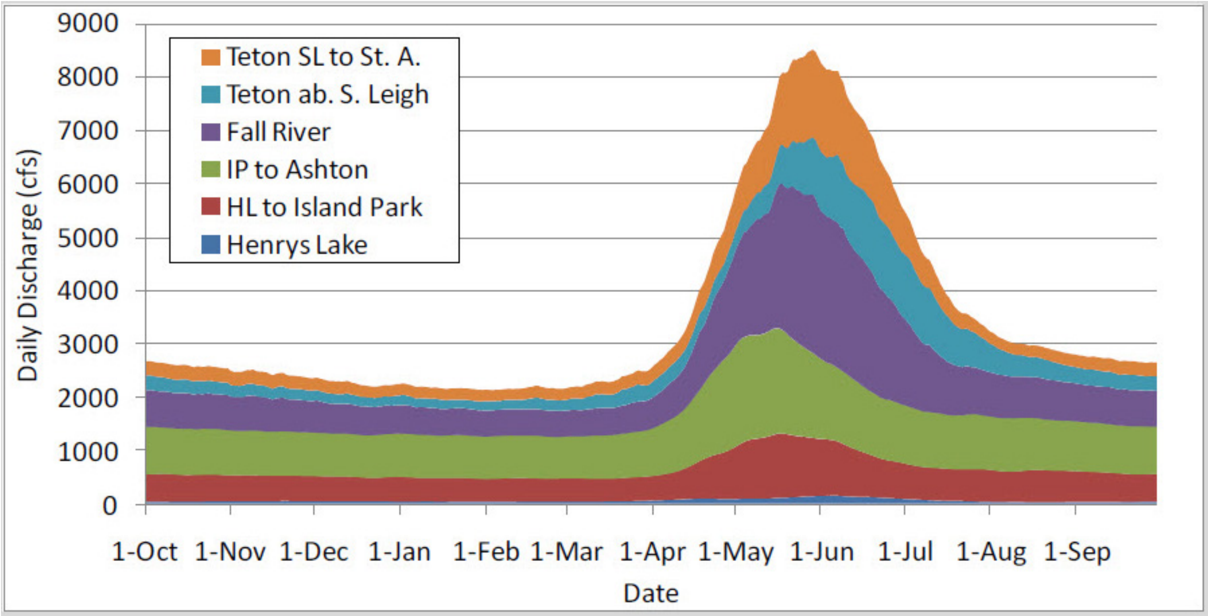


Figure 7. 30-year mean flows and river reach contributions to flows on the Henrys Fork River measured at the Rexburg gaging station (Van Kirk 2011).

Groundwater gains in the Henrys Fork River occur throughout the year, demonstrating that the aquifer is hydraulically connected to the river. As shown in Figure 8, groundwater gains are lowest in the winter months, rapidly increase at the start of the irrigation season in May and June, and gradually taper off during the remainder of the season. The gains peak early in the irrigation season, suggesting that some of the groundwater flow paths between FMID irrigated lands and the Henrys Fork are relatively short (Reclamation 2004).

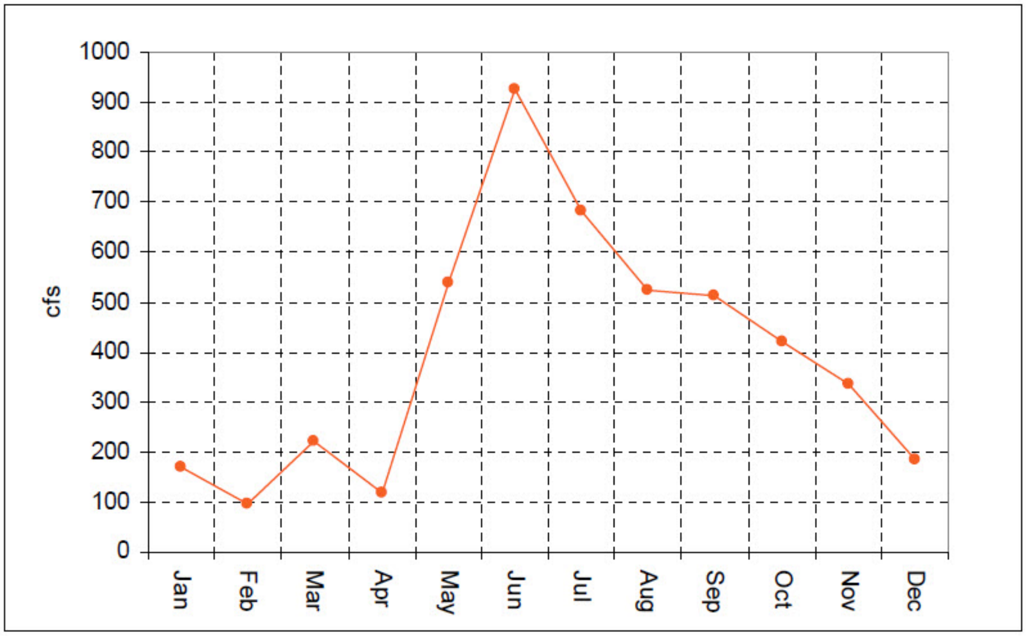


Figure 8. Computed average monthly gains from groundwater to the Henrys Fork Reach between St. Anthony and Rexburg from 1977 to 2002 (Reclamation 2004).

The highly localized shallow aquifer system connects directly to surface water flows above the confluence of the Henrys Fork River with the Snake River. A little more than 40 percent of the flow of the Henrys Fork River at Ashton is due to the groundwater sources, illustrating the strong connection between the river flows and groundwater recharge (JPC 2005). Groundwater discharge to the Henrys Fork River below St. Anthony ranges from about 80,000 acre-feet per year (IDWR 1999) to about 285,000 acre-feet per year (Reclamation 2004; Figure 8).

Recharge from irrigation seepage to the Teton Valley Aquifer and localized shallow aquifers is greater now than it was prior to irrigation development, but is less than the recharge during the early and mid-1900s when the irrigation systems were first constructed with unlined canals and laterals with high seepage rates. In the late 1970s, some of the canals were lined and sprinkler systems were installed which increased the efficiency of water use, resulting in less recharge to the aquifer from irrigation sources (Van Kirk 2010a). Ongoing research in the basin may further document the importance of irrigation seepage to the hydrologic system in the Henrys Fork River basin.

Eastern Snake Plain Aquifer (ESPA)

The ESPA, which extends into the southwestern corner of the Basin Study area, is located in basalt and interbedded sediments of the eastern Snake River Plain. Recharge to the ESPA comes from stream channel and irrigation seepage and then discharges primarily at Thousand Springs on the Snake River. Its discharge is higher now than it was historically due to the increased seepage from irrigation systems above it; however, recharge in the ESPA has also decreased since the mid-1900s due to more efficient irrigation delivery systems (Bayrd 2006).

Of the 2.1 million irrigated acres on the eastern Snake River Plain, 871,000 are irrigated by surface water, 889,000 acres are irrigated from groundwater, and 348,000 acres are irrigated from both sources. Additionally, municipalities, food processing facilities, aquaculture facilities, hydroelectric power generation, recreation, and fisheries are dependent on surface water and groundwater within the ESPA (IDWR 2009).

The surface water and shallow groundwater flows in the Henrys Fork River are connected with and provide recharge to the ESPA. The recharge to the ESPA from irrigation activity in the Basin Study area represents more than 10 percent of the regional aquifer's total recharge, entering the upstream end of the aquifer (Reclamation 1991).

3.0 Water Supplies and Facilities

Surface Water Storage and Appurtenant Facilities

Water supplies are dependent on the annual precipitation in the region and fluctuate with dry or wet years. To help mitigate the swings in water supplies, water is stored in three reservoirs in the Basin Study area (Henry's Lake, Grassy Lake, and Island Park Reservoir) to supplement low flows later in the year and meet the downstream needs. Water storage in the three reservoirs occurs primarily with base flows in the winter and is accomplished under Idaho's prior appropriation doctrine.

Henry's Lake and Dam

In the early 1920s, the North Fork Reservoir Company (NFRC) constructed a dam across the outlet of the natural Henrys Lake to increase the storage capacity of the lake and supply irrigation water to the St. Anthony area. NFRC owns the dam and reservoir, and operates the 90,000 acre-feet of storage in conjunction with the Minidoka Project.

Grassy Lake Dam and Reservoir

Constructed and operated by Reclamation, Grassy Lake Dam is located on Grassy Creek in Wyoming near the southern edge of Yellowstone National Park. Its storage capacity of 15,500 acre-feet provides supplemental water for FMID. No releases are made during the winter and summer releases are made on demand, usually in July and August. Additional releases may be made in late summer, if needed, to draft Grassy Lake to its winter operation level of 12,200 acre-feet.

Island Park Dam and Reservoir

Island Park Dam and Reservoir was constructed by Reclamation and is currently operated by the agency as part of the Minidoka Project. Island Park Dam, located on the Henrys Fork River, has a total storage capacity of 135,500 acre-feet. April is normally the fill target for the reservoir. Releases from the reservoir are made in consultation with FMID based on water supply, reservoir carryover, and irrigation demand. Releases during irrigation season are generally maintained at 1,200 cfs at the St. Anthony gage, but during years of low runoff, an operating target of 1,000 cfs is moved downstream to the Rexburg gage. Winter releases are determined in October or early November based on carryover storage and fall inflow.

In 2003, Congressional legislation included a stipulation that allowed adaptive management of Island Park Dam so that all water uses were considered in determining the flow releases. A

Drought Management Plan was developed to provide a strategy for addressing the needs of the watershed, including irrigation and fisheries, even in years of below-average precipitation. As part of the Drought Management Plan begun in 2005, Reclamation and FMID consult with local interest groups and State and Federal agencies in setting the timing and quantity of winter flows in the Henrys Fork River below Island Park Dam, based on reservoir carryover and current and predicted precipitation. Winter flows may be passed out of Island Park Dam and stored in American Forks Dam without shorting irrigation needs for the next irrigation season, allowing higher late winter flows below the dam which are critical to juvenile fish survival. Ramping rates and schedules are in accordance with the project's Federal Energy Regulatory Commission (FERC) license.

Cross Cut Diversion Dam

The Cross Cut Diversion Dam diverts water from the Henrys Fork River between Ashton and St. Anthony, immediately below the confluence with the Fall River. The dam is a concrete weir that raises the water level 10 feet above the streambed. The canal that runs from the dam carries irrigation water to 112,000 acres in Fremont and Madison counties, in part via the Teton River.

Teton Exchange Wells

In the early 1970s, Reclamation drilled five wells to serve the Lower Teton Division of the Teton Basin Project. In 1977, FMID and Reclamation entered into a contract to allow use of the wells as a supplemental water supply in exchange for the water that would have been stored behind the failed Teton Dam. During low water years, FMID pumps up to 30,000 acre-feet of water from the wells into the lower Henrys Fork River, the lower Teton River, and the North Branch Independent Canal to increase the water supply. Although the well water is discharged directly into the Henrys Fork River, it does not provide a net benefit to the instream flows, but replaces storage water that was released from Island Park Reservoir for irrigators downstream from FMID.

In 2004, Reclamation transferred title to the canals, laterals, and other components of the water distribution system; Cross Cut Diversion Dam; the Cross Cut Canal; and the five Teton Exchange Wells to FMID. Although the well permit allows for additional well developments, FMID has agreed to limit well expansion to supply a maximum of 80,000 acre-feet per year during low water years. The wells have only been developed to deliver 30,000 acre-feet. Exchange well pumping and additional exchange well development may impact the Henrys Fork River and Snake River by slightly decreasing river flows.

Groundwater Storage

Starting in the late 1800s, water was diverted from the Henrys Fork River near St. Anthony for lands on the Egin Bench west of the river. The water percolated so quickly in the sandy soils that little reached its intended destination. Soon, however, it was learned that these irrigation attempts elevated the local water table into the root zone. Utilizing this geologic phenomenon, pioneer farmers developed a subirrigation practice which carefully managed this shallow aquifer created by irrigation diversions. In 1943, approximately 434,000 acre-feet was diverted from the Henrys Fork River to the Egin Bench where the water table was held approximately 6 to 18 inches below the surface. Approximately 65,700 acre-feet were measured as return flows to the river and the remaining amount was consumptive use or recharge to the ESPA (Reclamation 1946).

As stated in the previous chapter, the interaction between surface water and groundwater is strong in the Basin Study area. Using the large aquifers of the region as underground reservoirs has been extensively studied, but mostly in regard to recharging of the ESPA (IDWR 1999). Decreasing recharge volumes to the aquifers because of increased irrigation efficiency and increases in groundwater pumping have lowered groundwater levels in the Basin Study area and in the ESPA.

Pursuant to legislative direction, the IWRB operates the Managed Aquifer Recharge Program (Recharge Program) in the ESPA. The Recharge Program provides a mechanism to evaluate and support the development of managed recharge capacity with the goal of stabilizing the ESPA. The IWRB seeks to stabilize the ESPA through the use of managed recharge, together with other measures as laid out in the ESPA CAMP. From 2009 through 2011, IWRB-sponsored managed recharge in the ESPA totaled almost 303,948 acre-feet, or 101,316 acre-feet on average, at a cost of over $900,000.

Between 1970 and 1974, the Idaho Water Resource Board undertook a pilot program in the Egin Bench region of the Henrys Fork watershed that concluded that recharge from the Egin Lakes site was achievable at an average infiltration rate of approximately 0.5 acre-foot per day. This pilot program was intended to evaluate the use of managed aquifer recharge at the Egin Lakes location to recharge on the ESPA. From 2009 through 2011, approximately 13,620 acre-feet of water was delivered by FMID to the Egin Lakes as part of the IWRB's operational ESPA recharge program, where groundwater levels were monitored by well and spring observations (IWRB 2012b).

Due to concerns about how to optimize the benefits of managed recharge to the ESPA, the IWRB authorized continuation of the managed recharge program in conjunction with a monitoring program on January 27, 2012. The monitoring program will be designed by the Idaho Water Resources Research Institute to verify the effects of managed recharge, and the results will be used in future actions regarding managed recharge to the ESPA.

Hydropower Facilities

Hydropower generation facilities in the basin are located on the Henrys Fork River (Island Park Dam, Chester Dam, and Ashton Dam), the Teton River (Felt Hydro), the Fall River (Marysville Hydro), and the Buffalo River (Buffalo River Dam). A new hydroelectric facility at the Cross Cut Canal provides additional hydropower generation.

The hydropower generating facilities on Island Park Dam were constructed between 1992 and 1994. The Fall River Rural Electric Cooperative owns the 4.8 megawatts facility that has been certified as a low impact structure by the Low Impact Hydropower Institute (LIHI 2012).

The Ashton Dam hydropower facility is the oldest power-generating structure, built in 1914 and expanded in 1925. The dam has a capacity of about 7 megawatts and is operated by PacifiCorp Energy (RMP 2012). Rehabilitation and improvement construction activities are currently ongoing at the dam to upgrade the structure and remove safety risks. The facility was certified as a low impact structure by the Low Impact Hydropower Institute in 2010 (LIHI 2010).

The Buffalo River Dam diverts a constant 100 cfs through a hydropower generating facility before discharging the flow to the Henrys Fork River. It generates 2,000 megawatts each year (FRREC 2012a). The Fall River Rural Electric Cooperative owns the project which was certified as a low impact structure by the Low Impact Hydropower Institute in 2006 (LIHI 2006). Fish passage improvements were made at the facility in 2005 and fish are monitored at the dam through a cooperative effort by Federal and State agencies and local organizations (HFF 2012a).

Chester Dam on the Henrys Fork River was built in 1938 to divert water into two canals on either side of river. From 2008 to 2012, the dam was retrofitted with a hydropower generating facility in conjunction with the installation of fish screens and a fish ladder to allow fish passage at the dam (FRREC 2012b).

Felt Hydro generates 7450 kW from the Teton River for the Fall River Rural Cooperative.

Marysville Hydro generates hydropower from the Marysville Canal on the Fall River and has an authorized capacity of 9,100 kW.

4.0 CURRENT WATER USE

Water is available for use only to the extent that flows exceed the demands of water users with priority water rights. Most of the water in the Henrys Fork basin is appropriated; however, new junior water rights may possibly be stored during high flows for short durations of time. Much of the water stored in Island Park Reservoir must be passed through the basin to out-of-basin senior rights holders. In accordance with spaceholder contracts for reservoir storage, water is stored in a manner that will maximize reservoir storage by keeping storage in the most upstream reservoirs. Under the Drought Management Plan, water may be passed downstream from Island Park Reservoir to American Falls Reservoir to increase late winter flows below the dam; consequently, water physically stored in one reservoir may actually belong to another reservoir.

Water professionals have developed quantitative models of groundwater and surface water use in the Henrys Fork River basin (Van Kirk 2011). Historical water supplies and uses were included in these studies to develop future strategies for increasing water availability for agricultural activities while enhancing environmental benefits within the basin (Van Kirk et al. 2011). One outcome of the studies was an estimation of the historical water supply and the current water budgets in the Henrys Fork watershed. The total water supply, computed as the mean annual rainfall over the total watershed area (30-year average) is 4,878,000 acre-feet. Almost half (2,333,600 acre-feet) of this water is lost to evaporation and deep groundwater on an annual basis and a little more than half (2,544,400 acre-feet) is measured as surface water (Table 5; Van Kirk 2011).

Table 5. Water budget for Henrys Fork River basin (Van Kirk 2011).*

	Component - Annual Values	**Value acre-feet**	
Surface Supply	Reservoir & Canal ET	15,000	
	Surface-Irrigated Crop ET	312,400	
	Basin Surface Outflow	1,666,000	
	Known Basin Outflow as Groundwater	224,000	
	Other ET & Groundwater Outflow	327,000	
		Total Surface Supply	**2,544,400**
Deep groundwater and non-irrigated ET		**Total deep groundwater and non-irrigated ET**	**2,333,600**

*The sum of the component uses equal total water supply at 4,878,000 acre-feet. ET denotes evapotranspiration.

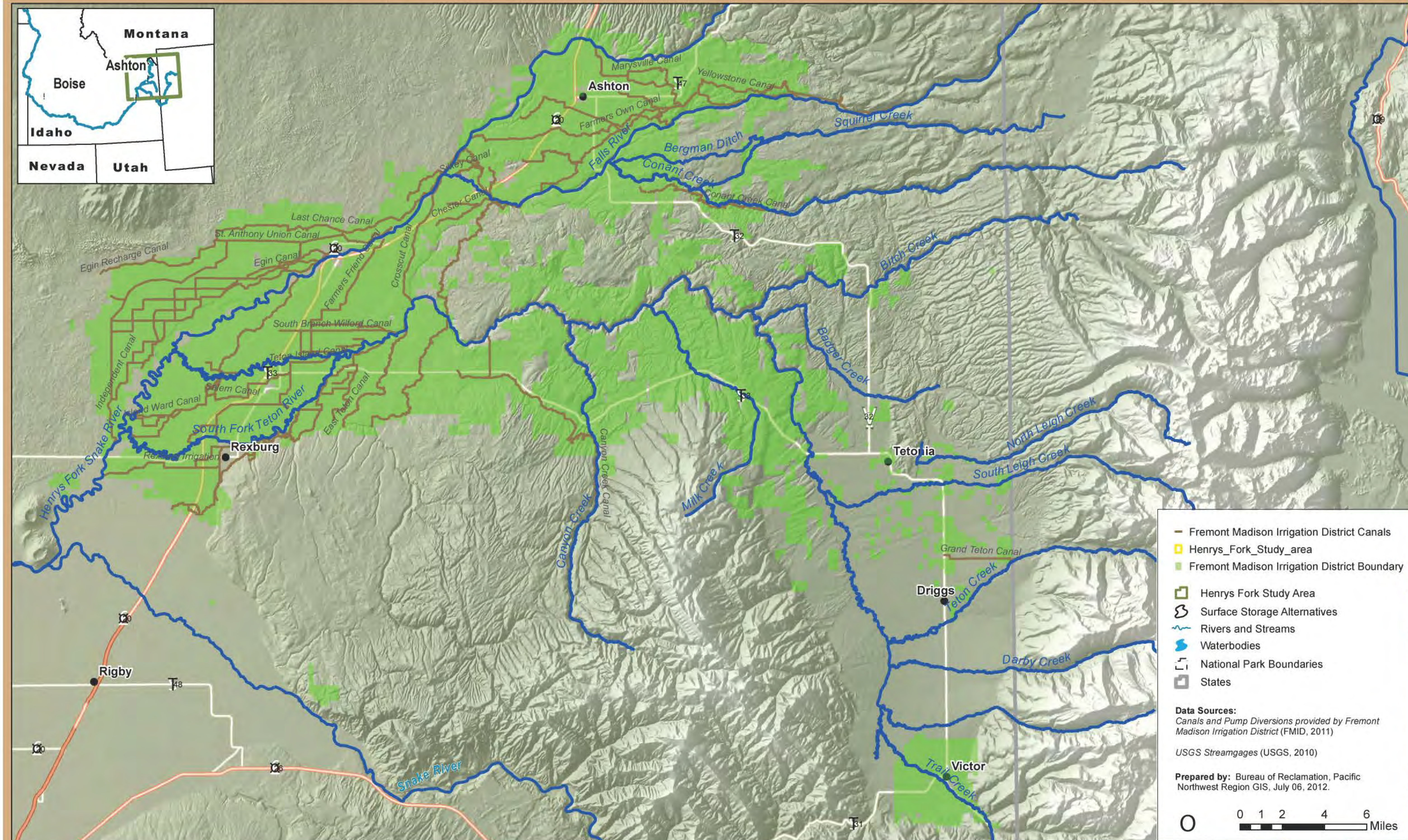
Agricultural Water Use

FMID was formed from numerous small irrigation companies across Fremont, Madison, and Teton Counties in eastern Idaho. FMID provides a supplemental water supply to about 1,500 water users irrigating over 285,000 acres associated with the original Upper Snake River Storage Division of the Minidoka Project and the Lower Teton Division of the Teton Project (Figure 9; Reclamation 2004). Irrigated acreage and irrigation methods have changed through the years, increasing the efficiency of water use. FMID estimates that over 70 percent of the acreage is sprinkler irrigated; the remaining lands are flood or subirrigated.

The four major irrigated regions shown in Figure 1 represent 77 percent (181,000 acres) of the irrigated lands in the Henrys Fork watershed. During years with drought conditions, many of the irrigators in the FMID have inadequate water supplies. A statistical analysis of all water years since 1972 showed that drought conditions occurred in one-third of those years. Water is usually stored as high in the basin for as long as possible during the winter which affects the critical winter and spring flows for optimal conditions for juvenile fish survival (JPC 2005). The Drought Management Plan allows some flows to pass to American Falls Reservoir to improve juvenile fish survival.

RECLAMATION
Managing Water in the West

Henrys Fork Water Needs Assessment
Freemont Madison Irrigation District Canal System



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The four irrigated regions currently divert over 1.1 million acre-feet of irrigation water (Table 6). Figure 10 shows the average daily flow for the four main diversions from the Henrys Fork between St. Anthony and Rexburg: the Egin Canal, the St. Anthony Union Feeder, the Independent Canal, and the Consolidated Farmers Ditch. Average monthly diversions of all four canals range from a low of 275 cfs during winter months to a high of almost 900 cfs during the irrigation season (Reclamation 2004).

Table 6. Summary of the four canal-irrigated regions.

Region	Irrigated acres	Average Annual Diversion (acre-feet)	Acre-Feet per Acre
Egin Bench	30,500	368,351	12.1
Lower Bench	73,000	641,724	8.8
North Fremont	32,500	41,681	1.3
Teton Valley	45,000	81,161	1.8
Totals	181,000	1,132,917	6.3

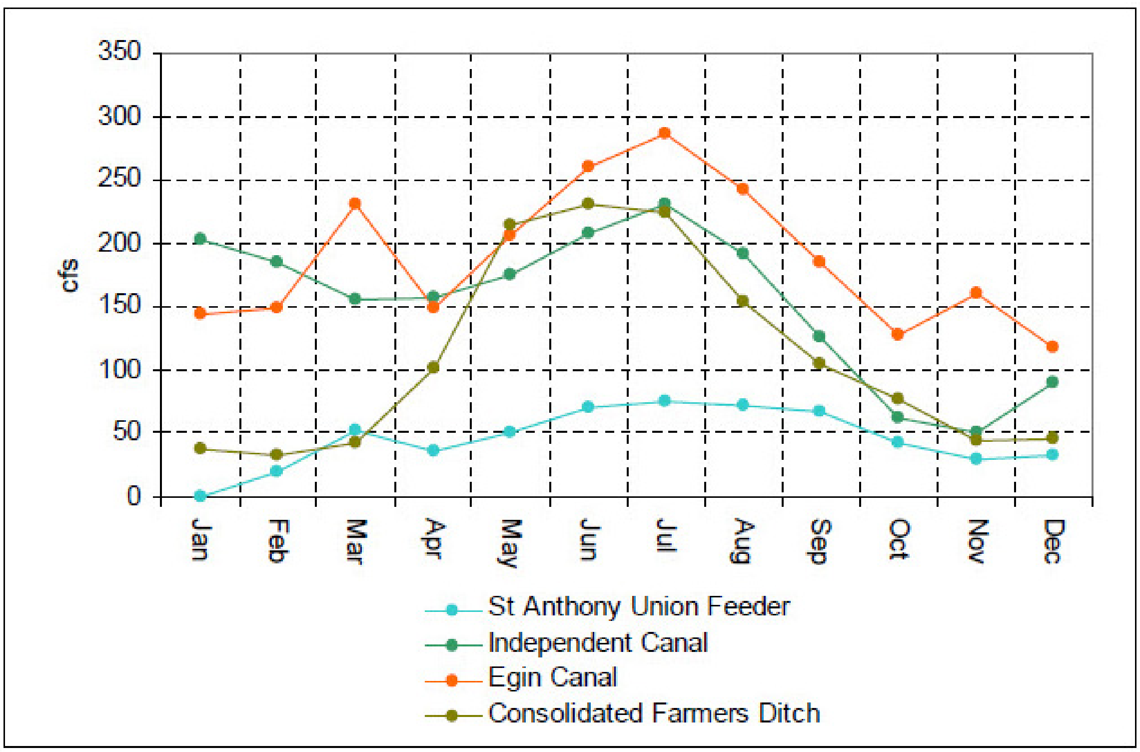

Figure 10. Average daily flow by month in St. Anthony Union Feeder, Independent Canal, Egin Canal, and Consolidated Farmers Ditch from 1977 to 2002 (Reclamation 2004).

The volume of diversions for the remaining 23 percent of the irrigated lands in the Henrys Fork River basin has not been ascertained at this time. Assuming that water use is the same as in the four canal irrigated regions, an extrapolated estimation added to the total irrigation for the four canal-irrigated regions indicates that 1,471,320 acre-feet are diverted annually for all irrigated lands in the Henrys Fork River basin.

The Teton Exchange Wells have operated in 10 of the past 25 years and much more extensively in some years than in others. Two of the wells were used to pump about 800 acre-feet in 1980, whereas all five of the wells were used to pump more than 29,000 acre-feet in 1992, over 27,000 acre-feet in 2001, and nearly 25,000 acre-feet in 2002 (Reclamation 2004).

The amount of irrigation water applied on crops varies with the method of delivery, the type of crop, precipitation received, and air temperatures, among other elements. The location of irrigated lands in the Henrys Fork watershed also slightly influences the amount of water needed by crops for the best harvest. Table 7 shows the estimated water use of crops at Ashton (elevation 5259 feet) and Rexburg (elevation 4865). Ashton, at its higher elevation, experienced a lower mean daily air temperature of 63.7 °F during July and August 2011, the heart of growing season, than Rexburg experienced with its 65.7 °F mean daily air temperature at the lower elevation (AgriMet 2012).

Table 7. Estimated total crop water use from emergence through harvest in 2011 (inches) (raw data from AgriMet 2012).

	Alfalfa	Barley	Potatoes	Winter Wheat
Ashton				
Estimated evapotranspiration totals and averages, 1988-2010	29.2	22.6	21.2	23.5
Estimated 2011 total crop water use from emergence through harvest	28.6	21.0	21.0	25.4
Rexburg				
Estimated evapotranspiration totals and averages, 1988-2010	30.4	21.5	20.2	23.7
Estimated 2011 total crop water use from emergence through harvest	31.4	21.8	21.5	25.3

Hydrologic modeling studies show that less than 30 percent of the diverted surface water is used consumptively and approximately 67 percent of the water becomes groundwater recharge, with canal seepage accounting for the majority of the recharge (Figure 11). Due to the increased efficiencies of sprinkler irrigation methods and changes in agricultural acreage, the total diversions in the basin have decreased about 20 percent since 1978 and recharge has decreased by approximately the same amount (Van Kirk 2011).

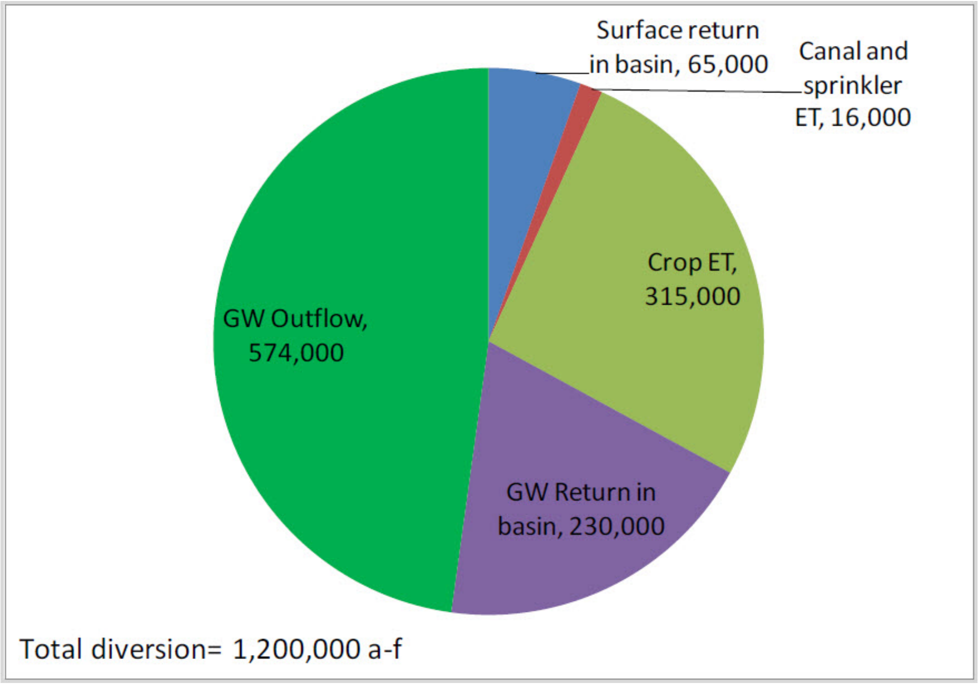

Figure 11. Hydrologic modeling results of the surface diversion budget (Van Kirk 2011).

An analysis of actual irrigation diversions in recent years indicates that even with the more efficient irrigation methods, FMID does not have a sufficient water supply during average and less-than-average water years, with the extent of shortages varying between individual canal companies in the irrigated regions that make up FMID (Table 8). This is a function of the prior appropriation doctrine and general western water law principles established at the turn of the century, which hold that in drought years only those water users with senior water rights can irrigate, leaving junior water right holders without water. During an average water year and without regard to water right priorities, the current unmet needs for all of the irrigated lands are estimated at more than 80,000 acre-feet or 23 percent of the total water needs (Table 8). A drought year exacerbates the water needs in the basin, with more than 36 percent of the total water needs unmet (Table 8). The Fremont irrigated region has the greatest number of irrigated acres and the largest impact to the basin's economy. During a drought year, 82 percent of the water needs are unmet (Reclamation 2004). On average, the Egin Bench area has a surplus water supply, but its location in the Henrys Fork River basin does not allow the transport of the surplus to the Fremont or Teton regions where the need is greatest.

The data used in Table 8 to estimate agricultural water needs consisted of a 30-year record of daily canal diversion for each irrigated region. Estimates of acres irrigated, canal loss (i.e., loss to the irrigated region), and on-farm irrigation efficiencies are based on knowledge of the region and standard irrigation efficiencies. This estimate is expected to be refined during future analyses of the Basin Study.

Table 8. Current unmet irrigation needs of the four canal-irrigated regions during April through September of an average water year and a drought year.

Region	Acres	Irrigation Required Per acre (inches)	Irrigation Required Region (acre-feet)	Diversion (acre-feet)	Estimated Canal Loss (%)	Estimated On-Farm Irrigation Efficiency (%)	Availailable for Irrigation (acre-feet)	Surplus/Deficit (acre-feet)	% Surplus +/ Deficit -
Current unmet irrigation needs (April through September) of the four canal-irrigated regions – average year (based on 30-year average of 1980-2010).									
Egin Bench	30,500	26.0	66,127	309,477	50%	55%	85,106	18,979	29%
Lower Watershed	73,000	26.0	158,271	512,839	45%	55%	155,134	(3,137)	-2%
Freemont	32,500	22.0	59,480	37,912	25%	60%	17,060	(42,420)	-71%
Teton	45,000	22.0	82,357	78,782	35%	50%	25,604	(56,753)	-69%
Total	**181,000**		**366,235**	**939,010**			**282,905**	**(83,331)**	**-23%**
Current unmet irrigation needs (April through September) of the four canal-irrigated regions – drought year (2002)									
Egin Bench	30,500	26.0	66,127	259,985	50%	55%	71,496	5,369	8%
Lower Watershed	73,000	26.0	158,271	424,689	45%	55%	128,468	(29,803)	-19%
Freemont	32,500	22.0	59,480	24,142	25%	60%	10,864	(48,616)	-82%
Teton	45,000	22.0	82,357	78,782	35%	50%	23,593	(58,764)	-71%
Total	**181,000**		**366,235**	**787,598**			**234,421**	**(131,814)**	**-36%**

In some areas, irrigated agricultural lands are being converted to housing developments to meet the needs of the growing population (Figure 12). The water rights of these lands can be retained by the seller, sold to the developer, or sold to another user in the same canal company. In any case, the water is still diverted and used on either adjoining land or applied as landscaping water for the new homes. On a per-acre basis, the conversion of agricultural water use to non-agricultural uses appears to have had no affect on the growing-season consumptive use of water between built-out residential lots and irrigated crop lands (Van Kirk 2011). While the conversion to non-agricultural uses appears to have no affect on the quantity of water being used, studies show that non-agricultural uses rely more heavily on groundwater than surface water.

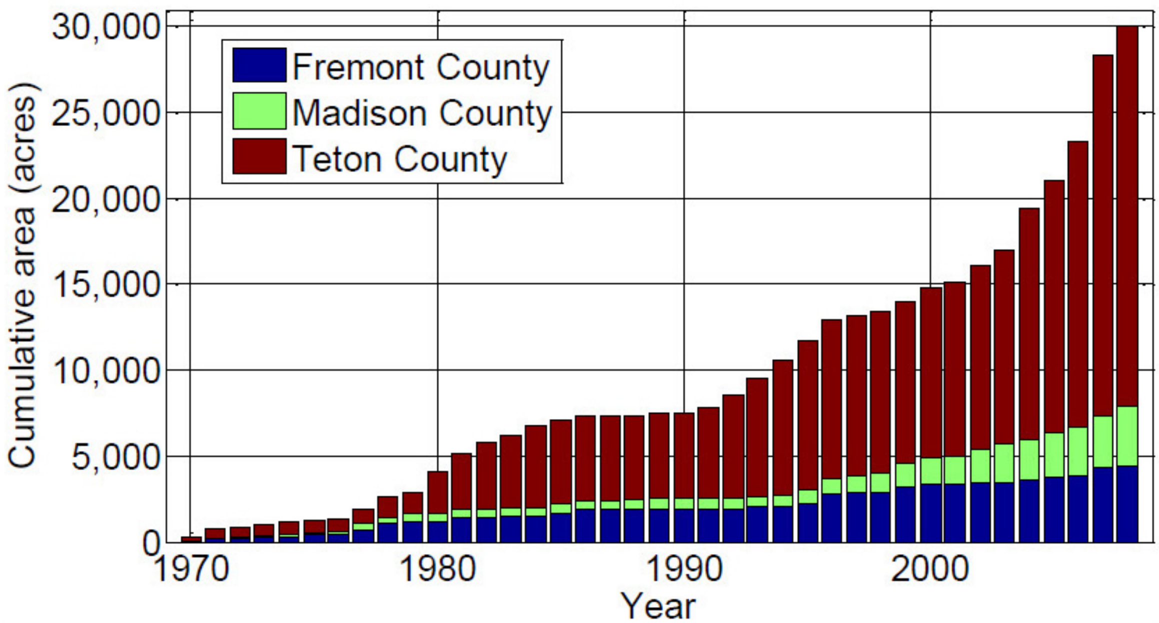

Figure 12. Cumulative area of subdivisions platted since 1970, excluding Island Park. Total irrigated land area in the Henrys Fork watershed is about 275,000 acres (Van Kirk 2010c).

Throughout the Henry's Fork Watershed, canal companies and landowners with water rights are beginning to work together with a variety of partners to explore site-specific, non-traditional water use options. Potential partners in this work include the Idaho Department of Water Resources, Idaho Department of Fish and Game, the Idaho Water Resources Board, the Henry's Fork Foundation, Friends of the Teton River, the Natural Resource Conservation Service, and city and county governments (Van Kirk 2012c).

Domestic, Municipal, and Industrial Water Use

Groundwater provides nearly all of the Basin Study area's drinking water through individual domestic wells or community water systems (systems that serve at least 25 people or have at least 15 service connections) (IDEQ 2011a). All but one of the incorporated towns in the Basin Study area relies on groundwater to supply their populations, drawing water from the Teton Basin Aquifer and ESPA (Table 9).

Table 9. Estimated population and water sources of incorporated towns in the three-county area (Census 2011, IDEQ 2011b).

County	Incorporated Towns	Estimated Population in 2009	Change since 2000 Census	Water Source	Aquifer
Fremont	St. Anthony	3,447	+105	groundwater	ESPA
	Ashton	1,089	-40	groundwater	Teton Basin Aquifer
	Drummond	14	-1	groundwater	NA
	Island Park	281	+66	Non-community system; groundwater	NA
	Newdale	351	-7	groundwater	ESPA
	Parker	317	-2	groundwater	ESPA
	Teton	671	+102	groundwater	ESPA
	Warm River	10	0	NA	NA
Madison	Rexburg	28,856	+11,599	groundwater	ESPA
	Sugar City	1,677	+435	groundwater	ESPA
Teton	Driggs	1,439	+339	groundwater	Teton Basin Aquifer
	Tetonia	244	-3	groundwater	Teton Basin Aquifer
	Victor	1,883	+1,043	groundwater and springs	Teton Basin Aquifer and local watershed
Estimated Totals		40,279	+13,583		

Water use for industrial activities is currently relatively small when compared to water used for agriculture, but water is essential for future economic growth and development (Table 10). Madison County is the only county in the Basin Study area that currently has industrial water use, totaling approximately 5.52 acre-feet per day (USGS 2011b).

Table 10. Estimated domestic, municipal, and industrial uses of water in the Henrys Fork River basin, county-level data for 2005 (USGS 2011b).

Water Use	Unit of Measure	Fremont	Madison	Teton	Totals
Public Supply, total withdrawals from groundwater	Mgal/day	1.93	4.71	1.06	7.70
	acre-feet/year	2,161	5,307	1,186	8,654
Public Supply, total withdrawals from surface water	Mgal/day	0	0	0	0
	acre-feet/year	0	0	0	0
Total industrial water use, self-supplied	Mgal/day	0	1.80	0	1.80
	acre-feet/year	0	2,015	0	2,015
Total withdrawals for irrigation of golf courses	Mgal/day	1.11	0.46	0*	1.57
	acre-feet/year	1,245	515	0*	1,760
Total withdrawal for livestock	Mgal/day	0.24	0.23	0.20	0.67
	acre-feet/year	270	259	22	551
Total withdrawal for aquaculture	Mgal/day	4.52	0	0	4.52
	acre-feet/year	5,063	0	0	5,063
Total withdrawals for mining	Mgal/day	0.06	0.22	0.01	0.29
	acre-feet/year	66	241	11	318
Total withdrawals	Mgal/day	7.86	7.42	1.27	16.55
	acre-feet/year	8,805	8,337	1,219	18,361

Hydroelectric Power Generation Use

The hydropower facilities in the Henrys Fork watershed are run-of-river projects, meaning their hydropower generating plants operate only on the available water and some short-term water storage called pondage which is used to meet daily peak demand needs or smooth weekly fluctuations. The water goes through the generating plants and is returned to the river. The dams may also provide some irrigation water from their small pondage; Chester Dam diverts water into two canals on either side of the Henrys Fork River.

Fish and Wildlife Water Use

A minimum stream flow is the amount of flow necessary to preserve the desired stream values such as fish and wildlife habitat, aquatic life, recreation, water quality, and aesthetic beauty. Under the Drought Management Plan, Federal and State agencies, FMID, and local interest groups work cooperatively to set the timing and quantity of winter releases in relation to available water and storage needs from Island Park reservoir that helps to promote high trout densities and quality fish habitat. Recommended minimum flow amounts have been planned by the IDFG (IDFG 1999; IDFG 1978) and the Snake River Resources Review panel (SR3 2001). In the Henrys Fork basin, the Idaho Water Resource Board holds minimum stream flow water rights on the Henrys Fork, Warm River, Bitch Creek, and Teton River, but the water rights are junior to the operation of Island Park Dam.

Fisheries in the Henrys Fork River basin and the Island Park Reservoir may suffer from drawdowns of Island Park Reservoir which eliminates habitat and benthic invertebrate production in the reservoir and inlet channels into the reservoir. Winter flow releases from Island Park Dam are the primary factor controlling trout abundance downstream of the dam in the Henrys Fork River. Under the Drought Management Plan, Reclamation cooperates with the IDFG and FMID to minimize these impacts while still considering irrigation needs.

The IDFG's Henrys Lake Hatchery is an egg-taking station only so fish are onsite during the mid-February through April spawning period. During this time, approximately 13 acre-feet a day are required for hatchery operations (Table 10). Water use of the hatchery is nonconsumptive and returns to the system after flowing through the hatchery.

Releases from Island Park Dam are sometimes made for the fish and swan habitat at the request of the IDFG and the Henrys Fork Foundation. Meetings between FMID, IDFG, Reclamation, Henrys Fork Foundation, and other interested entities are held to determine the flow needs for the Henrys Fork River in relation to fish and swan habitat needs and the availability water supplies (JPC 2005). If stored water is available in the reservoir, the water may be released to break up ice if low temperatures freeze the river. The ramping rates during those releases are determined by the FERC license; however, Reclamation also consults with the IDFG to minimize damage to fish and swan habitat.

Surface and Groundwater Interactions

Hydrologic investigations in the ESPA have demonstrated that groundwater gains in the Henrys Fork River basin contribute substantially to flows in the Snake River, especially during irrigation season (Reclamation 2004). More than 10 percent of all recharge to the ESPA comes from irrigation activity within the Henrys Fork River basin at the upper end of the aquifer. In addition to the ESPA recharge from irrigation, the Henrys Fork River basin contributes to the recharge of regional aquifers from precipitation, percolation from streambeds, and groundwater underflow from neighboring highlands (Reclamation 1991). Early-spring recharge could reduce the amount of groundwater pumping by sustaining summertime reach gains downstream in the river and could be used to store some of the spring runoff that might otherwise be lost to flood control actions (Contor et. al 2009).

FMID and its member canals participate in the IWRB's Recharge Program. Under contract with the IWRB, FMID has provided recharge water prior to and after the irrigation season.

Recharge occurs as a result of seepage from water diverted into canals and by direct delivery to the Egin Lakes recharge site. In both situations, water passively infiltrates into the ESPA; however, the proportion of water from the Egin Bench canals that goes into the ESPA is still unknown. Since 2008, FMID has provided an estimated 109,367 acre-feet for recharge (Table 11; IWRB 2010, IWRB 2012a).

Table 11. Annual groundwater recharge volumes by FMID since 2008 (IWRB 2010; IWRB 2012a).

FMID recharge	2008	2009	2010	2011
Acre-feet	4,860	37,317	49,466	18,286

Summary of Current Water Use

Surface water and groundwater are a critical component to the Basin Study area's economy and groundwater provides almost all of the drinking water for the area's inhabitants. Table 12 summarizes the estimated volume of water use; however, the requirements for sustaining fish species and other aquatic life in the river systems are not included in this table. The recommended flow volumes from various agencies differ widely and this is reflected in the table.

Table 12. Summary of estimated current water use in the Henrys Fork watershed.

Water Uses	Volume per year (acre-feet)
Agriculture	1,417,320
Domestic, commercial, municipal, & industrial water	18,361
Environmental uses	Various recommendations

5.0 FUTURE WATER NEEDS

Looking 40 years into the future, economic issues relating to irrigation, recreation, and associated businesses will require dependable water supplies. A more reliable water supply should provide irrigation benefits during periods of drought, provide a stable water supply for municipal/domestic and industrial needs, maintain current (near natural) peak flows in the Henrys Fork River, increase hydroelectric output, provide recreational opportunities, and protect fisheries habitat.

Potential Climate Change Impacts

Reclamation, the Bonneville Power Administration, and the U.S. Army Corps of Engineers collaborated to adopt climate change and hydrologic datasets to better understand how potential changes in water supply due to climate change may affect reservoir operations in the Columbia River Basin. Output (e.g., temperatures, precipitation) from Global Climate Models (GCMs) was spatially downscaled and bias corrected, then used in a hydrologic model that generated supply or flow values at various locations in the Columbia River Basin. Two future time periods called Hybrid-Delta were defined as the 30-year period surrounding the 2020s (2010 to 2039) and the 30-year period surrounding the 2040s (2030 to 2059). Those supply data were provided to stakeholders for use in their long-term planning models for several basins, including the upper Snake River basin where the Henrys Fork watershed is located. The entire Snake River basin above Brownlee Reservoir was modeled; however, the only location at which detailed calibration occurred was at Brownlee Reservoir. While the Henrys Fork watershed was modeled, additional calibrations would need to be made and climate change projections reevaluated for results specific to the watershed.

The climate projections were selected at the Columbia River Basin scale based on a desired range of precipitation and temperature changes. However, when those same projections were viewed at the Snake River basin scale, most of them were skewed toward wetter conditions in the future. Based on the GCMs selected, the upper Snake River basin is projected to experience warmer (0.5 ˚F to about 2 ˚F warmer in the 2020s scenarios and 1 ˚F to 3 ˚F in the 2040s scenarios) and wetter conditions in some cases (5 percent decrease to 10 percent increase in the 2020s and a 5 percent decrease to 15 percent increase in the 2040s) as compared to historical conditions (Reclamation 2011).

Several metrics, including inflow to reservoir groups, surface water delivery, and flow augmentation among others, were evaluated to better understand the potential impacts of the selected GCMs on the upper Snake River basin. Inflow was summed for all of the reservoirs in the upper Snake River above Brownlee Reservoir. The model indicated a shift in the timing of the peak flow and an increase in volume in most locations. The timing of peak inflow generally shifted to a month earlier and flow volume increased above historical flows earlier in the cool season (October or November to April) and decreased in the summer and fall seasons (May through September or October). This shift in timing and increase in inflow volume to earlier in the year resulted in an increase in the end-of-month storage earlier in the year and a greater need to draft reservoirs to provide irrigation water later in the summer months (Reclamation 2011). A decrease in surface water delivery also occurred in the latter part of the irrigation season or warmer months (Reclamation 2011). A decrease in instream flow in the late summer to early fall months would result in less water available for natural flow diversions.

Environmental objectives for both anadromous and resident fish species were evaluated in the climate change study. In the reservoirs that require minimum pools or flows, it was found that in some cases, it may be more difficult to meet these objectives in some of the reservoirs in the driest conditions (Reclamation 2011).

Agricultural Water Needs Assessment

Reclamation defines a water shortage as a maximum of 50 percent of a full water supply in a single year and a 10 percent average shortage in any 10 consecutive years. Based on these criteria, the canal-irrigated regions were assessed and water shortages were identified in the Lower Watershed (marginally), Fremont (significantly), and Teton (significantly) regions (Figure 1). The average annual irrigation water supply shortage in all four canal-irrigated regions is 83,331 acre feet (Table 8). The Teton Exchange wells are located at the lower end of the basin; consequently, supplemental water from the wells cannot be directly delivered to the areas with the greatest unmet irrigation demand. The Teton Exchange wells may be used to replace water that originated in Island Park Reservoir.

The unmet needs for the remaining 23 percent of the irrigated lands outside in the irrigated regions in Figure 1 has not been ascertained at this time. Assuming that water use is the same as in the four irrigated regions mentioned in Table 8, an extrapolated estimation of the 24,890 acre-feet is used by those irrigated lands.

Most of the district lands currently experience shortages during drought periods; shortages vary from 20 to 80 percent for individual canal companies. Local irrigators indicate that several management strategies are used during drought periods, particularly in regions like Fremont and Teton where there are already water shortages, to minimize the economic consequences of agricultural water shortages. These drought strategies include, among others, more spring grains with supplemental irrigation, rotations of spring grains with seed potatoes, and rotational fallow or dry land pasture.

For this study, it was assumed that there would be no increase in the number of irrigated acres in the future. Given the modeled warming global temperatures and changes in precipitation, the growing season for agriculture is expected to begin earlier in the season and end later season in the future than it currently does, depending on geography. While the shift of peak flow timing to earlier in the year may be counterbalanced by the shift in the volume of flow, the extension of the growing season to later in the year will likely only exacerbate any drought conditions currently experienced for instream flow users and create a greater reliance for those using stored water rights. These shifts may also affect the operations of dams and management of irrigation systems, increasing the need to release more water from the reservoirs and divert more water for irrigation later in the summer months (Reclamation 2011). The decrease in storage and instream flows in the late summer to early fall months could result in less water available for natural flow diversions.

Future water demands could be impacted by the continued conversion of agriculture lands to urban areas; changes in crop types in response to the market or climate conditions; and the employment of new conservation measures in agricultural practices or irrigation delivery systems, although it is unclear if these impacts will increase or decrease future demand.

Hydropower Water Needs Assessment

Growing populations and the demand for clean, renewable energy are expected to increase proportionally. The Basin Study area has the potential for further hydropower development in the future; however, the State Water Plan provides for the subordination of hydropower water supplies to assure an adequate water supply for future upstream beneficial uses (IWRB 2012c). Construction or installation of new hydropower facilities are not likely to occur in the near future. As more efficient hydropower generating technology is developed, the existing facilities may generate more power with the same volume of water currently being used.

Domestic, Municipal, and Industrial Water Needs Assessment

According to USGS (2011c), each person uses 80 to 100 gallons of water per day for normal household activities. Assuming the continued 2 percent annual population growth over the next 40 years (Table 1), the population and subsequent municipal and household demands would double to 36,772 acre-feet annually.

The Henrys Fork River basin lies in the non-trust water area as designated by the Idaho Department of Water Resources. Water rights from the Snake River in the non-trust area are not fully satisfied at certain times. For any new consumptive use of water, applicants must demonstrate to the State that their new diversion and consumptive use of water will not injure senior water rights or that mitigation can be done during times in which injury would otherwise occur. The interconnection between surface and groundwater in the area must be considered and addressed in any new proposal. These criteria may limit new water supplies in the future for municipalities and industries.

Ecological Needs Assessment

IDFG provided direction on the recommended stream flows to benefit fisheries and other aquatic life in the Henrys Fork River basin; the flow recommendations at St. Anthony that would be representative of the lower Henrys Fork River (IDWR 1999). As shown in Figure 13, the 30-year average flow at the St. Anthony gaging station is consistently lower than the IDFG flow recommendations to benefit aquatic life, except for during the high flows of spring runoff. The average annual streamflows are less than the maintenance flow recommendations by approximately 200,000 acre-feet, which is approximately 14 percent of recommend flows.

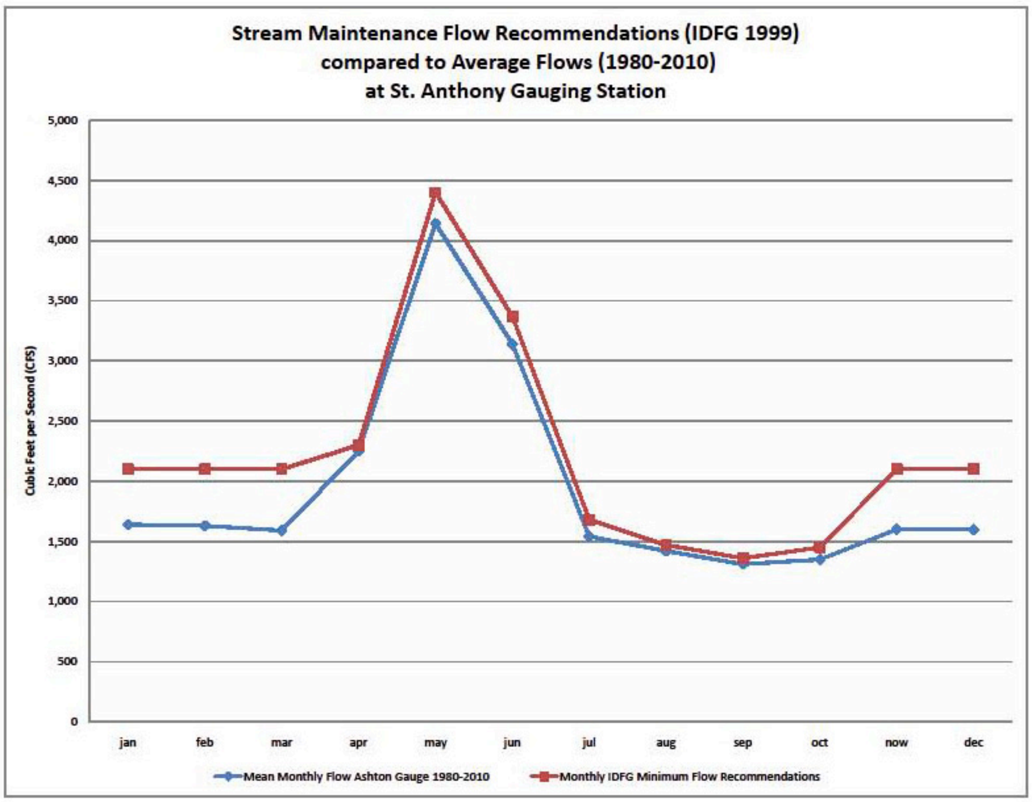

Figure 13. Stream maintenance flow recommendations to preserve stream value at St. Anthony gaging station (1980-2010).

Current water management practices allow Teton Valley irrigators to purchase water from storage facilities out of the basin (most commonly out of Island Park Reservoir) to provide water for downstream senior users when the State curtails surface water usage. This practice results in out-of-basin water exchanges and tends to exacerbate tributary dewatering issues. While groundwater recharge from irrigation activities helps replenish downstream flows, diversions often have a negative impact on fish and fish habitat.

Table 13 and Figure 14 present a list of stream reaches of concern as documented by Van Kirk et al. (2011) where flow alterations would negatively affect fisheries and/or ecological functionality. These reaches are mentioned most often when discussing flow needs for fish and aquatic/riparian species in the Henrys Fork watershed. Flow alterations are of concern every place they occur throughout the Henrys Fork River basin and have the ability to impact fish resources in all locations.

Table 13. Stream reaches of concern and flow needs as shown on Figure 14.

Stream Reach of Concern	Primary Stream Flow Needs
Henrys Lake Outlet (1)	Increase low winter flows
Henrys Fork Below Island Park Dam (2)	Increase low winter flows
Lower Fall River (Downstream of Fall River Canal Diversion) (3)	Increase late summer flows
Henrys Fork Downstream of St. Anthony (4)	Increased understanding of effects of low flows on fish
Lower Teton River North and South Forks (5)	Increase late summer flows
Teton Valley Tributaries (6)	Based on site specific information
Small Streams (7)	Based on site specific information

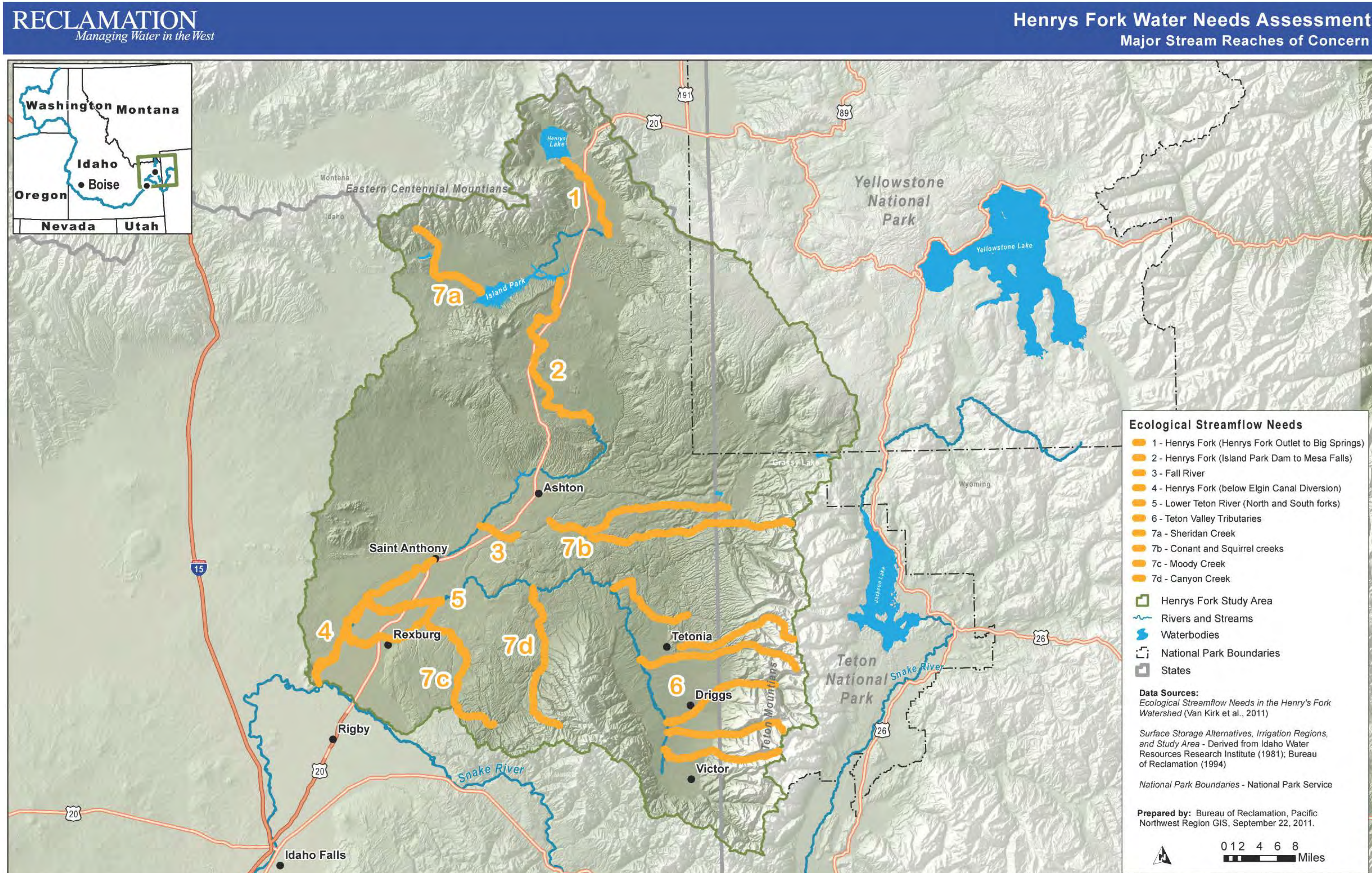

Figure 14. Map of the reaches of concern in the Henrys Fork River basin.

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The timing and magnitude of peak and seasonal flows in the Henrys Fork River and its tributaries are important to sustain its fisheries. The current alteration of flows below storage and power facilities on the rivers in the basin is mitigated to a small extent by inflows from the tributaries and groundwater recharge from irrigation activities. Additional water to reduce the impacts to fisheries is most needed in the tributary basins where there is less inflow and recharge and the water shortages are the greatest (Van Kirk et al. 2011).

Climate-induced changes in the hydrologic regime of the Henrys Fork River could impact early life stages of fish (i.e., Yellowstone cutthroat trout and rainbow trout). Earlier peak flows due to climate changes in the Basin Study area could potentially impact the timing of spawning and fry emergence. Warmer air temperatures may warm water temperatures enough that fish will move to higher elevations in search of cold water (Gresswell 2011).

Trumpeter swans feed on the macrophytes found in the Henrys Fork River below Island Park Dam. Idaho Department of Fish and Game suggests that between 5,000 and 10,000 acre-feet of water in Island Park Reservoir storage, if available, could benefit the downstream trumpeter swan habitat during the winter. Managed winter flows could reduce ice formation and dewatering of macrophyte beds; however, ice could still form in very cold temperatures. Storage releases between late January and April 1 may also benefit the trumpeter swans in the river below the dam by breaking up ice on the river in late winter (PFC 2002).

Groundwater Needs Assessment

The impact of future Teton Exchange Well pumping on groundwater gains in the Henrys Fork River basin and on the potential for depletions to the Snake River flows has been identified as a concern by Reclamation. The impacts of pumping may impact the Henrys Fork River depending on the rate of pumping, the proximity to the river, the water storage in Island Park Reservoir, and the amount of seepage recharge (Reclamation 2004).

Seepage from irrigation canals is a primary source of local aquifer recharge. With the installation of more efficient irrigation systems across the Basin Study area, recharge from irrigation has decreased which in turn has decreased groundwater inflows to the rivers which, over time, could impact wildlife and fisheries and their habitats (Van Kirk 2011). Changes in groundwater recharge could also potentially affect agricultural, municipal, and industrial water needs and limit future economic growth in the Basin Study area.

Other Future Needs in the Upper Snake River Basin

ESPA

Declining aquifer levels and spring discharges (e.g., Thousand Springs area), changing flows in the Snake River, and actions that have placed demands on already scarce water supplies (e.g., flow augmentation for anadromous fish survival) have resulted in insufficient supplies to satisfy existing beneficial uses across the upper Snake River basin. As previously mentioned, ESPA CAMP was developed after a series of water use conflicts had the potential to severely disrupt the economy of the Eastern Snake Plain. The ESPA CAMP and the long-term objective to adaptively manage and improve the conditions of the ESPA was developed collaboratively by the ESPA Advisory Committee following several years of detailed technical analysis and review. The ESPA CAMP identified an annual water budget deficit in the ESPA of 600,000 acre-feet, and established a long-term goal to adjust this deficit by implementing a mix of management strategies over a 20-year period at an estimated cost of $600 million.

The ESPA CAMP established a Phase I hydrologic water budget target of 200,000 acre-feet at a cost of $70 million to $100 million. The Phase I targets are:

- Groundwater to surface water conversions: the Phase 1 target (1 to 10 years) of 100,000 acre-feet
- Aquifer recharge: the Phase 1 target of 100,000 acre-feet
- Demand reduction: the Phase 1 target of 95,000 acre-feet
- Pilot weather modification program: the targeted Phase 1 volume of 50,000 acre-feet

Summary of Estimated Water Needs

Existing water needs vary from year to year with varying annual precipitation amounts; future water needs will vary with climate change impacts, population growth, changes in farming methods, water conservation, and other factors that may not be fully understood at this point in time. Table 14 summarizes the projected future water needs in the basin without consideration of the climate change impacts and the totals may vary as the impacts become more evident in the future.

Table 14. Summary of future water needs.

Water Needs	Current Water Use (acre-feet)	Projected Future Use (acre-feet)	Future Unmet Water Needs (acre-feet)
Agriculture (based on the four canal-irrigated regions)[1]	282,905 in average years 234,421 in drought years	366,235 in average years 366,235 in drought years	83,331 in average years 131,814 in drought years
Domestic, commercial, municipal, & industrial needs[2]	18,361	36,772	18,361
Environmental needs	Various Recommendations	Various Recommendations	Various Recommendations
Fisheries			200,000
ESPA (long-term target to be met through a mix of strategies)			600,000

[1] Agricultural Current and Future Use refers to crop consumptive requirements. To meet these crop requirements, additional water must be diverted to account for canal and on-farm inefficiencies.

[2] 2 percent annual increase over 40 years based past population growth and current water use.

LITERATURE CITED

Parenthetical Reference	Bibliographic Citation
AgriMet 2012	AgriMet from the Bureau of Reclamation. The Pacific Northwest Cooperative Agricultural Weather Network. http://www.usbr.gov/pn/agrimet/ accessed on January 17, 2012.
Bayrd 2006	Bayrd, G. 2006. *The Influences of Geology and Water Management on Hydrology and Fluvial Geomorphology in the Henry's Fork of the Snake River, Eastern Idaho and Western Wyoming*. A master's thesis at Idaho State University. 2006.
Census 2011	U.S. Census Bureau. http://quickfacts.census.gov/qfd/states/16000.html. Site visited on February 18, 2011.
Census 2012	U.S. Census Bureau. http://lmi.idaho.gov/PopulationCensus.aspx. Site accessed on January 5, 2012.
Christiansen 1982	Christiansen, R. 1982. "Late Cenozoic Volcanism of the Island Park Area, Eastern Idaho." *Cenozoic Geology of Idaho*: Idaho Bureau of Mines and Technology Bulletin 26, p. 345-368.
Contor et al. 2009	Contor, B., S. Taylor, and G. Quinn. 2009. *Monitoring of Egin, Idaho Recharge Experiment, Fall 2008.* IWRRI Technical Completion Report 200901. Idaho Water Resources Research Institute and Idaho Department of Water Resources. June 2009.
DeRito 2012	DeRito, J. 2012. Presentation at the Henry's Fork Watershed Council 2011 Annual Watershed Conference. "Yellowstone Cutthroat Trout Status for the Henry's Fork, Teton, and Sinks Drainages." November 29, 2011. http://www.henrysfork.org/shared/hff/files/HFWC%20Nov%2029%202011%20mtg%20notes%20FINAL.pdf accessed on June 21, 2012.
FRREC 2012A	Fall River Rural Electric Cooperative. http://www.frrec.com/myBusiness/greenPower_bus.aspx Accessed on February 17, 2012.

Parenthetical Reference	**Bibliographic Citation**
FRREC 2012b	Fall River Rural Electric Cooperative. http://www.frrec.com/myCooperative/aboutFallRiver.aspx Accessed June 12, 2012.
Gresswell 2011	Greswell, R.E. 2011. "Biology, Status, and Management of the Yellowstone Cutthroat Trout." *North American Journal of Fisheries Management*, 31:5, 782-812. September 20, 2011.
HFF 2012a	Henry's Fork Foundation. http://www.henrysfork.org/ecological-and-restoration-projects Accessed on February 16, 2012.
HFF 2012b	Henry's Fork Foundation. http://www.henrysfork.org/stewardship Accessed on February 16, 2012.
IDEQ 1998	Idaho Division of Environmental Quality. *Upper Henry's Fork Subbasin Assessment.* Idaho Department of Health and Welfare, Division of Environmental Quality, Idaho Falls, Idaho. December 1998.
IDEQ 2011a	Idaho Department of Environmental Quality. Water Quality: Drinking Water Program Overview. http://www.deq.idaho.gov/water/prog_issues/drinking_water/overview.cfm. Accessed on February 23, 2011.
IDEQ 2011b	Idaho Department of Environmental Quality. Water Quality: Source Water Assessment Reports Database. http://www.deq.idaho.gov/water/SWAReports/InternetQuery.cfm. Accessed on February 23, 2011.
IDFG 1978	Idaho Department of Fish and Game. 1978. *Stream Flow Investigations: Stream Resource Maintenance Flow Determinations on Idaho Streams*. Authored by T. Cochnauer and E. Buettner. State of Idaho, Department of Fish and Game. June 1978.
IDFG 1999	Idaho Department of Fish and Game. 1999. *Special Report: Instream Flow Recommendations for Maintenance of Fisheries in the Upper Snake River*. State of Idaho, Department of Fish and Game. 1999.

Parenthetical Reference	Bibliographic Citation
IDFG 2005	Idaho Department of Fish and Game. 2005. Idaho Comprehensive Wildlife Conservation Strategy. Idaho Conservation Data Center, Idaho Department of Fish and Game, Boise, ID. http://fishandgame.idaho.gov/cms/tech/CDC/cwcs.cfm.
IDFG 2007	Idaho Department of Fish and Game. 2007. *The Management Plan for Conservation of Yellowstone Cutthroat Trout in Idaho.* Idaho Department of Fish and Game. April 2007.
IDOL 2011a	Idaho Department of Labor. 2011. *Workforce Trend Profiles.* Idaho Department of Labor, Idaho Falls, Idaho. December 2011. Accessed on January 3, 2012 at http://labor.idaho.gov/dnn/Default.aspx?tabid=698.
IDOL 2011b	Idaho Department of Labor. 2011. *Tourism Industry, Fall 2011*. Idaho Department of Labor, Communications and Research, Boise, Idaho. Fall 2011. Accessed on January 3, 2012 at http://labor.idaho.gov/publications/tourism.pdf.
IDWR 1978	Idaho Department of Water Resources. 1978. *Water Resources of the Upper Henrys Fork Basin in Eastern Idaho*. Water Information Bulletin No. 46. Prepared by the U.S. Geological Survey in cooperation with the Idaho Department of Water Resources. May 1978.
IDWR 1999	Idaho Department of Water Resources. 1999. *Feasibility of Large-Scale Managed Recharge of the Eastern Snake Plain Aquifer System.* Prepared in cooperation with the Bureau of Reclamation. State of Idaho, Idaho Department of Water Resources. 1999.
IDWR 2009	Idaho Department of Water Resources. 2009. *Eastern Snake Plain Aquifer (ESPA), Comprehensive Aquifer Management Plan*. Idaho Water Resource Board. January 2009.
IWRB 1992	Idaho Water Resource Board. 1992. *Comprehensive State Water Plan: Henrys Fork Basin*. Idaho Water Resource Board. 1992.
IWRB 2010	Memorandum to the Idaho Water Resource Board from Bill Quinn, Recharge Coordinator, dated September 14, 2010. Subject: 2010 Early Season ESPA Recharge Summary and Late Season Plan.

Parenthetical Reference	Bibliographic Citation
IWRB 2012a	Memorandum to the Idaho Water Resource Board from Bill Quinn, Recharge Coordinator, dated January 17, 2012. Subject: 2012 Eastern Snake Plain Aquifer Recharge Summary Expected Recharge Activities for 2012.
IWRB 2012b	Personal communication between Cynthia Clark, Staff Engineer with Idaho Department of Water Resources, and Carol Kjar, Natural Resources Technical Writer/Editor with Bureau of Reclamation, February 22, 1012.
IWRB 2012c	Idaho Water Resource Board. 2012. *Draft Idaho State Water Plan*. Proposed May 2012.
JPC 2005	Joint Planning Committee. 2005. *Henrys Fork Drought Management Plan*. Prepared by the Joint Planning Committee made up of representatives from the Fremont-Madison Irrigation District, Henry's Fork Foundation, North Fork Reservoir Company, Trout Unlimited, The Nature Conservancy, and Bureau of Reclamation. March 2005.
LIHI 2006	Low Impact Hydropower Institute. http://www.lowimpacthydro.org/lihi-certificate-21-buffalo-river-project-buffalo-river-idaho-ferc-1413.html Accessed on June 12, 2012.
LIHI 2010	Low Impact Hydropower Institute. http://www.lowimpacthydro.org/lihi-pending-application-ferc-no.-2381-ashton-hydroelectric-project-henrys-fork-river-idaho.html. Accessed on June 12, 2012.
LIHI 2012	Low Impact Hydropower Institute. http://www.lowimpacthydro.org/lihi-certificate-2-island-park-henrys-fork-of-the-snake-river-idaho-ferc-2973.html and http://www.lowimpacthydro.org/lihi-certificate-21-buffalo-river-project-buffalo-river-idaho-ferc-1413.html Accessed on February 16, 2012.

Parenthetical Reference	Bibliographic Citation
Loomis 2005	Loomis, John. 2005. *The Economic Value of Recreational Fishing & Boating to Visitors & Communities along the Upper Snake River*. Dr. John Loomis, Department of Agricultural and Resource Economics, Coloration State University. May 2005. http://www.tu.org/atf/cf/%7B0D18ECB7-7347-445B-A38E-65B282BBBD8A%7D/Final%20Loomis%20%20HFF%20TU%20SR%20Full%20Report%205-02-05.pdf accessed on June 11, 2012.
NASS 2012	National Agricultural Statistics Service. U.S. Department of Agriculture. Idaho Statistics, County Estimates. http://www.nass.usda.gov/Statistics_by_State/Idaho/Publications/County_Estimates/index.asp accessed on January 17, 2012.
PFC 2002	Pacific Flyway Study Committee. 2002. *Pacific Flyway Implementation Plan for the Rocky Mountain Population of Trumpeter Swans*. Prepared for the Pacific Flyway Council and the U.S. Fish and Wildlife Service. July 2002. Accessed on February 24, 2011 at http://www.fws.gov/migratorybirds/CurrentBirdIssues/Management/FocalSpecies/Plans/Trumpeter%20Swan%20Plan.pdf.
Reclamation 1946	Bureau of Reclamation. 1946. *Clinton Report: Water Use in the Henrys Fork Valley*. Unpublished report. U.S. Department of the Interior, Bureau of Reclamation, Pacific Northwest Regional Office, Boise, Idaho. 1946.
Reclamation 1980	Bureau of Reclamation. 1980. *Modification of Island Park Dam, Stage Two, Minidoka Project, Idaho-Wyoming*. U.S. Department of the Interior, Bureau of Reclamation, Pacific Northwest Regional Office, Boise, Idaho. June 1980.
Reclamation 1991	Bureau of Reclamation. 1980. *Teton Dam Reappraisal Working Document*. U.S. Department of the Interior, Bureau of Reclamation, Pacific Northwest Regional Office, Boise, Idaho. February 1991.
Reclamation 2004	Bureau of Reclamation. 2004. *Final Environmental Assessment, Fremont-Madison Irrigation District Proposed Title Transfer, Minidoka Project, Idaho-Wyoming*. U.S. Department of the Interior, Bureau of Reclamation, Pacific Northwest Regional Office, Boise, Idaho. September 2004.

Parenthetical Reference	Bibliographic Citation
Reclamation 2006	Bureau of Reclamation. 2006. *Teton River Canyon Resource Management Plan*. U.S. Department of the Interior, Bureau of Reclamation, Pacific Northwest Regional Office, Boise, Idaho. December 2006.
Reclamation 2011	Bureau of Reclamation. 2011. *Climate and Hydrology Datasets for Use in the RMJOC Agencies' Longer-Term Planning Studies: Part II – Reservoir Operations Assessment for Reclamation Tributary Basins*. To be released in the Summer 2011. U.S. Department of the Interior, Bureau of Reclamation, Pacific Northwest Regional Office, Boise, Idaho. January 2011.
RMP 2012	Rocky Mountain Power. http://www.rockymountainpower.net/about/nr/nr2011/adrpra.html Accessed February 16, 2012.
SR3 2001	Snake River Resources Review. 2001. *Aquatics Resources Parameters Manual*. March 2001.
USGS 2011a	U.S. Department of the Interior Geological Survey. USGS Surface-Water Annual Statistics for Idaho. http://waterdata.usgs.gov/id/nwis/annual/?search_site_no=13056500&agency_cd=USGS&referred_module=sw&format=sites_selection_links. Accessed on February 24, 2011.
USGS 2011b	U.S. Department of the Interior Geological Survey. Estimated use of water at the county level for 2005. http://water.usgs.gov/watuse/data/2005/ . Accessed on February 23, 2011.
USGS 2011c	U.S. Department of the Interior Geological Survey. Water Q&A: Water use at home. http://ga.water.usgs.gov/edu/qahome.html#HDR3. Accessed on February 23, 2011.
Van Kirk and Burnett 2004	Van Kirk, R. and B. Burnett. 2004. *Hydrologic Alteration and its Ecological Effects in the Henry's Fork Watershed Upstream of St. Anthony*. Project Completion Report for the Greater Yellowstone Coalition, Henry's Fork Foundation, Henry's Fork Watershed Council, Snake River Cutthroats, The Nature Conservancy, and Trout Unlimited. June 16, 2004.

Parenthetical Reference	Bibliographic Citation
Van Kirk and Jenkins 2005	Van Kirk, R. and A. Jenkins. 2005. *Hydrologic Alteration in the Upper Teton Watershed and Its Implications for Cutthroat Trout Restoration*. Completed for Friends of the Teton River, Driggs, Idaho. January 2005.
Van Kirk 2010a	Van Kirk, R. 2010. Handouts during the Henry's Fork Watershed Council Summer Tour, July 20, 2010.
Van Kirk 2010b	Van Kirk, R. 2010. "Conservation of surface and ground water in a Western watershed experiencing rapid loss of irrigated agricultural land to development. Fiscal Year 2010 Annual Report: November 29, 2010."
Van Kirk 2010c	Van Kirk, R. 2010. "Conservation of surface and ground water in a Western watershed experiencing rapid loss of irrigated agricultural land to development." Presentation to the Henrys Fork Watershed Council, Rexburg, Idaho. March 16, 2010.
Van Kirk 2011	Van Kirk, R. 2011. "Conservation of surface and ground water in a Western watershed experiencing rapid loss of irrigated agricultural land to development." Presentation to the Henrys Fork Watershed Council, Boise, Idaho. January 11, 2011.
Van Kirk et al. 2011	Van Kirk, R., S. Rupp, and J. De Rito. *Ecological Streamflow Needs in the Henry's Fork Watershed.* Paper presented to Henry's Fork Watershed Council by Van Kirk (Humboldt State University), Rupp (Friends of the Teton River), and De Rito (Henry's Fork Foundation). September 2011.
Van Kirk 2012a	Van Kirk, R. 2012. Personal communication with Robert Schattin, Bureau of Reclamation.
Van Kirk 2012b	Van Kirk, R. 2012. "Components of Irrigation Water Budget Related Sprinkler Application." http://www.humboldt.edu/henrysfork/Documents_Presentations/sprinkler%20irrig.pdf accessed on June 20, 2012.
Van Kirk 2012c	Van Kirk. R. 2012. *In the Henry's Fork Watershed, Every Drop Leaves a Ripple: A Guide to Hydrology and Water Management.* http://www.humboldt.edu/henrysfork/Documents_Presentations/HFW%20Booklet%20final.pdf accessed on September 24, 2012.

Parenthetical Reference	Bibliographic Citation
WRCC 2012	Western Regional Climate Center. Idaho Climate Summaries. http://www.wrcc.dri.edu/summary/climsmid.html accessed on January 11, 2012.