FINAL REPORT

Eastern Snake Plain Aquifer (ESPA)

Review of Comprehensive Managed Aquifer Recharge Program

PREPARED FOR

Idaho Water Resource Board

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PREPARED BY

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IN COOPERATION WITH

Henry's Fork Foundation

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EXECUTIVE SUMMARY

The ESPA managed recharge program can work: Monitoring is the key.

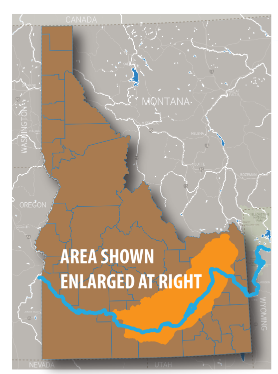
This report documents an independent review of the State of Idaho's managed recharge program.

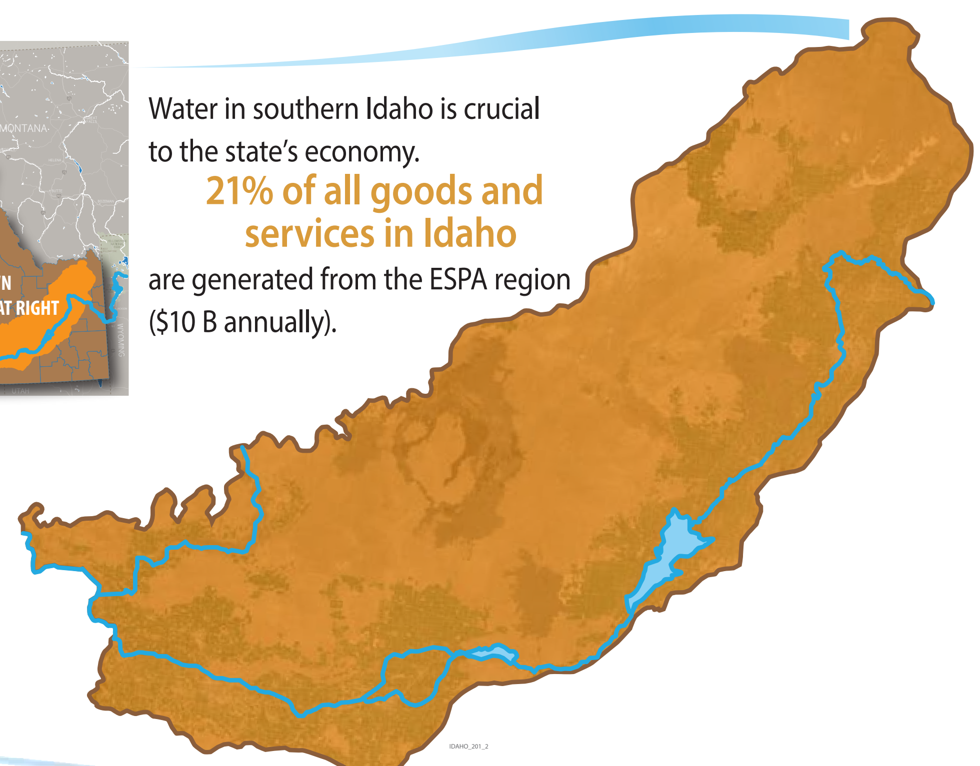
Program Objective: Aquifer Stabilization.

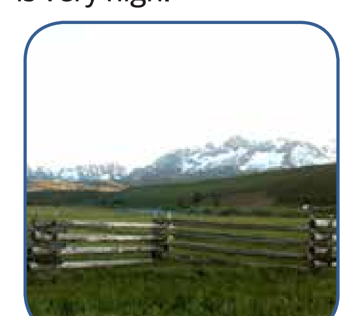
To accomplish specific goals, such as specific river reach gains, or increasing aquifer water levels in the long-term, each managed recharge location on the ESPA must be considered. To increase short-term (seasonal) river reach gains or spring discharge, ESPA recharge needs to occur in the proximity (within approximately 15 miles) of the specific reach or discharge area. Increasing aquifer water levels in the long-term requires more distant recharge locations, sites further from aquifer discharge locations, both natural (surface water discharge) and pumping, allowing the recharge to have the desired long-term water level impact.

Managed Recharge Review Conclusions

1. Water is consistently available for managed recharge on almost every day during the winter months downstream of Minidoka.
2. The USBR unsubordinated power right prevents winter recharge upstream of Minidoka in about half of all years.
3. System-wide, water is available for managed recharge during irrigation season in about two-thirds of all years, during a 30-day window between mid-May and early July.
4. If future climate yields water supply statistically similar to that of the 1980-2014 period, median availability of water for managed recharge will be 600,000 acre-feet per year downstream of Minidoka, and about 150,000 acre-feet per year upstream of Minidoka.
5. If future climate is more statistically similar to that of the period since 2000, which is drier, median availability of water for managed recharge will be about 200,000 acre-feet per year downstream of Minidoka, and 7,000 acre-feet per year upstream.
6. Capitalizing on existing winter availability requires ability to recharge 500-1,000 cfs every day of every winter downstream of Minidoka and operational flexibility and canal capacity to accommodate opportunistic availability of late-winter recharge upstream of Minidoka.
7. Fully utilizing availability of water during the spring freshet will likely require expansion of canal capacity at key points of diversion throughout the basin.
8. Canal capacity, physical logistics, weather, and fish and wildlife concerns will reduce the amount of water available for recharge below the theoretical maximum amounts presented in this report.
9. Assuming that pending managed recharge water-rights applications are approved, the combined diversion rates of the IWRB rights and junior private rights will be sufficient to capture all available natural flow in the upper Snake River system except on a very small fraction of days when natural-flow supply is very high.







This report documents an independent review of the State of Idaho's managed recharge program.

Our review of the state's managed recharge program suggests that recharging 150 to 250 thousand acre-feet to the ESPA annually is possible. To consistently achieve this goal, there may be site-specific improvements needed at recharge locations to overcome limitations, such as diversion, infiltration, and recharge capacity.

The State is on the Right Path

The State is implementing an adaptive implementation strategy, per the 2009 ESPA CAMP, and we believe this approach is appropriate. This phased approach provides an opportunity to adapt to future conditions. The 2009 ESPA CAMP appropriately identifies the importance of monitoring to test assumptions and adjusting the implementation plan accordingly to meet the long-term objective. Successful implementation of the plan will increase aquifer water levels, spring discharge, and river reach gains in some areas. Monitoring is fundamental, providing data to demonstrate the plan is effective and results in the desired managed recharge benefits.

Our assessment confirms that sufficient water is available for the managed recharge program. To consistently recharge 150 to 250 thousand acre-feet per year requires improvements, including:

1. Managed recharge site identification and canal system improvements/modifications to capitalize on the 500 to 1,000 cfs of water available nearly every day of every winter downstream of Minidoka.
2. Canal capacity improvements upstream of Minidoka, combined with funding for operational flexibility to accommodate opportunistic availability of late-winter recharge upstream of Minidoka.
3. Expansion of canal capacity at key points of diversion throughout the basin to capture water that is available for recharge in the spring.

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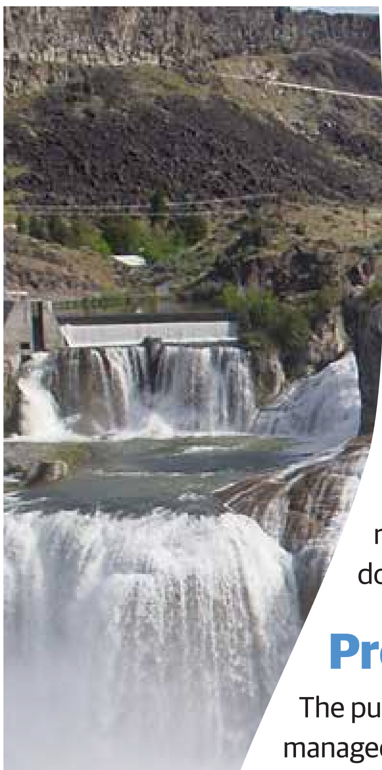
INTRODUCTION

Background

How to achieve the long-term goal of recharging the ESPA.



Based on the results of the Eastern Snake Plain Aquifer (ESPA) comprehensive aquifer management planning process (CAMP), adopted by the Idaho Water Resource Board (IWRB) in January 2009, there is a long-term goal of implementing a net annual ESPA water budget change of 600,000 acre-feet through a variety of management actions. To that end, the state has a goal of recharging 250,000 acre-feet per year to the ESPA through managed aquifer recharge. The state's managed aquifer recharge program is funded by the Board and is being implemented on behalf of the Board by the Idaho Department of Water Resources (IDWR). The program currently relies on existing canal systems to carry and deliver water under the Board's recharge water rights. The program varies year to year, based on willing participation by recharge entities, such as canal companies and irrigation districts. Because of the evolving nature of the program, there is no one stand-alone document detailing the state's managed recharge program for the ESPA. The goals of the program, however, are clearly documented in the ESPA CAMP (Idaho Water Resource Board, 2009).

Project Objective and Report Structure

The purpose of this project is to document an independent assessment of the state's ESPA managed recharge program, evaluating the probability for successfully recharging 250,000 acre-feet per year to the ESPA.

The following sections detail our review of the state's ESPA managed recharge program, including:

- **Section 1:** A summary of the history of the State's recharge program and how it has evolved over time
- **Section 2:** An independent water right and water supply availability analysis
- **Section 3:** A summary of basin hydrology and hydrogeology and how these can impact the ability to satisfy long-term ESPA recharge goals
- **Section 4:** Information on local considerations and potential limits to aquifer recharge
- **Section 5:** Literature cited

Definitions

Adjudication: A court action for the determination of existing water rights which results in a decree that confirms and defines each water right.

Administrative Transfer: A required process used to change the elements of a water right (for example, the point of diversion, place of use and or purpose of use).

Allocate or Allocation: Storage (water) volume allotted to a diversion available to be used during the irrigation season.

Application for Permit: An application form filed with IDWR requesting the right to appropriate the water of the State of Idaho for a beneficial use. An application for permit requires public notice.

Beneficial Use: Beneficial uses include domestic use, irrigation, stock-watering, manufacturing, mining, hydropower, municipal, aquaculture, recharge, recreation, as well as fish and wildlife. The amount of the water right is the amount of water put to beneficial use. Because of the beneficial use requirement, a water right (or a portion of a water right) might be lost if it is not used for a continuous five-year period.

Carryover: The remaining storage in a diversion's or spaceholder's storage allocation (after all debits and credits for storage usage, rentals, and any other adjustments have been made in the water right accounting) carried over from one irrigation year to the next irrigation year.

Channel Losses: Surface water exiting the stream channel between the beginning and ending points of a reach caused by evaporation, evapotranspiration, bank storage, or surface water percolating down to ground water below the channel bottom.

Conjunctive Administration: The administration of groundwater and surface water sources by priority, as one source.

Conjunctive Management: The management of groundwater and surface water deliveries in response to a priority call under conjunctive administration.

Consumptive Use: The quantity of water consumed during beneficial use (for example, evapotranspiration from plants as a result of irrigation use). Although consumptive use is not an element of a water right, it must be considered during an administrative transfer to prevent injury to other water users when the nature of use of a right is changed (for example, irrigation to municipal).

Conveyance losses: Water losses in a channel incurred as a result of conveying water from one point to the next.

Diversion: A structure used to divert water from its natural source. Typical diversion structures include pumps, headgates, ditches, pipelines, and dams—or some combination. A diversion is generally required to establish a water right. The Idaho Water Resource Board is authorized to acquire water rights without diversions. These water rights are called "instream flow" water rights and are typically authorized for purposes of protecting some public interest in a natural stream or lake such as recreation, wildlife, or natural beauty.

Fill: Can have several different meanings 1) distributing natural flow to a water right in the accounting, 2) accruing natural flow to a reservoir water right in the accounting, 3) the paper fill of a reservoir, or 4) the physical fill of a reservoir.

Flow Augmentation: Water deducted from storage allocations or deducted from rented storage supplies released past Milner Dam for augmenting downstream river discharges.

Idaho Department of Water Resources (IDWR): The State regulatory agency responsible for water rights in Idaho.

Idaho Water Resource Board (IWRB): The agency described in Idaho's constitution to formulate and implement a state water plan. The duties and authorities of IWRB include comprehensive basin planning, protected rivers designations, minimum stream flow program, water project financing, water supply banks, and water rentals.

In-priority: When natural flow is sufficient to fill (or partially fill) a diversion's water right after senior diversion water rights have been satisfied, the diversion's water right is said to be "in priority."

Instream Flow Water Right: A water right typically authorized for the purposes of protecting some public interest in a natural stream or lake such as recreation, wildlife, or natural beauty.

Lateral: A ditch used to convey or deliver water, especially for irrigation purposes.

Natural Flow: The reach gain, or total cumulative upstream reach gains, in a river system.

Place of Use (POU): The legal location where a water right is used, generally described as quarter-quarter sections down to a 40-acre tract. Other legal descriptions that might be used are government lots, block, subdivision, parcel numbers, townsite names, mining claim information, homestead entry surveys, and other survey information.

Point of Diversion (POD): The legal location where water is diverted from its source, generally described as quarter-quarter sections down to a 40-acre tract or smaller. Other legal descriptions that might be used are government lots, block, subdivision, parcel numbers, townsite names, mining claim information, homestead entry surveys, and other survey information. Legal locations for instream flow claims are marked with a beginning point and an ending point.

Prior Appropriation Doctrine: The policy whereby a water use developed prior to other uses has a right to divert water ahead of the uses developed later in time, during times when the amount of natural flow is insufficient to fill all water rights. Prior Appropriation is also referred to as "first in time is first in right."

Priority Date: The date when a water right was established; this date determines which water users can receive water when supply is insufficient to meet all rights. Water rights with younger (more recent) priority dates are called "junior" and are the first to be curtailed when supply is short. Water rights with older priority dates are called "senior" and are the last to be curtailed.

Reach Gain: The gain (positive value) or loss (negative value) of water between the beginning and ending of a river reach (A reach is a general term for a length of a stream or river), computed as the reach outflow minus the reach inflow, plus the reach's surface diversions, change in reservoir content, reservoir evaporation, and injections from groundwater exchange wells.

Return Flow: Water that returns to the stream after being diverted from the stream.

Season of Use: The specific season when a water right can be used.

Water Right Permit: A conditional approval issued by IDWR authorizing development of a new water right. A water right permit is issued based on the filing of an application for permit.

Water Right: A right to divert and make beneficial use of water. Water is a publicly owned resource in Idaho, but the right to use water can be privately owned.

Water Right Decree: A decree issued by a court as the result of an adjudication of water rights.

Water Right License: The document issued by IDWR documenting the extent of a water right. A water right license is issued after development under a water right permit is complete and the extent of beneficial use is verified by IDWR.

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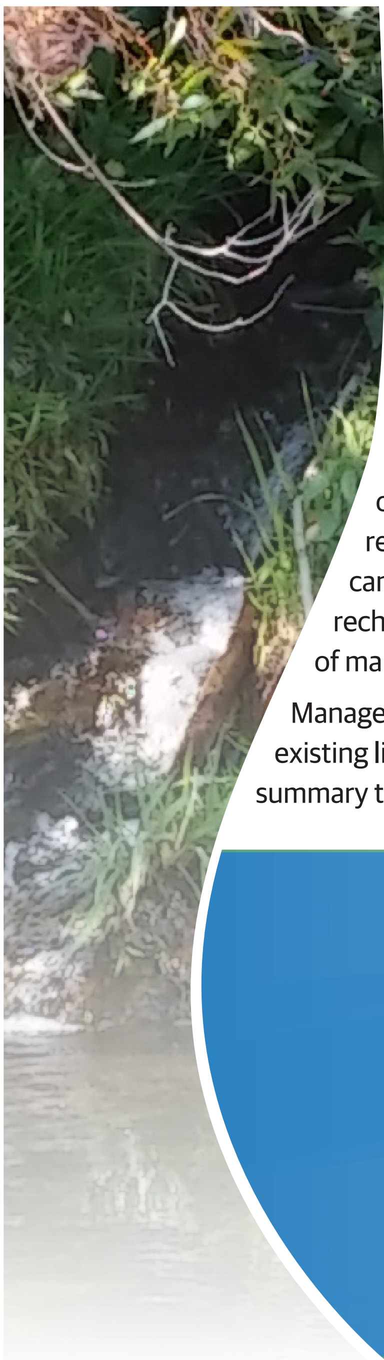
SECTION 1

Summary of the State's Recharge Program and Its Evolution Over Time

Significant work has been done related to ESPA recharge.



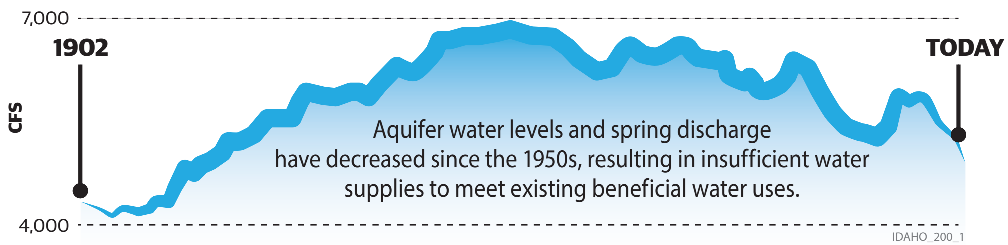


FIGURE 1. Average annual spring discharge to Snake River between Milner and King Hill

Since 2009, the state has had a specific managed recharge goal, recharge 250,000 acre-feet each year to the ESPA. Prior to 2014, the IWRB has conducted managed recharge through an opportunistic approach, working with canal operators to recharge using canals and specific constructed sites. Managed recharge generally occurred during the early spring and late fall. In partnership with canal operators, 2014 was the first year that IWRB was able to conduct managed recharge throughout the winter. In winter 2014/2015, there was over 75,000 acre-feet of managed recharge on the ESPA.

Managed recharge to the ESPA has evolved over decades. We compiled and reviewed the existing literature and various presentations related to ESPA managed recharge, providing a summary timeline on the following page.

The literature review is summarized in Appendix A.

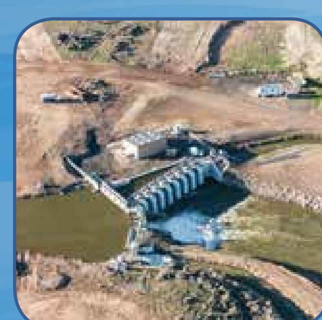


FIGURE 2. Significant work related to ESPA recharge has been documented in various reports and presentations

2009
IGWA uses Northside Canal Company's canal system to recharge 13,700 acre-feet in the fall of 2009.

2009
ESPA comprehensive aquifer management plan (CAMP) is adopted by the IWRB and signed into law as part of Idaho's state water plan.

2008 through 2009
IWRB implements the W-Canal recharge pilot project off of the Northside Canal near Wendell, Idaho.

2006
IWRB's recharge rights are used for the first time; approximately 38,000 acre-feet of recharge from the Snake River and 22,500 acre-feet of recharge from the Wood Rivers.

2001
Idaho legislature appropriates $60,000 to IWRB for the Sugarloaf recharge site on the Northside Canal Company's canal system.

1992 through 1997
Initiated Southwest Irrigation District's high plains groundwater recharge demonstration project: 13 injection wells, 23,154 acre-feet recharge between 1992 and 1997.

1980
LSRARD acquires water right permit (currently held by IWRB) for recharge with a 1980 priority date and constructs the Shoshone recharge site.

1978 through 1980
Legislation creating the Lower Snake River Aquifer Recharge District (LSRARD).

1962
U.S. Geological Survey investigation into the feasibility of artificial recharge in the Snake River basin. Discussed three areas: Roberts-Plano recharge area, including Egin Lakes, Idaho Falls area, and the Milner-Shoshone area including the Wood River area.

1955 to 1960
Bureau of Reclamation/Corps of Engineers Upper Snake River Basin Study.

2014/2015
Since 2009, the state has had a specific managed recharge goal, recharge 250,000 acre-feet each year to the ESPA. In winter 2014/2015, there was over 75,000 acre-feet of managed recharge on the ESPA.

2007
Idaho Ground Water Association (IGWA) acquires 29,500 acre-feet of water for mitigation; this water was put into Northside Canal Company's canal system in the fall of 2007.

2005
Idaho legislature passes HCR 28, HB 373, and HB 392, directing the IWRB to sponsor and fund managed recharge programs.

1999
IWRB releases the ESPA Managed Recharge Feasibility Report.

1998
IWRB files for additional recharge rights, allowing for diversion rates under all the rights combined to be 14,072 cfs, with PODs throughout the system.

1995
Idaho legislature appropriates $945,000 to the IWRB for recharge on the ESPA. The Board delegates the program to Water District 01 to convey water through the existing canals in that district.

1981
IWRB documents the cost-benefit of full-scale recharge at Egin Lakes.

1970-1974
Idaho Water Resource Board (IWRB) implements the St. Anthony pilot recharge project. 16,200 acre-feet diverted to Egin Lakes area (temporary water right permit).

1960
First year of the investigation of the Snake Plain Recharge Project (1960 through 1962). Identified several potential recharge areas, including: St. Anthony, Idaho Falls, Idaho Falls-Blackfoot gravel pit areas, and to a lesser extent the Milner-Gooding area and Big and Little Wood recharge areas.

SECTION 2

Water Rights and Water Supply Availability

2.1 Introduction

Generally, the majority of water available to the eastern Snake River plain comes from snow falling on the mountains along the flanks of the basin. This snow melts, and much of it is captured in surface water reservoirs. This water is released for irrigation supply during the months of April through October, depending on the climate in any given year. This irrigation water is conveyed in earthen channels across the plain and is used to meet irrigation demands. Water delivered in excess of crop needs (evapotranspiration) and other consumptive use (any water used in manufacturing, agriculture, food preparation, etc. that is not returned to the river) can infiltrate into the ground and eventually recharge the aquifer.

Irrigation on the eastern Snake River plain began in the 1880s. Prior to irrigation, recharge to the ESPA occurred from stream seepage, subsurface inflow from tributary basins, and direct precipitation. Pre-development aquifer discharge appeared to be relatively constant. As the area was colonized in the early part of the 20th Century, the state issued water rights. This led to steadily increasing aquifer recharge, and in turn aquifer discharge, primarily as a result of recharge incidental to irrigation. During this time, irrigation water was withdrawn from streams, delivered in earthen canals, and applied directly to crops via flooding, furrows, or subirrigation. In the middle of the 20th Century, irrigation technology advanced, allowing farmers to increase efficiency by using sprinkler application. Although most conveyance still occurs in the earthen canals, conversion to sprinkler irrigation has led to a reduction in incidental recharge, as has been observed in other areas in the West (Venn et al., 2004). Increased irrigation efficiency, coupled with the advancement of pumping technology and subsequent issuance of water rights for using groundwater for irrigation, led to changes in the nature and extent of recharge to the ESPA, resulting in a steady decline in Thousand Springs discharge that began in the early 1950s.

Availability of water for managed recharge on the ESPA is governed by physical water supply, management of the upper Snake River reservoir system, water rights priorities within Water District 01 (WD01), and policies established by the IWRB, including those specified in the State Water Plan and the ESPA CAMP. The primary policy elements are managed recharge on the ESPA:

- Is an opportunistic use of available natural flow in the upper Snake River system,
- Shall not interfere with optimal storage of water in the upper Snake River reservoirs,

- Will be conducted in accordance to the prior appropriation doctrine, as administered by WD01,
- Shall not interfere with exercise of the U.S. Bureau of Reclamation's unsubordinated power right at Minidoka,
- Will be consistent with the State Water Plan and the ESPA CAMP.

These policies have been summarized in a number of documents, including the support narrative accompanying resubmittal of the IWRB's water-right applications for managed recharge (IWRB, 2013). The support narrative includes several attachments that translate these policies into specific criteria that define when, where and how much water is available for managed recharge. These attachments include analysis of availability of water for managed recharge at a monthly time scale over irrigation years 2000-2012 at five stream gage locations throughout the upper Snake River basin. Availability was reported as monthly volume of available water and number of days during each month on which water would have been available for managed recharge over those irrigation years. That analysis showed that managed recharge was possible downstream of Minidoka Dam every year, on an average of about 200 days per year, primarily during the winter. Recharge upstream of Minidoka is possible in about half of the years, on an average of about 20 days per year, primarily during spring and early summer. However, the annual volume of natural flow passing Milner over a longer period of record—irrigation years 1980 through 2011—showed much higher potential for managed recharge availability during periods of above-average water supply, including the sequences of wet years 1982-1987 and 1996-1999. Total volume of natural flow passing Milner averaged 1.8 million acre-feet per year over 1980-2011, with a median of 366,000 acre-feet per year.

2.1.1. Purpose, Objectives, and General Methodology

The purpose of this analysis is to expand on the assessment of availability of water for managed recharge presented in the support narrative (IWRB, 2013). The project objectives, and water availability assessment methods are:

1. Estimate availability of water for managed recharge under the IWRB's existing and pending managed-recharge water rights over irrigation years 1980-2014 (n = 35), at seven locations throughout the upper Snake River basin.
2. Identify, at a daily time scale, the water-supply and water-rights constraints that allow or limit availability of water for managed recharge at each location.
3. Compare availability over the 1980-2014 period of record with that presented in IWRB (2013) for 2000-2012.
4. Discuss implications of water availability for attainment of managed recharge goals for the ESPA.

This analysis focuses solely on availability of water as constrained by physical supply and water rights, including the Milner zero-flow principle, which states that the minimum daily flow at the Milner gauging station shall remain at zero cubic feet per second (IWRB, 2012). Other constraints on managed recharge, including conveyance and infiltration capacities, weather, and physical infrastructure, are discussed elsewhere in this report. However, Section 2.4 includes brief summaries of interactions between water availability and other constraints, including private recharge water rights and fish, wildlife and recreational resources.

2.1.2. Reporting of statistics

Hydrologic quantities such as precipitation, streamflow, and groundwater storage are what statisticians call random variables, because their value at any point in space and time varies randomly around an expected value. A random variable can be fully described only by specifying the underlying probability distribution, which is a complicated mathematical formula useful only in specialized analysis and modeling. Thus, in management and planning contexts such as this, random variables are usually summarized by reporting a measure of the central tendency (the "typical" value) and dispersion (variability around the central tendency). Commonly reported values of central tendency and dispersion are the mean and standard deviation, respectively. These values work well for random variables that have "nice" distributions such as the Normal distribution, which most of us visualize as the bell-shaped curve we saw in high-school math class.

For example, consider the following set of hypothetical annual streamflow values (in 1,000s of acre-feet): 125, 144, 160, 178, and 210. These numbers are typical of natural streamflow in a basin with large groundwater inputs. The mean (average) of these is 163.4, and the standard deviation is 32.6. The mean describes the "typical" value well, as the "middle" number in the set is 160, very close to the mean. Two of the remaining five values are below the mean, and the other two are above the mean by about the same magnitude. The smallest value in the set is 1.2 standard deviations below the mean, and the largest value in the set is 1.4 standard deviations above the mean. In accordance with the bell-shaped curve, the numbers are symmetrically distributed around the center; the left half of the distribution is a mirror image of the right half. In these types of distributions, extreme values—those that occur less than 5% of the time—lie about 2 standard deviations away from the mean. Thus, in this example, we would expect streamflow to be lower than 98.2 thousand acre-feet or greater than 228.6 thousand acre-feet less than 5% of the time. The mean and standard deviation, together with the assumption or knowledge that the distribution is "bell-shaped," provide good guidance for water-resource planning and management. Planners can count on around 160 thousand acre-feet of water in the typical year and water availability between 98.2 and 228.6 cfs thousand acre-feet per year in 95% of all water years.

Now consider the set of five values: 0, 0, 10, 200, and 607. These numbers are typical of water availability under water rights that are junior in the priority system. The mean of these is 163.4, just as above, but now the standard deviation is 262.2. In this case, the mean is not typical at all of values in the data set. Three of the five values are far below the mean, one value is slightly larger than the mean, and the fifth is much greater than the mean. The maximum value is 1.7 standard deviations above the mean, whereas the minimum value is only 0.62 standard deviations below the mean. By the 2-standard deviation rule, an extremely low value in this distribution would be negative 361 thousand acre-feet, which is meaningless. The distribution is obviously not symmetric; instead, the large values are much farther away from the center than the small values. Statisticians refer to this as a right-skewed distribution. In this case, the mean and standard deviation do not provide good guidance for water-resources planning. If, based on the mean of these data, an irrigation district planned on having 164.4 thousand acre-feet of water in the typical year, it would greatly overestimate the amount of water available. In reality, the district would receive no water at all in two years out of five, and in the "middle" year, it receives 10 thousand acre-feet. Only in the wettest half of the years does the district receive a large amount of water. In these types of data sets, the median is a much more meaningful measure of the center. The median is literally the number that sits in the center of the data set; half of the values lie below the median and half above. In this case, the median is 10, indicating that water availability is greater than 10 thousand acre-feet in only in the wettest half of all water years. The most meaningful measure of dispersion for a data set such as this is to report percentiles, most commonly the 25th and 75th percentiles. In this case, the 25th percentile is 0, indicating that in 25% of all years, there is no water available under this right. The 75th percentile is 200, indicating that availability exceeding 200 thousand acre-feet occurs in only 25% of all water years. Minimum and maximum values are also typically reported for highly skewed distributions.

Because distribution of water available for managed recharge proved to be highly right-skewed, we use medians, percentiles, minimum, and maximum values as summary statistics in this report. Furthermore, we use graphs of availability across irrigation years to illustrate the full distribution of annual values and illustrate within-year variability at the daily scale with selected years that are representative of the different types of water years that can occur. However, for thoroughness and transparency, means are reported in detailed tables of results, which appear in Appendix B.

2.2. Methods

This section presents methodology, with emphasis on the water-rights accounting aspects of determining water availability for managed recharge. A detailed description of water-rights accounting in WD01 is given in Olenichak (2015); we present only elements relevant to calculating availability of water for managed recharge under the IWRB rights.

2.2.1. IWRB water rights for managed recharge

Table B.1 in Appendix B lists all water-right permits and applications for groundwater recharge in the upper Snake River basin. The IWRB holds one water right for managed recharge in the upper Snake River basin and has applied for eight others. The existing water permit (01-7054) has a priority date of 8/25/1980 and a diversion rate of 1,200 cfs. Although the Milner-Gooding Canal is listed as the only point of diversion (POD) associated with this right, water has been diverted under this right at other PODs throughout the upper Snake River system using water rented from the water supply bank. The current water supply bank rental agreement, which is valid from January 1, 2014 through December 31, 2018, allows water from the supply bank to be diverted for groundwater recharge at PODs on the Henrys Fork, Fall River, South Fork Snake River, Snake River between Menan and Blackfoot, and Snake River between Minidoka and Milner (IDWR, 2014). Given this precedent, it was assumed for this analysis that this water permit can be exercised in any stream reach in the upper Snake River basin. Figure 3, on the following page, shows these stream reaches, as well as other important points in the basin.

Each of the eight applications has a priority date of 3/20/1998. Diversion rates range from 94 cfs to 3,738 cfs, and the eight applications together include a large number of PODs across the upper Snake River basin, as summarized in Table 1. We assumed that these applications will be approved as submitted and that diversion of water for managed recharge under the resulting permits will be limited to the PODs listed in the applications.

TABLE 1. Water District 01 accounting nodes used in this analysis, corresponding stream reaches where groundwater recharge points of diversion (PODs) are located, and applicable 1998-priority groundwater recharge rights. We assume that diversion for groundwater recharge under the 1980-priority right (1200 cfs) can occur in any of the stream reaches.

Accounting Node	Station ID	Recharge Diversion PODs	IWRB 1998 Right(s)	Diversion Rate (cfs)
Milner	13088000	Minidoka to Milner	1-7142, 1-10609	6569
Minidoka	13081500	Minidoka	1-10609	3738
Near Blackfoot	13069500	Shelley to Near Blackfoot	1-10612	2106
Shelley	13060000	Menan to Shelley	1-10612	2106
Heise	13037500	Heise to Lorenzo	1-10613	3206
HF St. Anthony	13050500	Henrys Fork Ashton to Rexburg, and Fall River	21-7577, 21-7578, 21-7580, 21-13160	2191
Teton St. Anthony	13055000	Teton St. Anthony to mouth	21-13160	1130

2.2.2. Flow at Milner: Winter versus summer

By the Milner zero-flow principle, natural flow that passes Milner Dam is available for appropriation and use upstream of Milner (IWRB 2012). In water-rights accounting terminology, flow at Milner Dam is referred to as "Milner total flow," which is the sum of flow at U.S. Geological Survey (USGS) gaging stations 13087995 (Snake River at Milner) and 13087505 (Lower Milner Power Plant). Total flow at Milner is reported in WD01 water-rights accounting records as "actual flow" at the Milner accounting node, numbered 13088000.

"Natural flow" at Milner, which is equivalent to natural flow for the entire upper Snake River system, is defined as the sum of reach gains over all upstream accounting nodes, adjusted for travel times down the river (Olenichak, 2015). Mathematically, natural flow at Milner is actual flow plus diversions plus change in reservoir storage plus reservoir evaporation and is thus an estimate of the physical quantity of water that would flow past Milner in absence of diversions and reservoirs. Figures 4 and 5 illustrate the relationships among diversions, natural flow, storage, and groundwater inflow in the upper Snake River basin.

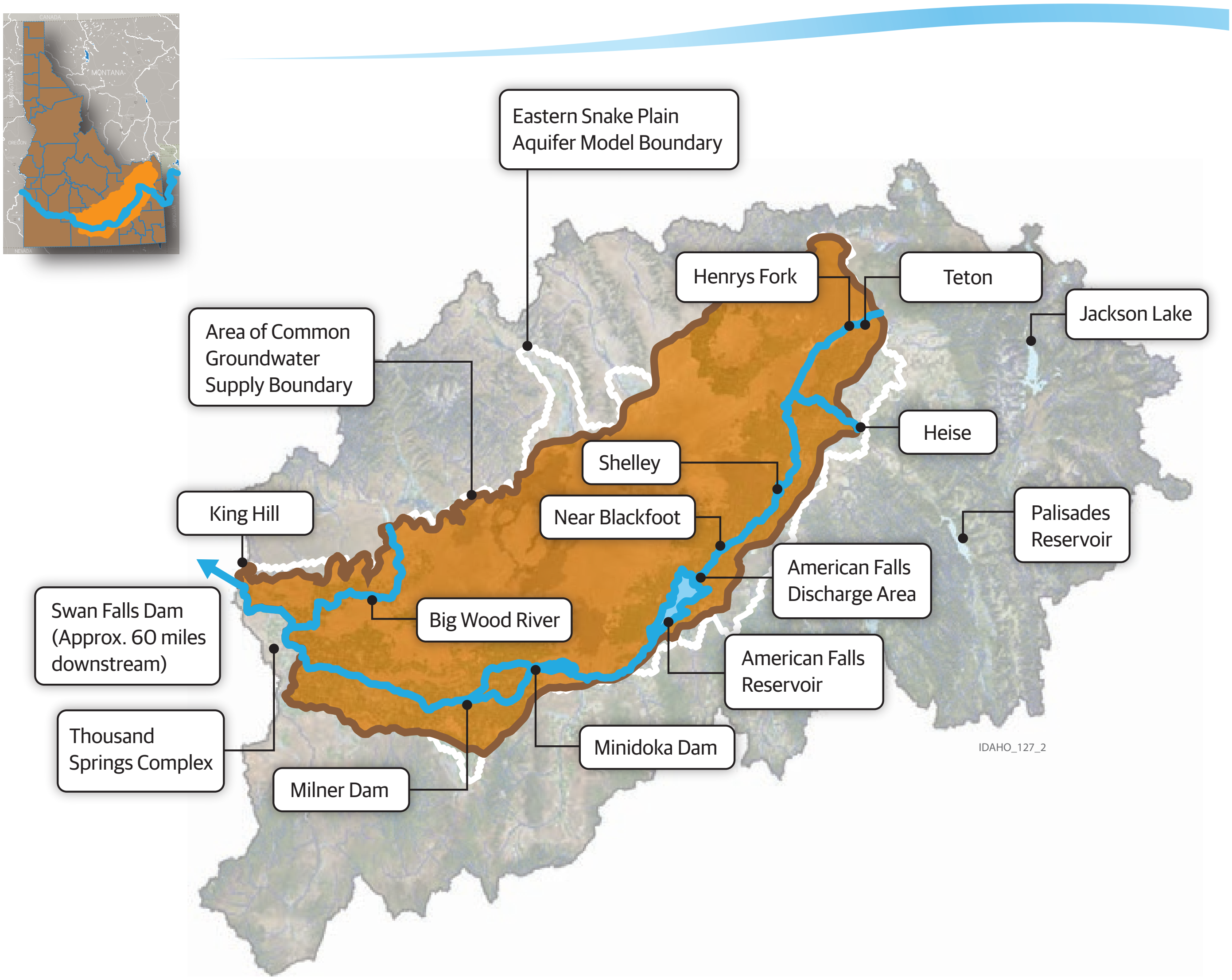


FIGURE 3. Map of upper Snake River basin, showing relevant points of interest

Because most surface water rights in the WD01 accounting system have a season of use contained within the April 1 through October 31 irrigation season, we divide the year into two time periods for estimating whether flow at Milner is available for diversion under the IWRB rights: "winter" (November 1 through March 31) and "summer" (April 1 through October 31). During winter, the primary water-management operation in the upper Snake River is storage in the reservoir system, although a small amount of diversion occurs under year-round water rights for stock water, groundwater recharge, and a few other uses. The U.S. Bureau of Reclamation (USBR) manages winter operation and fill of the reservoir system, based on physical reservoir system carryover from the previous irrigation season, reservoir inflows, and actual and projected snow accumulation. In general, winter reservoir operations are designed to maximize annual storage, subject to flood control rules and a few other operational guidelines. In general, there is sufficient storage capacity upstream of Minidoka that all system inflow upstream of that point can be stored when needed. Because storage capacity of Milner Reservoir itself is small, river reach gain between Minidoka and Milner exceeds storage capacity at Milner, even when storage of that water would be desired to maximize system-wide storage. Therefore, we assume that any and all actual flow at Milner during the winter period is water that was either not needed for storage or not possible to store in the reservoir system. This water is available for managed recharge.

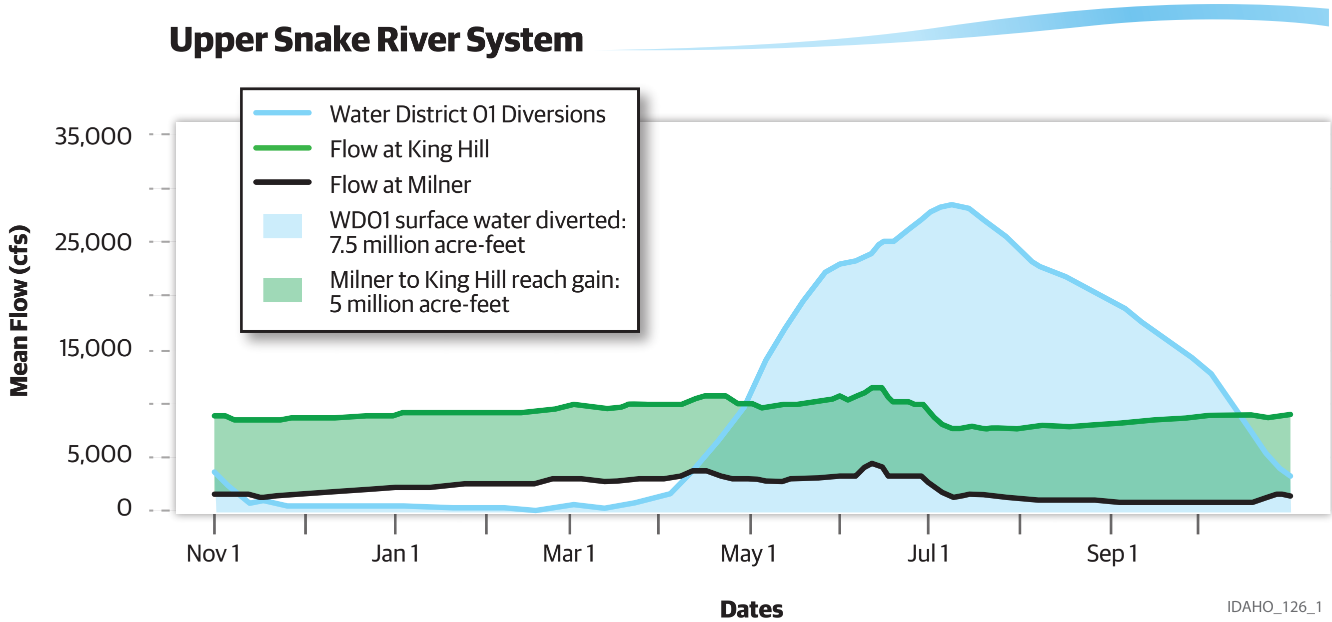


FIGURE 4. Mean hydrographs showing total surface water diverted in Water District 01, in comparison to flow in the Snake River past Milner and flow in the Snake River at King Hill.

The green shaded region depicts inflows to the Snake River between Milner and King Hill, the majority of which is discharge from Thousand Springs.

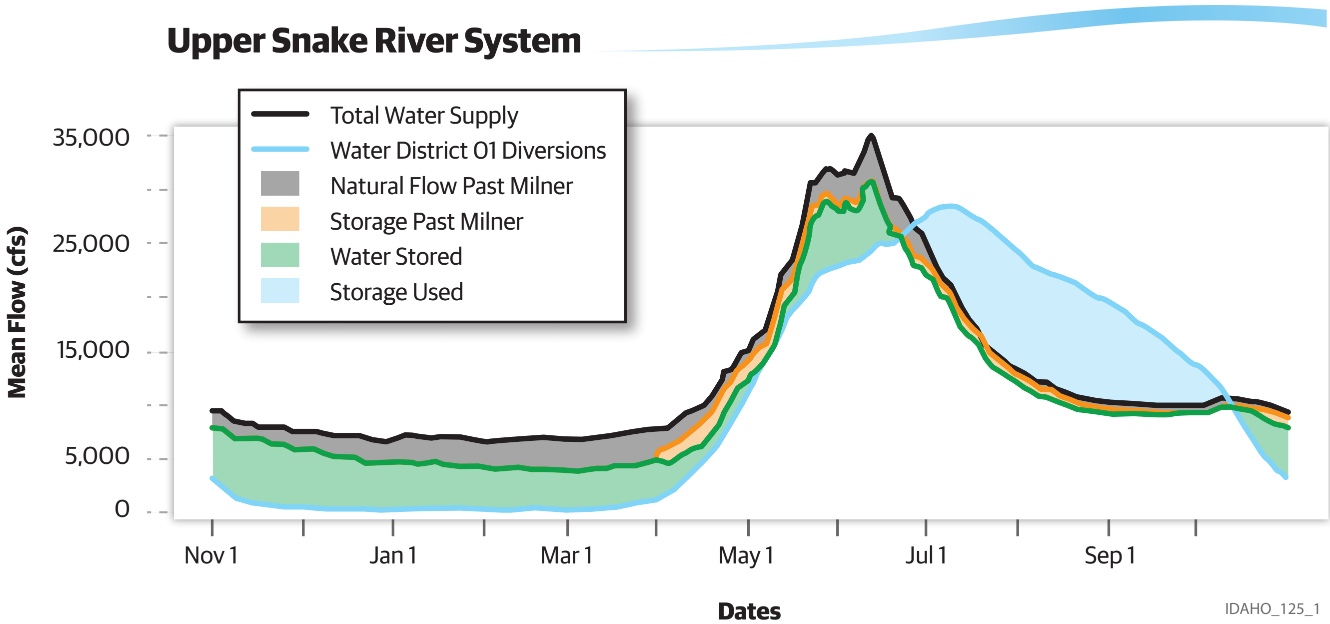


FIGURE 5. Mean hydrographs for the major components of Water District 1 surface-water management.

Means are taken over irrigation years 1988-2014. Water supply peaks in mid-June, whereas irrigation demand peaks in early July. On average, water is stored in the reservoir system from mid-October through late June, except for a brief period around May 1. Storage water is used to meet irrigation demand from late June through mid-October. Natural flow past Milner, which is greatest in late winter and during peak runoff, is available for managed recharge. Storage water delivered past Milner is not available for managed recharge.

During the summer, system operations and analysis of availability of flow for managed recharge are more complex. Diversion of water for irrigation at most PODs in the upper Snake River system begins on April 1. In most years, there is a period of time during the early part of irrigation season when diversion equals or even exceeds availability of natural flow, preventing additional storage from being captured. Actual flow at Milner is usually zero during this time period, since reach gains between Minidoka and Milner can be diverted at Milner Dam. Once snowmelt begins, inflow increases, allowing additional storage to occur concurrently with diversion. If the combination of storage and diversion exceeds natural flow, actual flow at Milner will be zero. If not, then water in excess of storage capacity and diversion will spill past Milner. This water is available for managed recharge during summer. As irrigation season progresses and natural flow decreases, diversion exceeds natural flow at some point in time, and subsequently, reservoir storage is delivered as needed to meet demand. Flow at Milner will be zero after this point in time, except when storage water is delivered past Milner. Most often, storage delivered past Milner consists of flow augmentation for anadromous fish migration in the lower Snake River and water for hydroelectric power generation at Idaho Power facilities downstream. For example, over the 10-year period 2005-2014, delivery of water past Milner for anadromous fish flow augmentation was very constant at an average of 188,621 acre-feet per year, almost all of which was storage (USBR, 2005-2014). Flow augmentation delivery from the upper Snake River system most often occurs between early May and mid-August. This and other storage water delivered past Milner is not available for managed recharge. Thus, during the summer, total flow at Milner can consist of natural flow, stored flow or some combination. Using WD01 accounting data, subtraction of stored flow at Milner (when this number is positive) from actual flow at Milner yields the amount of natural flow at Milner, if any, that is available for diversion upstream of Milner above and beyond that already diverted under existing appropriations. In this document, we use the term "available natural flow at Milner" to indicate water that is available for managed recharge. By our assumptions, this is any and all flow at Milner during the winter and actual flow less stored flow during the summer. It is important to note that recharge system-wide is limited by available natural flow at Milner, regardless of the location of the POD(s) and the amount of actual flow that may be present at any given POD. Of course, at any given POD, the amount available for diversion under the recharge rights is limited by the amount of actual flow at that location.

2.2.3. Water-rights constraints

Diversion of water for managed recharge under the IWRB recharge rights requires those rights to be in priority at the POD. In addition, diversion under the IWRB rights cannot interfere with the USBR's unsubordinated power right of 2,700 cfs at Minidoka. Therefore, recharge under the IWRB rights cannot occur upstream of Minidoka unless flow at Minidoka exceeds 2,700 cfs and then only up to the difference between Minidoka actual flow and 2,700 cfs. Finally, diversion under the IWRB rights can only occur up to the maximum diversion rate allowed at the POD.

2.2.4. Decision tree for determining recharge availability under IWRB rights

We have summarized the discussion above in a decision tree that can be used to determine availability of water for managed recharge under the IWRB 1980- and 1998-priority water rights. The decision tree is shown in Figure 6, on the following page. For diversion during the winter, the decision tree is identical to that presented in IWRB (2013). However, we have added a "summer" branch to emphasize that during the summer: 1) the recharge water rights must be in priority at the POD, and 2) only natural flow at Milner is available for recharge.

2.2.5. Data and computational details

We applied the decision tree to WD01 water-rights accounting data for irrigation years 1980-2014 (n = 35) at seven accounting nodes that cover all PODs at which water could be diverted under the IWRB managed recharge rights . Our intent was to estimate the amount of water that would have been available for managed recharge at each POD in each of these water years, under current water-rights priorites. Accounting data were available in electronic form for irrigation years 1988-2014; data for irrigation years 1980-1988 were available only in hard-copy form in annual watermaster reports. However, actual flow at each node was available electronically from USGS, and we manually entered only the minimum amount of data necessary to implement the decision tree. This minimum set of data consisted of two pieces of information from the watermaster reports: 1) water-rights priorities at each node on each day of the irrigation season on which at

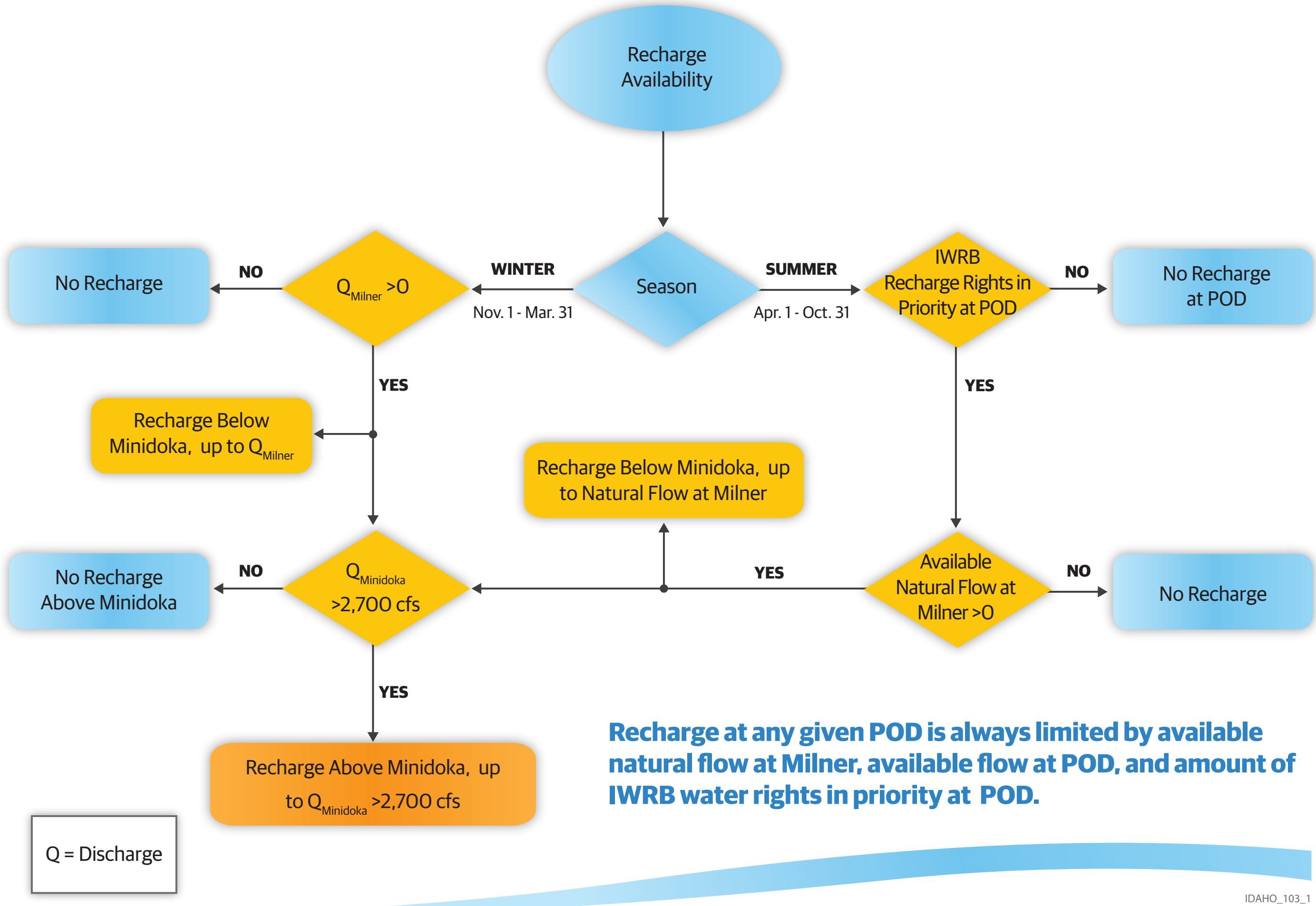


FIGURE 6. Decision tree used to determine availability of water for groundwater recharge under IWRB recharge rights

least the 1980 IWRB right could have been in priority, and 2) stored flow at Milner on each of these days.

We made a few adjustments to the water-rights accounting data in order to account for changes in the WD01 accounting system that have occurred since 1980. **First**, we adjusted available natural flow at Milner by adding the cumulative diversion rate of natural-flow rights with priority dates after 1998 to the recorded amount of available natural flow at Milner, on days when those rights were in priority. This was done because water diverted under rights with priority dates after 1998 would have been available for diversion under the 1998 rights. The cumulative diversion rate of rights with priorities after 1998 is small except for two that have been added to the accounting system relatively recently. One is 60 cfs in Minidoka to Milner reach, with priority 2/17/2009, and the other is 50 cfs in the same reach, with priority 9/28/2009. On days when these rights were in priority, their respective quantities were added to available natural flow at Milner. The cumulative diversion rate of rights with priorities after 1998 is no more than 2 cfs in all other river reaches, so these rights were ignored at those accounting nodes.

Second, for each irrigation year in the period of record, we recorded the most junior water-right priority that was senior to the 8/25/1980 and 3/20/1998 priority dates of the respective IWRB recharge rights. These dates were obtained from the annual watermaster reports. For example, in irrigation year 1985, the most junior right senior to the 8/25/1980 right had a priority date of 3/27/1979, and the most junior right senior to the 3/20/1998 right had a priority date of 6/7/1982. These priority dates were used to identify days in the historic period of record when the IWRB recharge rights could have been in priority, had the IWRB rights been in the accounting system in the given irrigation year. Using 1985 as an example, on any day of the irrigation season on which the 3/27/1979 right was in priority, any remaining natural flow at Milner could have been used to fill the 1980 recharge right.

Third, we recorded the cumulative diversion rate of rights with priority dates between 1980 and 1998 that are now in the accounting system but were not in accounting system in the given irrigation year. When the 1980 recharge right could have been in priority, we first applied any remaining natural flow at Milner to diversion under the 1980 IWRB right, then filled these 1980-1998 rights with any remaining natural flow, and lastly applied any remaining natural flow to the 1998 IWRB right, when it could have been in priority. These three adjustments allowed the most accurate estimation of availability of water over the past 35 water years for managed recharge, under current water-rights priorities and the existing and pending IWRB recharge rights.

On each day of the period of record and at each node, we recorded the amount of water that would have been available for managed recharge under the IWRB rights, assuming independence of the nodes. For each day, we also recorded the limiting constraint on the amount of diversion that could occur under the IWRB rights at PODs within the given river reach. In reality, water availability at any given location is dependent on all upstream nodes because water diverted at any point other than Milner reduces actual flow at downstream PODs. In addition, water diverted at any location counts against the available natural flow at Milner, against the total diversion rate allowed under the IWRB rights, and, if diverted upstream of Minidoka, against water available to the Minidoka power right. Across the system, the maximum amount of recharge is always available at Milner, and total diversion for recharge is always limited by available natural flow at Milner. We assumed independence of nodes because without any guidelines or constraints other than those described above, there is no unique way to distribute available water among all of the PODs at which water could be diverted for managed recharge.

All calculations, statistical summaries, and graphs were done in the R computing environment (R Core Team 2015). All calendar dates are reported in Milner time. Data for February 29 in leap years were removed before irrigation-year statistics were calculated.

2.3. Results

2.3.1. General patterns of recharge availability

Water was available for recharge at Milner and Minidoka during at least some period of the year during each of the 35 irrigation years, whereas water was available upstream of Minidoka only during years of high water supply. These patterns are evident in Figures 7 and 8. Downstream of Minidoka, water was available every winter, and during the two sequences of wet years in the 1980s and 1990s, respectively, there was enough available during the winter to fill the IWRB rights, as shown in Figure B.1 in Appendix B. Upstream of Minidoka, winter recharge was available only during wet years. Sufficient winter water was available in some years to fill the IWRB rights at some of the upstream nodes, but there was never enough winter recharge water available in the Henrys Fork or Teton River to fill the IWRB rights there. Summer availability was more consistent across the seven nodes. When water was available under either of the 1980 or 1998 rights at Milner, it was generally available at the other locations as well, and when available, it often filled all of the IWRB rights at each location. Availability of summer recharge under the 1980 and 1998 rights is shown in Figures B.2 and B.3, respectively.

2.3.2. Annual volumes of water availability

As shown in Figure 9 and Tables B-2 and B-3, availability of water was greatest and Milner and generally decreased with distance upstream, except that availability at Heise during wet years such as 1996-1999 was slightly higher than that at Shelley or Blackfoot. There was very little difference in availability between Shelley and Blackfoot, reflecting similar physical water availability and water-rights priorities at these two locations in the river system. Median annual volume available for recharge ranged from 627,000 acre-feet at Milner down to 85,800 acre-feet in the Teton River. Median winter-time availability was 402,000 acre-feet per year at at Milner, 361,000 acre-feet at Minidoka, and 693 acre-feet per year at all locations upstream of Minidoka. Median summer-time availability ranged from

134,000 acre-feet per year at Milner down to 46,000 acre-feet in the Teton River. Table B-2 shows that annual availability exceeded 10,000 acre-feet at any node upstream of Minidoka in only 22 of the 35 years analyzed. No recharge was available at any of the nodes upstream of Minidoka in 10 years, and in three other years, less than 10,000 acre-feet was available at any of these nodes.

2.3.3. Duration and timing of water availability

As shown in Figures 9 and 10 and Table B-2, the number of days on which water was available for recharge was far greater downstream of Minidoka than upstream. Figure 10 shows that downstream of Minidoka, water for managed recharge was available essentially every day of every winter. Upstream of Minidoka, water for managed recharge was available much less consistently from year-to-year, and when it was available, it was more likely to be available during the summer than winter. For example, at Heise, water was available for summer-time recharge in 23 of the 35 years analyzed but was available for winter-time recharge in only 19 of 35 years. In the median year, recharge was available on all 151 days during the winter period at Milner and Minidoka but on only 3 days upstream of Minidoka. During the summer, the median number of days of recharge availability was around 30 at all seven locations. As detailed in Table B-4, recharge was available at Milner and Minidoka over a period of at least 142 contiguous days during all 35 years, and during the median year, recharge was available over periods of 164, and 155 contiguous days at these two locations, respectively. These periods generally consisted of a few days at the end of irrigation season, together with the entire winter period. Upstream of Minidoka, recharge was available for a period of 34 contiguous days in the median year. These periods of contiguous days occurred during May, June and July. In 13 of the 35 irrigation years analyzed, there were no periods of longer than 3 contiguous days on which recharge was available upstream of Minidoka.

The hydrographs in Figure 11 illustrate duration and timing of water availability for managed recharge in each of four irrigation years that represent distinct patterns we observed in the 1980-2014 period of record. During years with high reservoir storage carryover, water was available for recharge at all nodes for most of the winter. In years such as 1987, availability decreased later in the winter because of low snow accumulation and forecast need to store spring runoff. In years such as 1996, large snowpack accumulations and resulting forecast need for flood control increased water availability as the winter progressed. In years with low reservoir storage carryover, around 600-800 cfs was available for winter recharge downstream of Mindoka, but none was available upstream of Minidoka. Water was available for summer-time recharge only in years of high snowpack, such as 1996 and 2009, regardless of whether winter recharge was available in those years. In such years, water was simultaneously available at all locations across the river system, with timing ranging from late May through early July, depending on timing and duration of peak snowmelt in a particular year. No recharge was available during the first three weeks of September at any node in any year. In most years, a small amount of water was available downstream of Minidoka during the last few weeks of irrigation season.

2.3.4. Limiting constraints on recharge availability

Table B.5 provides a detailed analysis of the constraints that can prevent managed recharge at given times and places and those that can limit diversion rates when recharge is possible. During the winter, recharge was possible downstream of Minidoka every year; rate of diversion was generally limited by available flow at Milner or the POD. In the median year, diversion rate was never limited by that allowed under the IWRB rights. Upstream of Minidoka, the Minidoka power right prevented recharge on the majority of days during the winter, and when flow was sufficient at Minidoka to allow winter recharge, the Minidoka power right constrained diversion rates. At all locations, water-rights priorities prevented recharge over the majority of days during the summer. When recharge was possible during the summer, diversion rate was most often limited by available natural flow at Milner in the lower stream reaches, by the IWRB rights in the middle reaches (including Heise), and by available flow at the PODs in the Henrys Fork and Teton River. During the summer,

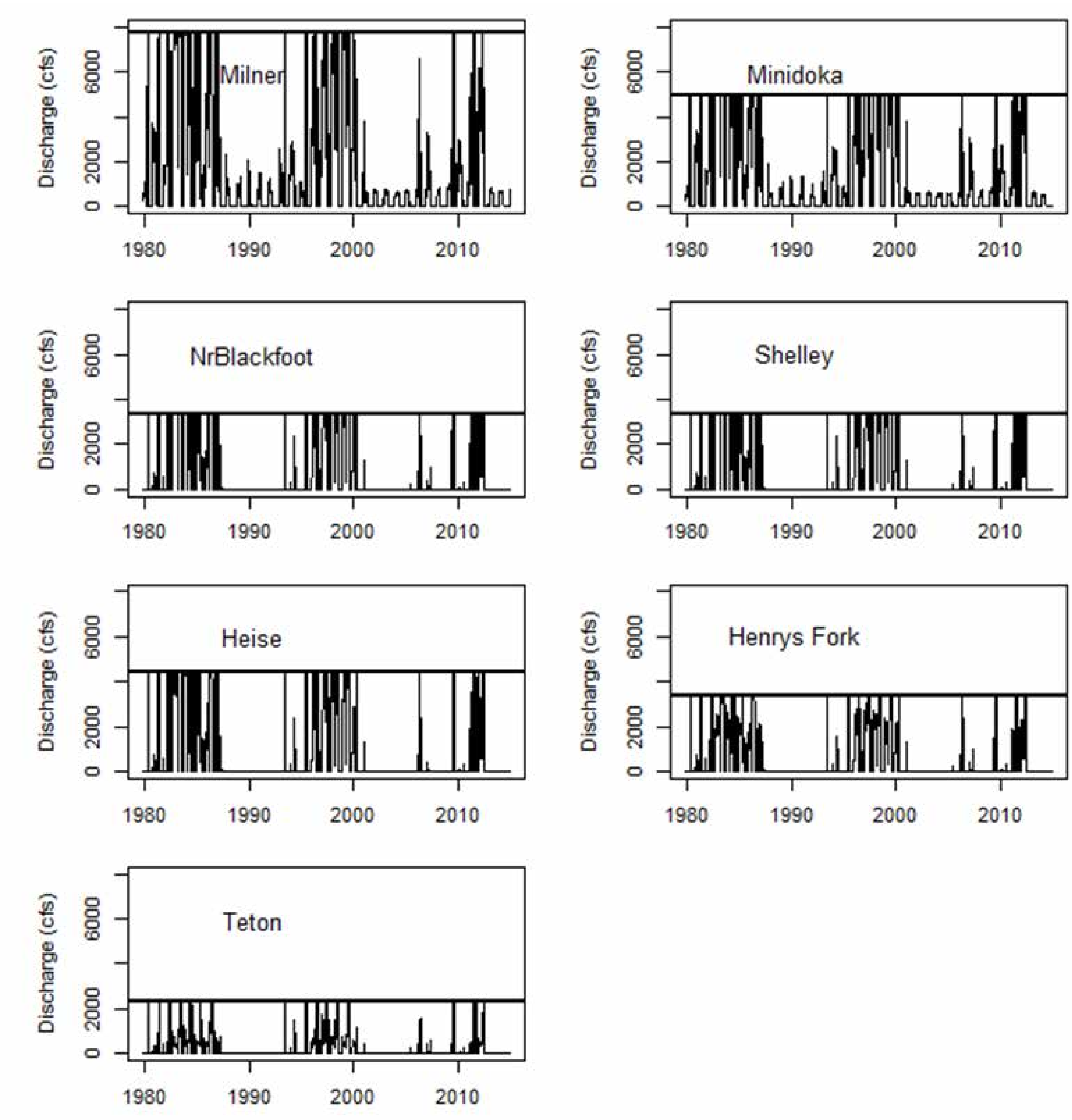


FIGURE 7. Total daily recharge availability, by stream reach, irrigation years 1980-2014.

The horizontal line on each graph is the maximum diversion rate of IWRB recharge rights. There is water available for recharge at Milner and Minidoka for some period of time during every irrigation year. During dry years (for example, the late 1980s through the early 1990s, and early 2000s) the water available for recharge is minimal, as expected. Water is available for recharge above Minidoka about 66% (two-thirds) of the time, based on historical data. Note, that when water is available for recharge, there is often sufficient water to fill the entire water right.

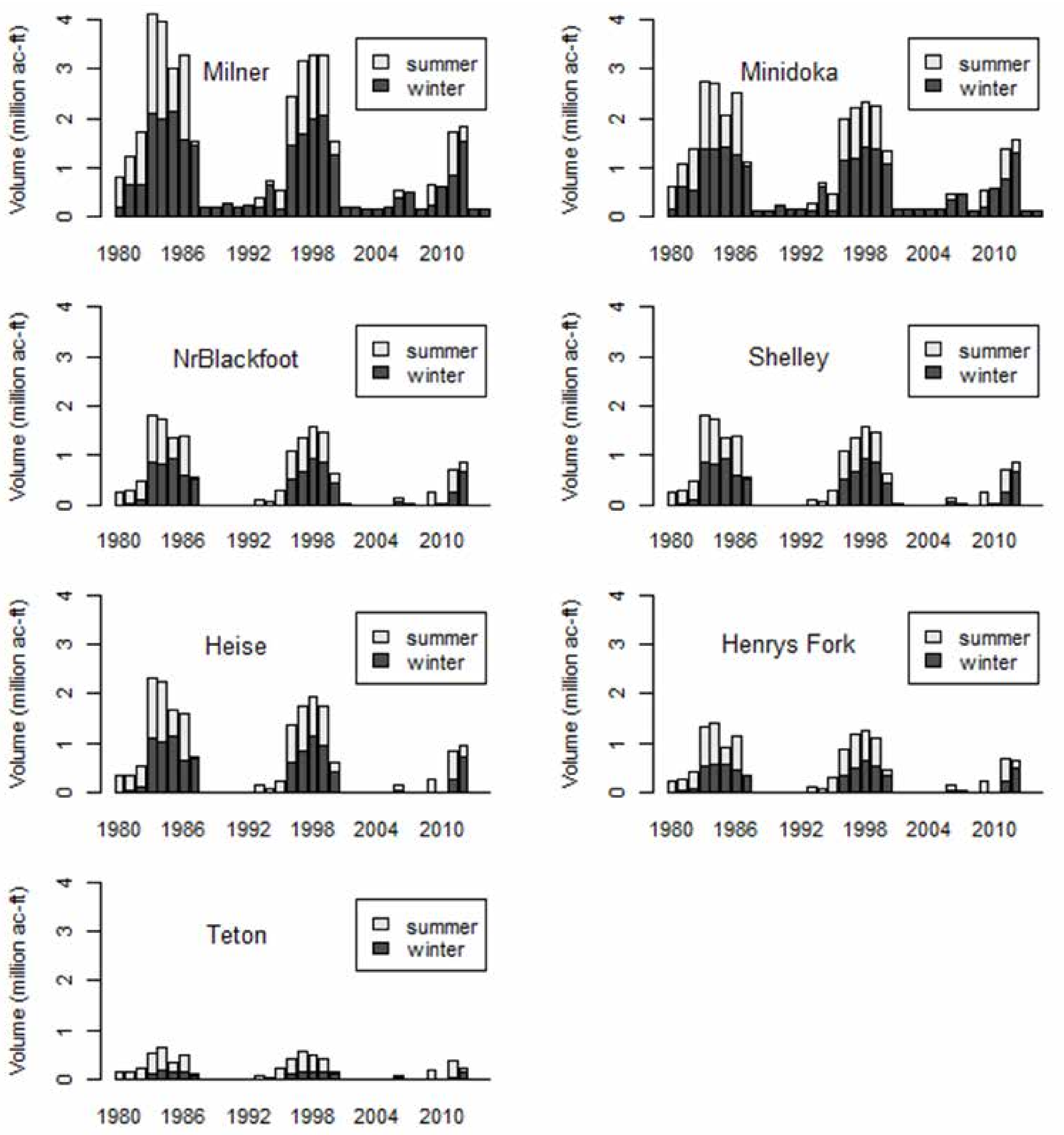


FIGURE 8. Total annual volume of water available for recharge, by stream reach, irrigation year, and season.

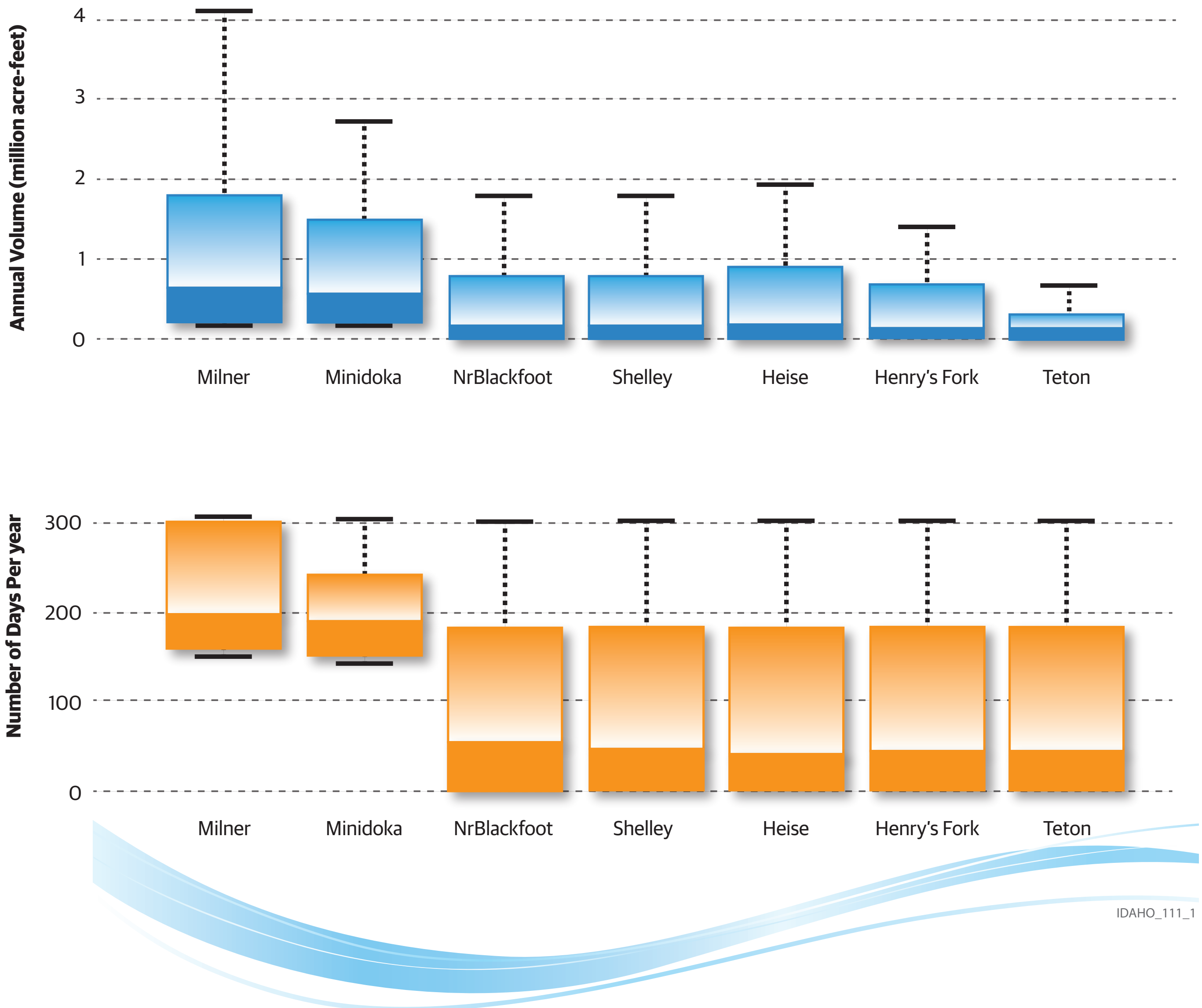


FIGURE 9. Box plots of total annual volume of water available for recharge (top) and number of days per year on which recharge could occur (bottom), by stream reach, irrigation years 1980-2014.

The top and bottom of the box are the 75th and 25th percentiles of the data, and the line in the middle of the box is the median (50th percentile). Top bar is the maximum value observed in the data, and bottom bar is the minimum. At all locations upstream of Minidoka, minimum recharge volume and the minimum number of days per year recharge was available were both 0 and coincided with 25th percentiles, so the bottom bar on those plots is not visible. This indicates that no recharge was available at these locations in at least 25% of all irrigation years.

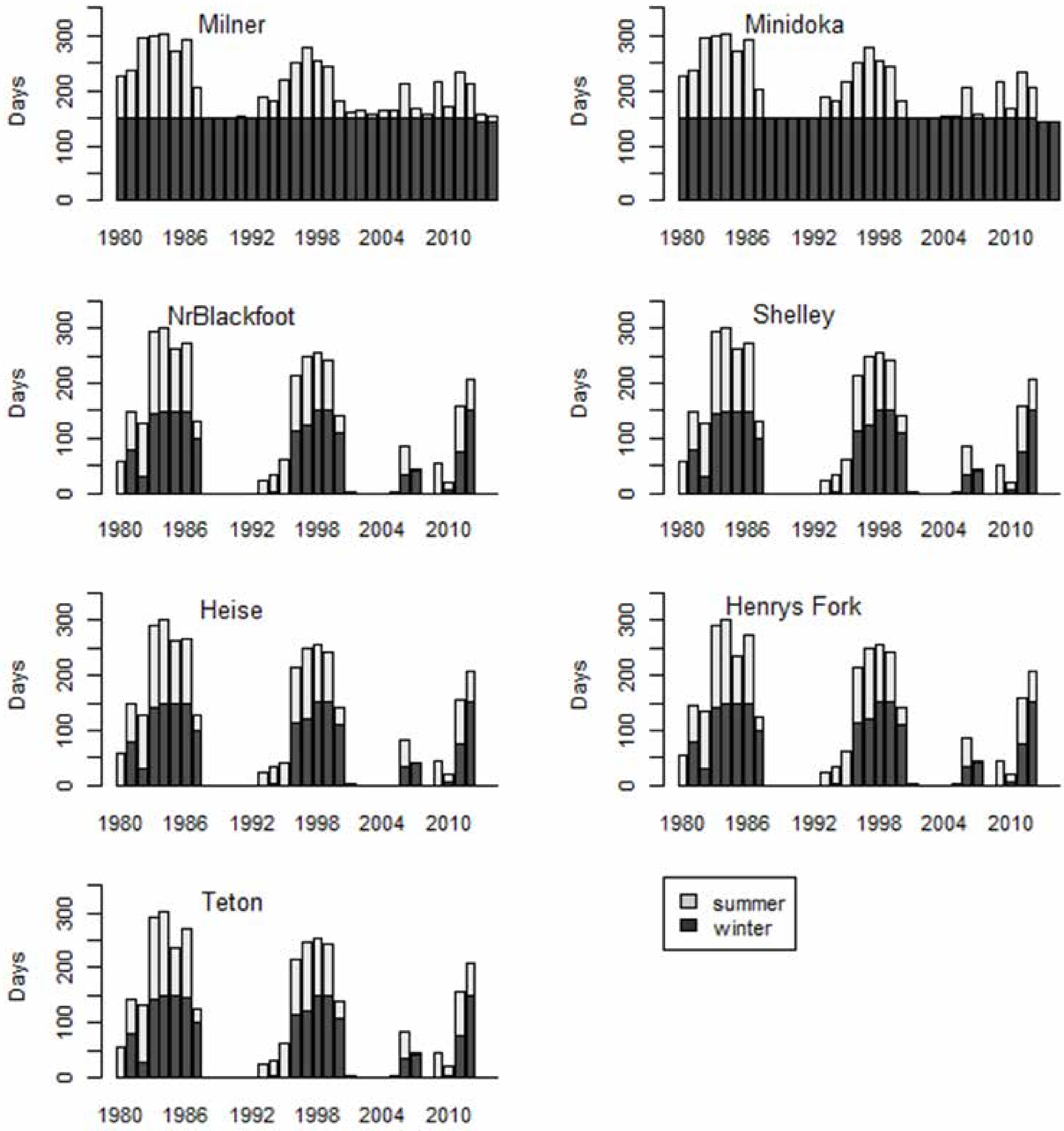


FIGURE 10. Number of days on which recharge could occur, by stream reach, irrigation year, and season.

The number of days recharge water is available above Minodoka comes in blocks of wet years. At Milner and Minodoka, there are only two years in the dataset where recharge water was not available for the full 151-day winter season, 2013 and 2014.

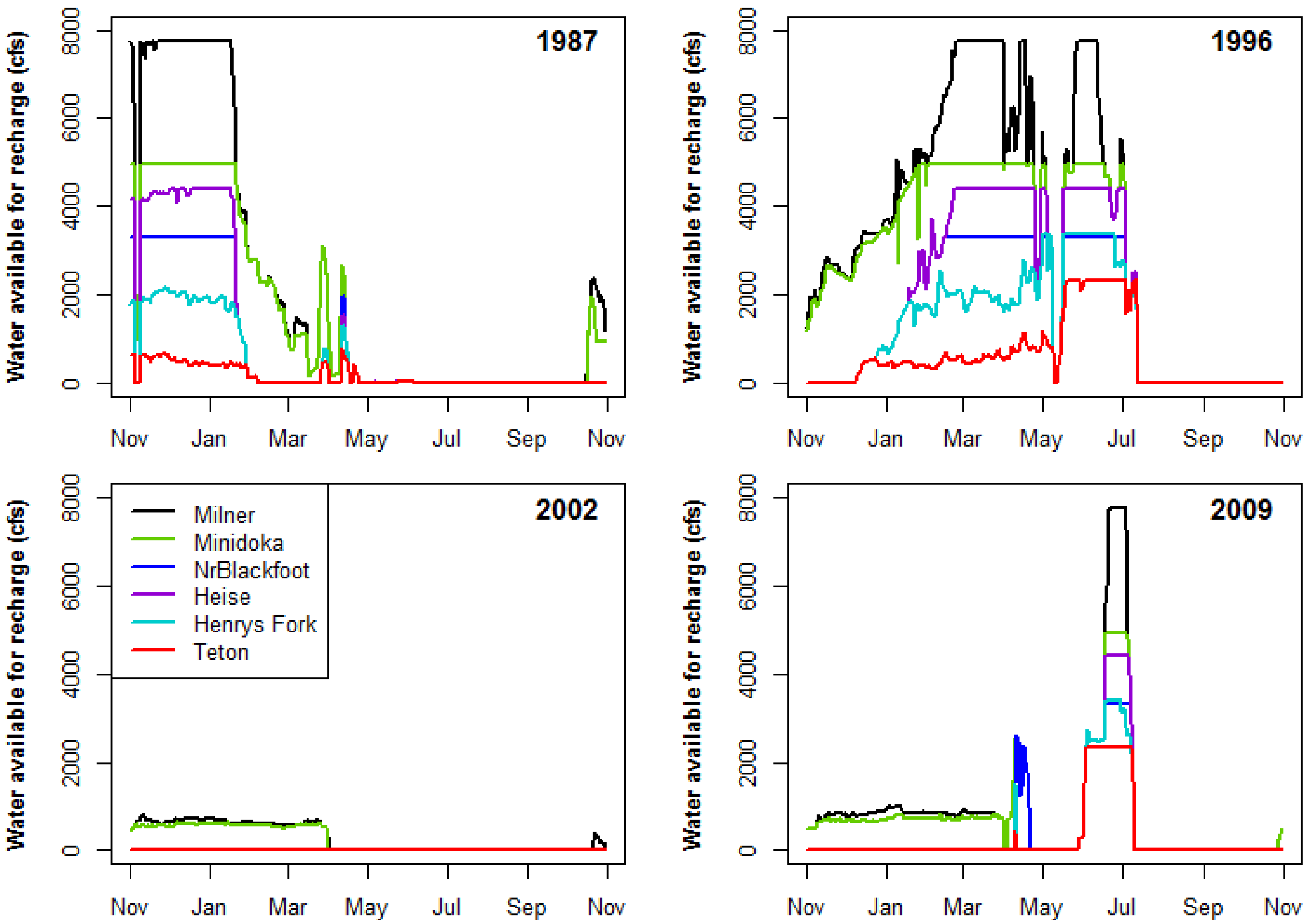


Figure 11. Hydrographs showing daily diversion possible for recharge, by location, in each of four representative irrigation years. Recharge availability at Shelley was nearly identical to that near Blackfoot, so the Shelley data are not shown on these graphs.

These four years were chosen because they illustrate timing, duration and magnitude of recharge availability across the seven locations in the four general types of irrigation years that occurred during the period of record.

1. 1987: Dry year that follows a year with low use of storage water. High reservoir carryover from previous year provides winter recharge opportunity, but low snowpack and high irrigation demand prevent summer-time recharge.
2. 1996: Wet year that follows other wet years. High reservoir storage carryover provides winter recharge availability across all locations, and subsequent high spring runoff allows system-wide summer-time recharge.
3. 2002: Dry year following a dry year. Low reservoir carryover allows only a small amount of winter recharge, and then only downstream of Minidoka, and there is no water for summer recharge anywhere in the system.
4. 2009: Good snowpack following a dry year. Low reservoir carryover allows only a small amount of winter recharge, and then only downstream of Minidoka, but good snowpack allows system-wide summer recharge.

the Minidoka power right rarely prevented recharge or constrained diversion rates.

2.4. Discussion

2.4.1. Dependence of availability on climate

General patterns of recharge availability presented here are consistent with those summarized in the support narrative for the IWRB 1998 recharge applications (IWRB, 2013). Differences between this and the previous analysis result primarily from the much longer period of record used in this analysis. In particular, the 1980-2014 period of record contains two sequences of years—the mid-1980s and late 1990s, respectively—that were much wetter than any experienced since 2000. For example, data reported in the previous analysis indicates that median annual availability of water for managed recharge was 192 days per year at Milner and 0 days per year at Heise (IWRB, 2013). Our analysis produced median availability of 192 days per year at Milner and 42 days per year at Heise. Comparison of these figures confirms the consistent availability of recharge downstream of Minidoka over all types of water years, as well as the dependence of recharge availability upstream of Minidoka on high rates of snowmelt during late spring and early summer. This latter observation emphasizes the dependence of future recharge availability on climatic conditions. If future climate produces sequences of years such as 1983-1987 and 1995-1999, then we can expect the opportunity to divert spring runoff at all locations to augment consistently available winter recharge downstream of Minidoka. This opportunity would occur in roughly two-thirds of all irrigation years and consist of a period of roughly 30 contiguous days in the late spring and early summer. In addition, a small amount of winter recharge will be available upstream of Minidoka during years when reservoir system carryover is high. Under these conditions, median recharge availability is about 600,000 acre-feet per year downstream of Minidoka and 150,000 acre-feet upstream of Minidoka. If the full volume of 150,000 acre-feet is diverted upstream of Minidoka, a net amount of 450,000 acre-feet per year would remain for recharge downstream of Minidoka.

On the other hand, if irrigation years 2000-2014 are more indicative of future climatic conditions, then opportunities for recharge are much more limited. Under these conditions, median annual recharge availability is about 200,000 acre-feet per year downstream of Minidoka and only 7,000 acre-feet upstream. These volumes are still sufficient to meet the 250,000 acre-feet per year mean target, but there would be much less flexibility available to accommodate non water-supply constraints. Some of these are discussed below.

Summary statistics on available recharge volume and number of days per year on average recharge could occur are provided in Appendix B.

2.4.2. Capitalizing on winter recharge availability

Our results give upper bounds on the amount of water available for managed recharge, because the availability analysis did not account for logistical constraints such as canal capacity, infrastructure maintenance, geographic alignment water availability with hydrogeologic properties of the aquifer, and weather, among others. However, the water supply results clearly show that the most consistent availability of water for managed recharge occurs during the winter and downstream of Minidoka. Taking advantage of this consistently available water requires operations and infrastructure capable of recharging 500-1,000 cfs over the majority of days every winter. Winter recharge upstream of Minidoka is much more opportunistic; under current conditions this can occur during only about one-half of all years and in some years for only relatively short periods of time. These time periods often occur late in the winter, when knowledge of reservoir storage, snowpack, and long-term weather forecasts provide a reasonable degree of certainty that water can be released past American Falls without jeopardizing physical fill of the reservoir system later in the spring. In addition, the practice of filling Milner Reservoir and Lake Walcott during March frequently provides a short window for winter recharge upstream of Minidoka. However, during late winter, canals upstream of

Minidoka, especially those on the South Fork, Henrys Fork and Teton, can be filled with snow and ice, rendering recharge logistically difficult. Increasing the availability of winter recharge upstream of Minidoka will require administrative, legal and policy changes that will allow recharge ahead of USBR's unsubordinated power right at Minidoka. In addition, taking advantage of existing late-winter windows for recharge upstream of Minidoka may require modifications to existing infrastructure or operations that will allow dormant canals to be put into service on short notice prior to spring thaw.

2.4.3. Capitalizing on summer recharge availability

Summer recharge is opportunistic regardless of location and can be expected to occur over a 30-day window during the early summer of about two-thirds of all irrigation years. Canal capacity is likely to be the limiting logistical constraint during these windows of opportunity, since normal irrigation delivery would already be taking place during this time period. During most years, maximum diversion occurs during this time period, when all crop types are being irrigated and natural flow is sufficient to meet demand. Diversion rates decrease later in the summer as demand decreases and junior natural-flow rights fall out of priority. This creates additional canal capacity that could be used to convey water for recharge, but recharge is not possible once junior natural-flow rights fall out of priority. A more detailed analysis of water availability relative to existing canal capacity would be required to estimate the actual amount of available water that could be diverted during these early-summer windows and identify needs for enlargement of canal capacity to convey water for early-summer recharge in addition to that required for irrigation.

2.4.4. Flow needs for fish and wildlife

Availability of water for managed recharge could also be constrained by the desire to maintain adequate streamflows and habitat for fish and wildlife in key stream reaches. The support narrative for the IWRB's 1998 water-right applications outlines the intent of the IWRB to consider potential effects of managed recharge on fish and wildlife resources through establishment of one or more environmental consultation committees and through coordination with Idaho Department of Fish and Game (IWRB, 2013). Although diversions for managed recharge potentially affect fish and wildlife resources at all locations downstream of the PODs, the stream reaches of greatest concern are the Henrys Fork downstream of the Fall River confluence, South Fork Snake River from Heise to the Henrys Fork, and Snake River upstream of American Falls Reservoir. Numerous documents describe the fish, wildlife, ecological, and recreational resources of these stream reaches and their economic importance (e.g. Hahn et al., 2005; Loomis 2006, Grunder et al., 2008; IDFG, 2014; IDFG and Van Kirk, 2014). The two greatest streamflow needs for maintenance of these resources in these stream reaches are sufficient winter flow and a springtime "freshet" of adequate magnitude and frequency.

Survival of juvenile fish during the winter is often the single factor that limits the size of trout populations in the upper Snake River basin and is directly related to magnitude of winter flow (Griffith and Smith, 1993; Smith and Griffith, 1994; Meyer, 1995; Gregory, 2000; Mitro et al., 2003; Garren et al., 2006; DeVita, 2014). Thus, during years when flows at Minidoka allow winter recharge upstream of Minidoka, the need to maintain sufficient winter flows will reduce the actual availability of water for managed recharge from the theoretical maximum values we have calculated in this analysis. However, given the fact that winter recharge can occur upstream of Minidoka only in years when winter streamflows are high, it is likely that winter recharge can be done in such years with minimal effect on trout population sizes. On the other hand, if legal and administrative adjustments are made to allow recharge upstream of Minidoka out of priority with USBR's power right there, then winter recharge could occur during years of low streamflow, with potentially negative effects on trout populations.

Peak flows, which occur during the snowmelt period of May and June in the upper Snake River basin, are critical to maintenance of in-channel, floodplain, and riparian habitat in alluvial river reaches such as the lower Henrys Fork, South Fork, and Snake River between Shelley and American Falls (Ligon et al., 1995; Collier et al., 1996; Merigliano, 1996; Magilligan and Nislow, 2001; Stromberg, 2001; Nislow et al., 2002; Hauer and Lorang, 2004; Hauer et al., 2004). In addition, peak flows during May and June can limit rainbow trout spawning success (Fausch et al., 2001) and benefit reproduction and survival of native cutthroat trout, which spawn on the descending limb of the freshet (Van Kirk and Jenkins, 2005; Gresswell, 2011). Springtime flow releases from Palisades Dam to mimic the shape and timing of the natural freshet have been a component of the cutthroat trout conservation program on the South Fork Snake River since 2004 (IDFG 2007, High et al., 2008; DeVita, 2014). Given that summer recharge is available only during the freshet period and only during years when it is high in magnitude, diversion for summer recharge during these years will necessarily reduce the magnitude of the springtime freshet in the years when it has the greatest potential to positively affect channel, floodplain and riparian habitat and cutthroat trout populations. Conversely, maintaining high peak flows during these years will reduce availability of water for managed recharge. On the South Fork, the PODs that would be used for managed recharge are downstream of the canyon reach, but important fish and wildlife resources also occur downstream of these PODs, between Heise and the Henrys Fork confluence. On the Henrys Fork, the greatest need for peak flows occurs in river reaches downstream of most of the PODs that would be used for managed recharge. Any summer recharge upstream of Minidoka will decrease streamflow in the Shelley-to-American Falls reach, since all PODs occur in or upstream of this reach. Potential negative effects of summer recharge on any given stream reach except Shelley-to-American Falls could be minimized by distributing summer recharge geographically across the South Fork, lower Henrys Fork, and lower Teton.

2.4.5 Water rights for managed recharge

Maximum diversion rates allowed under the IWRB managed recharge rights can limit availability of water for managed recharge. The 1998 rights allow a total diversion of 14,072 cfs across all PODs, in addition to the 1,200 cfs allowed under the 1980 right. During both winter and summer of high-supply years, available natural flow at Milner can exceed the maximum diversion rate of these rights at most PODs. However, in the median year, diversion rates under the 1980 and 1998 rights never limited winter recharge and limited summer recharge on only a few days in any given stream reach. Because the availability analysis treated each accounting node as independent, the reported frequency of limitation by diversion rates is higher than would actually occur in practice. Diversion from upstream reaches reduces actual flow in downstream reaches, thereby reducing the chance that diversion rates would limit availability in the downstream reaches. Thus, during periods of high availability, geographic distribution of recharge across all stream reaches maximizes opportunity to divert available water and minimizes limitation by diversion rates associated with the IWRB recharge rights. In addition, numerous private water rights for groundwater recharge provide opportunity to capture available natural flow above and beyond that allowed by the IWRB rights. Although the majority of private groundwater-recharge rights in the upper Snake and its tributary basins are relatively small and have PODs in tributary basins, seven private groundwater recharge permits and applications exist for PODs on the upper Snake River, Henrys Fork, and lower Teton River. All have priority dates junior to the IWRB 1998 rights. Combined, they allow a maximum diversion of 2,785 cfs from the Snake River between Menan and Blackfoot and 1,200 cfs from the Henrys Fork, Fall River, and lower Teton River. These rights, together with the IWRB rights, allow a maximum diversion rate of 19,257 cfs. Over the 35 irrigation years we analyzed, available natural flow upstream of Milner exceeded this on only 52 days, less than 0.5% of all days in the analysis. Therefore, assuming that pending IWRB and private applications are approved, the combined rates of all groundwater recharge rights with priority dates of 1980 or later will allow diversion of all available natural flow in the upper Snake River system except during a few days on which supply is extremely high. On these days, canal capacity and other infrastructure considerations would limit recharge before water-rights diversion rates would.

As a final note on private managed recharge, 17 privately held water rights, all with priority dates of 2/5/1902 or senior, allow winter diversion for sub-irrigation and stockwater in the Henrys Fork, and lower Teton basins. Combined, these rights allow diversion up to 1912 cfs. Analysis of water-rights accounting data in the Henrys Fork watershed shows that substantial recharge has routinely occurred under these rights for decades.

For example, November 1 – March 31 diversions from Henrys Fork, lower Fall River, and lower Teton River averaged 329 cfs over water years 1979-2008 (Van Kirk, 2012). Although some of this water is consumed by livestock, the vast majority of this winter diversion contributes to groundwater recharge through canal seepage (Van Kirk, 2012), amounting to about 98,000 acre-feet of annual recharge under senior water rights that has already been occurring outside of State-sponsored recharge. Future managed recharge conducted under junior IWRB and private rights should neither interfere with this existing recharge nor count it toward attainment of future goals for managed recharge. In fact, continuation of this historic winter-time diversion should be encouraged because canals that convey small amounts of water during the winter remain free of ice and snow, providing capacity for additional recharge under the IWRB rights late in the winter when such opportunity arises.

2.4.6 Managed recharge in tributary basins

Our analysis assessed water availability for managed recharge strictly within WD01, which includes the Snake River upstream of Milner Dam, the Henrys Fork and all of its tributaries, and the Willow Creek watershed. Diversion of water for managed recharge in tributary basins will not interfere with water availability for managed recharge within WD01 because very little of the water originating in tributary basins flows into streams within WD01. On the north side of the ESPA, the so-called "Sinks drainages"—Camas, Beaver, and Medicine Lodge creeks and the Big Lost and Little Lost rivers—would not flow into the Snake River upstream of Milner as surface water, regardless of whether water is diverted for consumptive use, diverted for within-basin managed recharge or allowed to flow out onto the ESPA. The only other tributary basin on the north side of the ESPA, the Wood River, flows into the Snake River downstream of Milner as the Malad River. The only two streams with appreciable streamflow in excess of consumptive use on the south side of the ESPA are the Blackfoot and Portneuf rivers. Together, these contribute an average annual net flow of around 380,285 acre-feet into the upper Snake River surface-water system, about 4% of the total water supply upstream of Milner. There are currently no water rights claimed or permitted for managed recharge within either of these basins. If applications for managed-recharge water rights were filed in either of these basins, they would be junior in priority to those applications and rights that already exist in WD01 and hence legally could not interfere with exercise of those senior recharge rights. A number of water rights exist for managed recharge within the Raft River and Goose Creek basins, but neither of these tributaries contributes appreciable surface flow to the Snake River.

From a hydrogeologic standpoint, managed recharge within any of the ESPA tributary basins has the potential to contribute to the long-term goals of aquifer stabilization on the ESPA. In most of the tributary basins, shallow, unconfined aquifers are hosted in valley-fill sediments. Managed recharge in these basins would increase storage and flow through these shallow aquifers, which eventually discharge either to the ESPA itself or directly to the Snake River. If the water used to conduct this managed recharge would have reached the Snake River as surface flow, then in theory, managed recharge in tributary basins contributes to the overall retention of water within the upper Snake River basin, decreased chance of spill at Milner, and therefore to the overall goal of increasing groundwater storage in the ESPA. However, if water that is used for future managed recharge has historically contributed to incidental recharge anyway, then there is no net benefit to the ESPA, even if specific locations and timing of managed recharge provide some improvement in local aquifer conditions relative to historic incidental recharge. This is particularly true in the Sinks drainages on the north side of the ESPA, including the Little Lost and Big Lost rivers. Historically, any surface water in excess of consumptive recharged the ESPA, either through groundwater underflow or from direct seepage of surface water that flowed out onto the ESPA. Using some or all of this water for managed recharge within the tributary basins will not increase the net amount recharge to the ESPA.

Of all of the tributary basins, the Wood River provides the greatest potential for managed recharge to provide a net contribution to stabilization of the ESPA. During wet years, streamflow in the Wood River basin in excess of existing natural-flow and storage rights is available for managed recharge. If not diverted for recharge, this excess water would flow into the Snake River downstream of Milner during the early summer. Recharge of this water, either directly to the ESPA or in the Wood River Valley alluvial aquifer, would therefore provide a net increase in groundwater recharge in the upper Snake River basin using water that would otherwise exit the basin as surface flow during a short time window. This additional recharge would eventually increase discharge at Thousand Springs, thereby replacing short-duration peak-flow contributions to the Milner-to-King Hill reach with long-term increases in year-round spring discharge to that reach. Existing water rights and applications for managed recharge in the Wood River basin allow a maximum diversion rate of 1,042 cfs, enough to accommodate peak flows in the basin in all but the most extreme years. The largest of these rights, for 800 cfs, is held by the IWRB. However, for recharge within the Wood River basin to be a net benefit to the ESPA, the total amount of new recharge must exceed increases in consumptive use of groundwater and decreases in recharge incidental to historic irrigation practices. Current trends in the Wood River Valley include both increased consumptive use of groundwater and increased irrigation efficiency, which both decreases incidental recharge and increases consumptive use. Therefore, future use and management of water in the Wood River valley will need to be carefully monitored to determine whether new recharge efforts there actually result in net benefits to the ESPA or simply offset increases in local consumptive use.

In summary, managed recharge in ESPA tributary basins will not reduce the amount of water available for managed recharge within WD01. In theory, managed recharge in tributary basins can contribute to aquifer stabilization on the ESPA, but only if the managed recharge does not simply replace historic incidental recharge and if any increases in total recharge volume are not offset by increases in consumptive use.

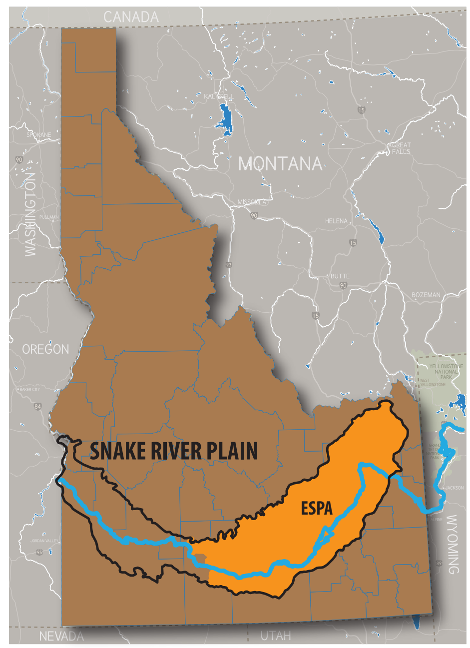
SECTION 3

Basin Hydrogeology

Implications for Long-Term ESPA Recharge Goals.

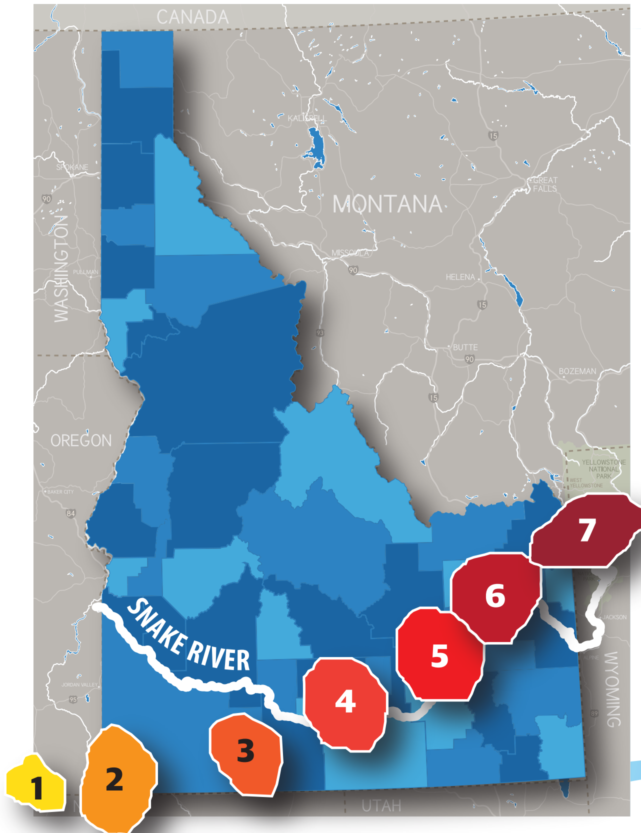
There are numerous reports detailing the hydrology and hydrogeology of the ESPA. An exhaustive summary of each is not warranted for this report. However, we provide a general summary of the basin hydrology and hydrogeology here, in the context of how the physical properties of the ESPA can impact the ability to satisfy long-term ESPA recharge goals.

ESPA Hydrogeology



A large, relatively flat, crescent-shaped basin (a topographic depression that is concave to the north) is evident on an aerial photo of southern Idaho and the surrounding area. This "swath" across southern Idaho is the Snake River Plain. It has a fairly consistent width of approximately 60 miles, and it is surrounded by mountain ranges. The Snake River Plain formed as the North American plate migrated over a hot spot under present-day Yellowstone National Park (Pierce and Morgan 1992).

Eruptions forming these calderas produced large volumes of magma. These lava flows generally have a permeable flow top, a dense, relatively impermeable flow interior, and a variable flow bottom. These are often referred to as intraflow structures, originating during the emplacement of the flow and subsequent cooling and solidification of the lava after it ceased flowing. The flow top is the crust that formed on the top of a molten lava flow. Flow tops typically range from simple, glassy to very fine-grained basalt that is riddled with spherical and elongate vesicles to very brecciated or rubbly. Flow interiors are dense, nonvesicular, glassy to crystalline basalt that contain numerous contraction joints (termed cooling joints) that formed when the lava solidified. Joints are organized regularly and generally exhibit two main styles, columnar and colonnade. With alteration, cooling joints become filled with precipitated minerals. The character of the flow bottom largely is dependent on the environmental conditions the molten lava encountered as it was emplaced. They can be thin, vesicular, and glassy if the flow encountered dry ground, or rubbly and thick where the lava flowed into a body of water



1. McDermitt Caldera (16-15.1 Ma)
2. Owyhee-Humboldt Caldera (13.8-12 Ma)
3. Bruneau-Jarbridge Caldera (12.5-11.3 Ma)
4. Twin Falls Caldera (10-8.6 Ma)
5. Picabo Caldera (10.2 Ma)
6. Heise Caldera (6.6-4.4 Ma)
7. Yellowstone Caldera (2.0-0.6 Ma)

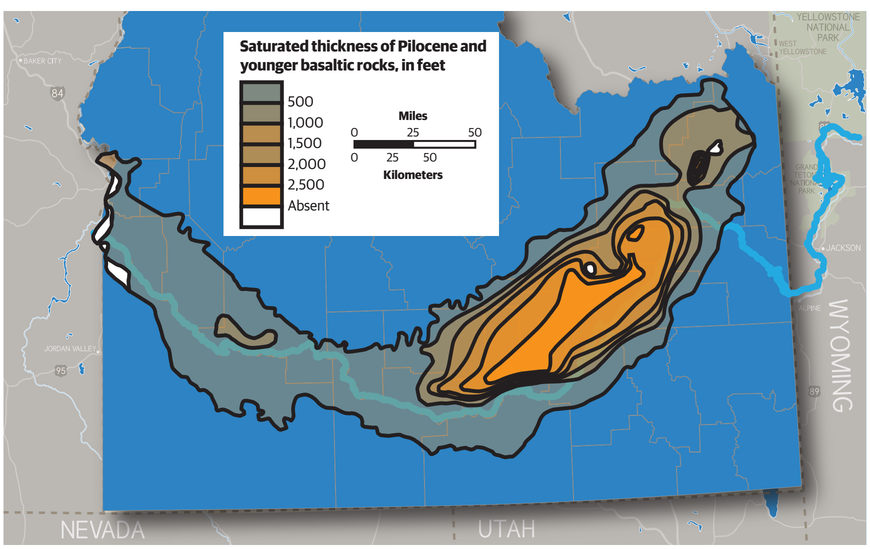
Evidence for the migration of the North America plate over a hot spot at Yellowstone includes calderas that become progressively younger eastward on the Snake River Plain that are similar in size to Yellowstone's three Pleistocene calderas.

SOURCE: Adapted from Branney et al., 2008

IDAHO_120_3

FIGURE 12. Progressive Development of Calderas Similar to Those in Yellowstone

The eastern portion of the Snake River Plain extends nearly 200 miles upstream from King Hill (King Hill is about 10 miles west of Bliss, Idaho) northeastward to approximately Ashton, Idaho. The plain slopes southwestward, with the altitude near Ashton at 6,000 feet to approximately 3,000 feet at King Hill. The ESPA is primarily formed of highly fractured, interfingered Quaternary basalt flows, with lenses of sediment between the flows (Smith, 2004). The thickness of the basalt making up the ESPA may exceed several thousand feet (Whitehead, 1986), but it is generally believed the useful thickness of the aquifer is limited to the upper several hundred feet.



SOURCE: Adapted from Whitehead, 1994

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FIGURE 13. Saturated Thickness of the Pilocene and Younger Baslatic Rock in the Snake River Plain

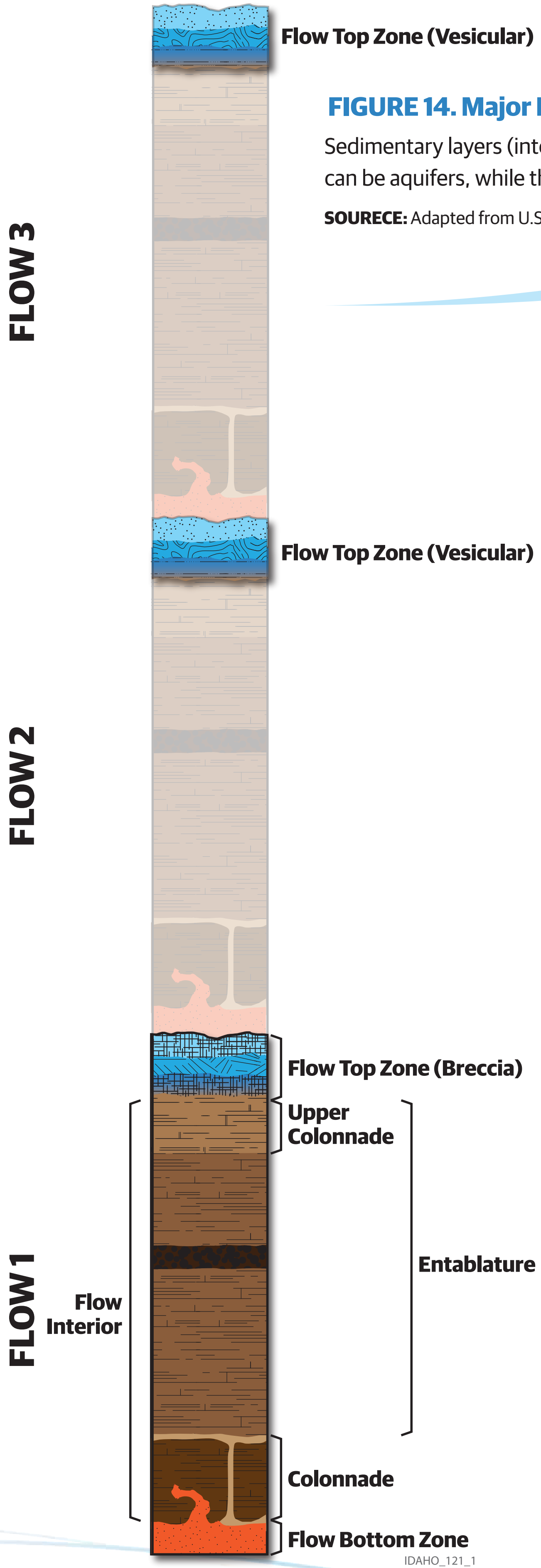


FIGURE 14. Major Basalt Flows

Sedimentary layers (interbeds) and basalt intraflow zones can be aquifers, while the dense flow interiors are often aquitards.

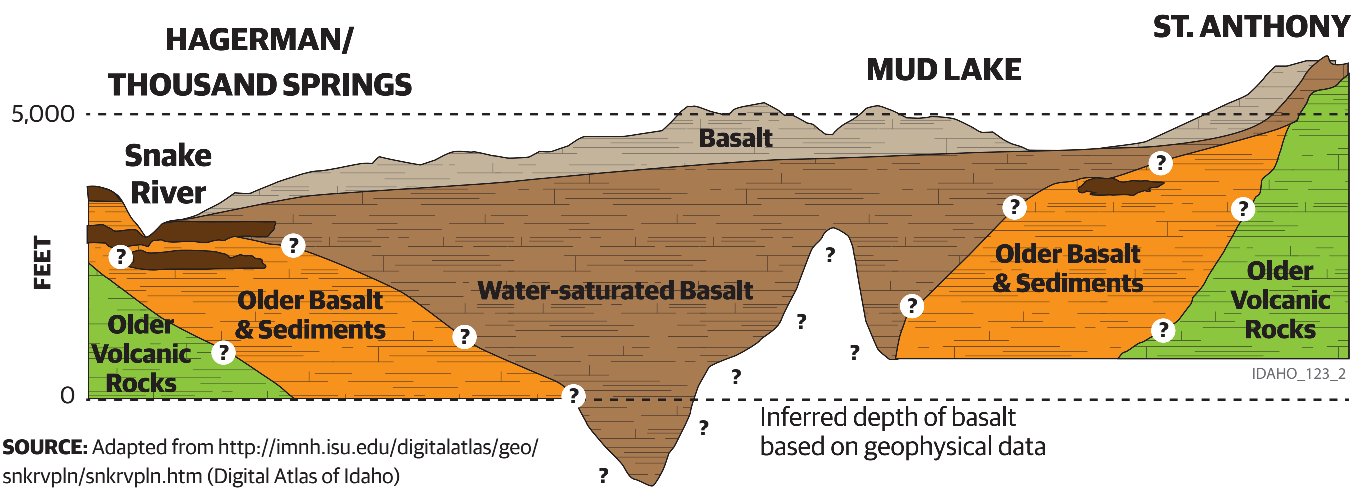
SOURECE: Adapted from U.S. Department of Energy, 2005.

and formed a pillow complex. Interflow zones are the intervals between successive lava flows that contain various combinations of flow top (from the underlying flow) and flow bottom (from the overlying flow) features. From a hydrogeologic standpoint, the interflow zones host most of the groundwater and dense flow interiors generally forming impediments to groundwater movement. In outcrop, this can be seen in spring lines on valley walls were water is discharging from interflow zones. In the subsurface, this layered aquifer system is commonly seen in wells where water bearing interflow zones alternate with non-water bearing flow interiors, thief zones, and cascading water.

On the Snake River Plain, there are large lava caves and tubes that can be found in several places, many collapsed tubes are evident, and there are shallow depressions in the exposed basalt. These are all highly fractured features that to some may give the impression that the fractured basalt extends continuously to great depths. That is not always the case, given the nature of the sequence of lava flows described above. There can be impediments to vertical flow, including the dense flow interior and sedimentary deposits such as silt and clay.

The aquifer is generally considered unconfined, but there are areas where the aquifer responds as a confined system (Spinazola, 1993; Frederick and Johnson, 1996). The ESPA is bounded structurally by faulting on the northwest, where granitic rocks of the Idaho batholith, along with pre-Cretaceous sedimentary and metamorphic rocks, border the ESPA (Garabedian, 1992). There is downwarping and faulting on the southeast of the ESPA (Whitehead, 1986). Yellowstone Group rhyolite bounds the ESPA in the northeast, while Idavada volcanics bound the ESPA in the southwest. More detailed descriptions of the geology of the eastern

FIGURE 15. Simplified Geologic Cross Section of the Eastern Snake River Plain



SOURCE: Adapted from http://imnh.isu.edu/digitalatlas/geo/snkrvpln/snkrvpln.htm (Digital Atlas of Idaho)

Snake River Plain are provided by Anderson (1991), Whitehead (1986), and Kuntz et al. (1992).

The ESPA is one of the largest and most transmissive aquifers in the world, covering an area of about 26,000 km^2. The water table averages approximately 100 m below land surface, resulting in minimal direct evapotranspiration from the aquifer. The ESPA has an estimated saturated volume of over 123,350 Mm^3, and total discharge from the aquifer is about 9,900 Mm^3/year (Johnson et al., 1999). The permeability of the aquifer is controlled primarily by the distribution of the basalt flow contacts (Smith, 2004). Groundwater flow through the ESPA is complicated by interactions between groundwater and surface water (Cosgrove and Johnson, 2004).

Implications for Long-Term ESPA Recharge Goals – Qualitative Description

Anything that influences the ESPA water budget impacts ESPA water levels and spring discharge from the aquifer. For example, when more water goes into aquifer than is removed (that is, a positive change in the ESPA water budget occurs), aquifer water levels increase and spring discharge and river gains increase accordingly. When a negative change to the ESPA water budget occurs (for example, from pumping or from a reduction in aquifer recharge), ESPA water levels decrease and spring discharge and river gains decrease accordingly. The State's ESPA CAMP is rooted in the goal of making a positive change to the ESPA water budget to increase aquifer water levels and spring discharge and river gains.

This simple description of the State's goal is complicated by the fact that the ESPA is connected to surface water. Aquifer discharge varies in response to aquifer stress. Increases to ESPA water levels can increase aquifer discharge to the Snake River and other surface water features. Given this fact, the managed recharge program must consider the timing, location, and magnitude of recharge to meet the State's goal. Managed recharge occurring in close proximity to a connected surface water body (the Snake River, for example), may not satisfy the State's goal of increasing ESPA water levels for the long term, given this temporary aquifer water level increase from recharge results in the water moving quickly to the river without increasing the water level in the regional aquifer over time. The same concept applies when recharging in the vicinity of pumping. If the aquifer is recharged, and the water is removed by pumping, the recharge effort is futile if the goal of the effort is to increase aquifer water levels over time.

Implications for Long-Term ESPA Recharge Goals – Quantitative Description

If an aquifer stress, such as a managed recharge event, occurs at some distance from the aquifer discharge location (Thousand Springs, for example), the associated aquifer discharge that occurs may be lagged by months or years relative to the timing of the recharge. This lag develops as the stress propagates through the aquifer. The magnitude of the aquifer stress is also dampened as the stress moves through the aquifer. With these basic concepts in mind, we provide a short summary of the relationship among lag time, stress attenuation, and distance between a given recharge event and resulting aquifer discharge below.

Analytical results suggest that the diffusive aquifer time unit governs the relationship among lag, attenuation, and distance between aquifer stresses and discharge from the aquifer (Boggs et al., 2010). An aquifer's time unit, or diffusive aquifer time scale, is defined as L^2/D, where L is the aquifer length and D is aquifer diffusivity. Aquifer diffusivity is the ratio of aquifer transmissivity to storativity.

The relationships between aquifer properties and the diffusive aquifer time scale L^2/D have been thoroughly analyzed and discussed by many authors (for example, Polubarinova-Kochina, 1962; Chow, 1964; Gelhar and Wilson, 1974; Crank, 1975; Bear, 1979; Turcotte and Schubert, 1982; Bhar and Mishra, 1997; Furbish, 1997; Domenico and Schartz, 1998; Manga, 1999; Criss and Winston, 2003, 2008a,b). When the temporal scale of recharge exceeds the diffusive aquifer time scale, recharge will be reflected in discharge quickly and with little attenuation. When aquifer time scale is large, most recharge events are shorter in scale than that of the aquifer, resulting in large attenuation.

Given the physical properties of the ESPA, namely its long length (approximately 300 km) and its highly fractured basalt composition that is highly transmissive, D for the ESPA is large (205 km^2/year, calculated using the geometric mean of transmissivity and specific yield distributions estimated in a previous version of the ESPA numerical model; Cosgrove et al., 2006), resulting in an aquifer time unit for the ESPA of approximately 440 years. What this generally means for managed recharge events on the ESPA is that, for a given recharge location on the ESPA, there are relatively short lag times and small attenuation between recharge events and associated aquifer discharge. Most recharge events relevant to management of the ESPA occur on time scales that are very short compared to the aquifer time unit, resulting in rapid attenuation with distance. For example, analytical results demonstrate that annual cycles in ESPA discharge (for example, annual discharge cycles from the Thousand Springs complex) can result from recharge no farther than about 20 km from the springs (Boggs et al., 2010). Furthermore, although the effects of long-term recharge occurring far away from the springs can be detected in aquifer discharge, lag times for such recharge are on the order of several decades.

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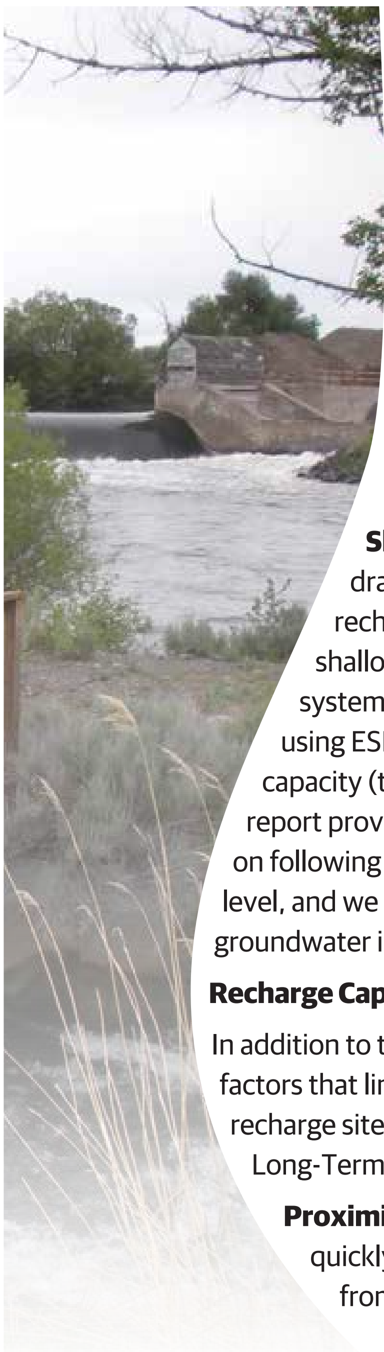
SECTION 4

Local Considerations and Potential Limits to Aquifer Recharge



Potential limits to managed recharge include local considerations, such as site-specific infiltration capacity, and broader factors, such as climate change that could limit water supply that were detailed in our water supply analysis. IDWR completed a detailed review of local considerations and potential limits to ESPA recharge, detailing information for specific potential recharge sites (Figure 16), including:

Diversion Limitiations: The ability to get recharge water to a recharge site.

Infiltration Capacity: The ability of an area/recharge site to accept water.

IDWR reports that the specific numbers provided for each site in their report should be verified though field measurements where and when possible (IDWR, 2015). Furthermore, a recharge site could be modified in a way to overcome recharge limitations. For example, a diversion could be modified to allow more water to be diverted to a specific recharge site.

Shallow Groundwater: May limit aquifer recharge by allowing water to go to drains, canals, or other features that allow the water to leave the subsurface without recharging the regional aquifer. In addition, adding additional water in an area with shallow groundwater has the potential to enter infrastructure, such as basements, septic systems, canals, sewers, etc. In IDWR's recharge limitations report, they present an analysis using ESPAM2.1 to show generally where there are areas with sufficient groundwater capacity (that is, areas without shallow groundwater as a potential recharge limitiation). The report provides a calculated groundwater capacity value for each recharge site (see Figure 16 on following page for recharge sites). This limitiation has not been widely studied at the local level, and we believe a site-specific evaluation should be completed in areas where shallow groundwater is a potential concern.

Recharge Capacity: The physical ability to conduct recharge at a site.

In addition to the considerations reported in IDWR's recharge limitiation evaluation, other general factors that limit the benefit of recharge to the aquifer should be considered when selecting a recharge site, including the factors detailed in Section 3, Basin Hydrogeology – Implications on Long-Term ESPA Recharge Goals:

Proximity to Surface Water Features: The benefit to the aquifer may be limited by how quickly recharge water returns to the river or any other feature that prevents the water from recharging the regional aquifer.

Proximity to Pumping: If there is pumping in the vicinity of the recharge water, the benefit to the regional aquifer may be limited if the recharge water is removed via pumping rather than recharging the regional aquifer.

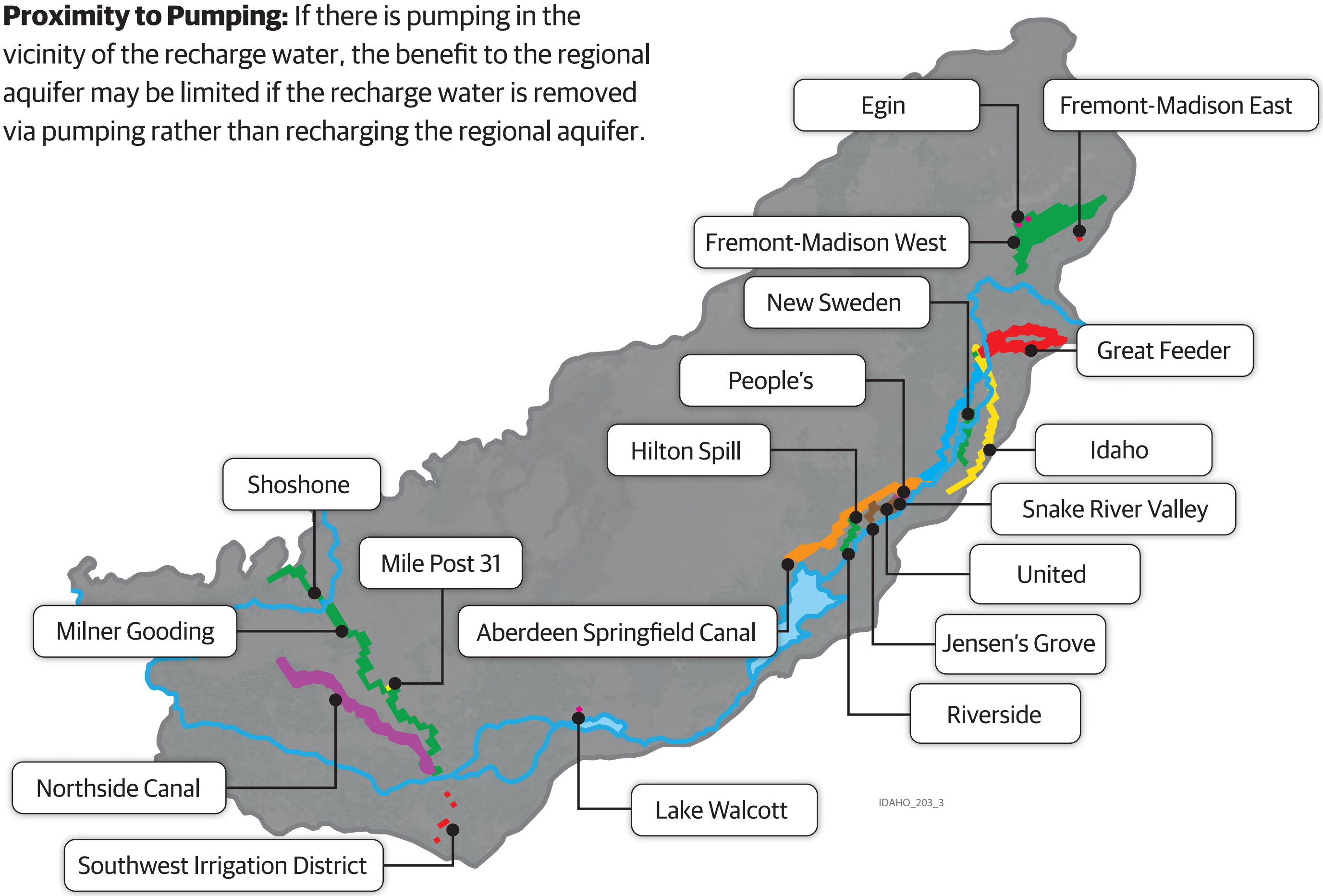


Figure 16. Model cells for locations considered in the recharge prioritization

SOURCE: Adapted from IDWR, 2015

SECTION 5

Conclusions

This report documents an independent review of the State of Idaho's managed recharge program.

Managed Recharge Review Conclusions

1. Water is consistently available for managed recharge on almost every day during the winter months downstream of Minidoka.
2. The USBR unsubordinated power right prevents winter recharge upstream of Minidoka in about half of all years.
3. System-wide, water is available for managed recharge during irrigation season in about two-thirds of all years, during a 30-day window during May and June.
4. If future climate yields water supply statistically similar to that of the 1980-2014 period, median availability of water for managed recharge will be 600,000 acre-feet per year downstream of Minidoka, and about 150,000 acre-feet per year upstream of Minidoka.
5. If future climate is more statistically similar to that of the period since 2000, which is drier, median availability of water for managed recharge will be about 200,000 acre-feet per year downstream of Minidoka, and 7,000 acre-feet per year upstream.
6. Capitalizing on existing winter availability requires ability to recharge 500-1,000 cfs every day of every winter downstream of Minidoka and operational flexibility and canal capacity to accommodate opportunistic availability of late-winter recharge upstream of Minidoka.
7. Fully utilizing availability of water during the spring freshet will likely require expansion of canal capacity at key points of diversion throughout the basin.
8. Canal capacity, physical logistics, weather, and fish and wildlife concerns will reduce the amount of water available for recharge below the theoretical maximum amounts presented in this report.
9. Assuming that pending managed recharge water-rights applications are approved, the combined diversion rates of the IWRB rights and junior private rights will be sufficient to capture all available natural flow in the upper Snake River system except on a very small fraction of days when natural-flow supply is very high.

Our review of the state's managed recharge program suggests that recharging 150 to 250 thousand acre-feet to the ESPA annually is possible. To consistently achieve this goal, there may be site-specific improvements needed at recharge locations to overcome limitations, such as diversion, infiltration, and recharge capacity.

The State is on the Right Path

The State is implementing an adaptive implementation strategy, per the 2009 ESPA CAMP, and we believe this approach is appropriate. This phased approach provides an opportunity to adapt to future conditions. The 2009 ESPA CAMP appropriately identifies the importance of monitoring to test assumptions and adjusting the implementation plan accordingly to meet the long term objective. Successful implementation of the plan will increase aquifer water levels, spring discharge, and river reach gains in some areas. Monitoring is fundamental, providing data to demonstrate the plan is effective and results in the desired managed recharge benefits.

Our assessment confirms that sufficient water is available for the managed recharge program. To consistently recharge 150 to 250 thousand acre-feet per year requires improvements, including:

1. Managed recharge site identification and canal system improvements/modifications to capitalize on the 500 to 1,000 cfs of water available nearly every day of every winter downstream of Minidoka.

2. Canal capacity improvements upstream of Minidoka, combined with funding for operational flexibility to accommodate opportunistic availability of late-winter recharge upstream of Minidoka.

3. Expansion of canal capacity at key points of diversion throughout the basin to capture water that is available for recharge in the spring.

SECTION 6

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APPENDIX A

Agency activities since the 1960's have progressively identified more action needed to successfully recharge the ESPA.

TITLE	DATE	AUTHOR
Feasibility of Artificial Recharge in the Snake River Basin, Idaho: U.S. Geological Survey Open-File Report 62-92	1962	USGS (Mundorff, M.J.)
Summarizes the challenge of reversing the trend of decreasing ESPA water levels through artificial recharge. Describes three areas investigated for artificial recharge on the ESPA: 1) the area beteween Plano and Roberts in eastern Idaho (in the Egin Lakes area), 2) west of Idaho Falls, a 50- to 75-square mile area of exposed basalt, and 3) along the Milner-Gooding canal between Milner and Shoshone. Suggests that artificial recharge will not reverse the declining water level trends due to lack of available water to offset increasing irrigation demand. Indicates that artificial recharge of one million acre-feet, assuming a consumptive use of 50%, will allow for an additional two million acre feet of pumping on the ESPA. The report summarizes a water availability analysis, suggesting that excess water is available for artificial recharge in some years. Identifies St. Anthony as a reasonable diversion point on the Henry's Fork, given its elevation. Describes the first recharge experiments on the ESPA near the Egin Lakes area (Egin Lakes Seepage Study), reporting an average seepage loss of 0.29 acre-feet per acre per day.		
Snake River Plain Recharge Project, Idaho, Special Report	June 1962	USBR
Documentation of the reconnaissance-level assessment of the Snake Plain Recharge project, evaluating the potential for expansion of the development of the ESPA in order to accommodate additional crop irrigation on the plain. Proposed diverting surplus "wet-year" surface water to infiltration areas, water that would otherwise spill past Milner Dam, allowing this surplus water to be stored in the aquifer for future use. The report suggests that because of the high transmissivity of the aquifer, and the fact that the basalt that makes up the aquifer is highly fractured and exposed at the surface, artificial recharge using surplus surface water could occur at one place without excessive groundwater mounding. The Bureau suggests that the most beneficial recharge sites would be at the "head" of the aquifer to increase water levels over as much of the aquifer as possible. The Bureau identified three sites for a detailed study and reconnaissance plan for artificial recharge: St. Anthony, Idaho Falls, and Idaho Falls-Blackfoot gravel pit areas. The Bureau also, to a lesser extent, assessed two additional recharge areas, the Milner Gooding recharge area, and the Big and Little Wood recharge areas. The Bureau concluded that artificial recharge at the three primary recharge sites would be beneficial, recommending feasibility-level studies		
Artificial Recharge to the Snake Plain Aquifer; An Evaluation of Potential and Effect (Water Information Bulletin No. 12)	August 1969	IDR
In the same vein as the Bureau's 1962 assessment, the state suggested that any water flowing past Milner Dam could have been diverted upstream for artificial recharge, and indicated that 1.3 million acre-feet or more flows past Milner Dam on a recurrence interval of every other year. The state constructed a transient, electric-analog model of the ESPA to predict aquifer water level responses to artificial recharge. The state developed a hypothetical recharge program to assess the practical use of the electric-analog model, choosing four ESPA recharge areas. The state made it clear that they chose these four sites to test their model because they are places where surface water could be conveyed by gravity and they are upgradient and distant from groundwater pumping and natural aquifer discharge areas. The conclusion of the report was that the state did not satisfactorily validate the analog model, suggesting that additional field data from test drilling and a more detailed evaluation of aquifer recharge areas was needed.		
St. Anthony Pilot Recharge Project 1970-1974	February 1975	IDWR
The state developed a pilot recharge project at St. Anthony in 1970 to assess the feasibility of implementing an ESPA managed recharge project. The recharge site is approximately 11 miles west of the town of St. Anthony. This report documents the data findings developed from the project through 1974. The state concluded that they could artificially recharge the aquifer at the site at a rate of 0.5 acre-feet per acre per day, making the project feasible. The state suggested that significant questions remained following this pilot project, including how a recharge project water right could be established, indicating that demonstrating beneficial use and identification of the beneficiaries would be difficult. The state was concerned that legal questions over what entity could sponsor an ESPA recharge project were not resolved. According to the report, the Planning Division of IDWR suggested that a large recharge project may be needed in the future to replace water pumped from the ESPA. The state concluded that until it completed studies of a large-scale recharge project, the areas identified by the Bureau (USBR 1962) should be protected for possible future managed recharge sites.		
An Assessment of the Capability of Existing Canal Companies to Deliver Artificial Recharge Water to the Snake Plain Aquifer in Southeast Idaho	December 1996	IWRRI
This work assessed the capability of major canal systems to deliver artificial recharge to the ESPA using existing delivery systems, and the associated limitations and challenges. Data for this study was obtained from existing canal company records and from interviewing canal company managers. The study concluded that existing canal systems are capable of providing up to 1 million acre-feet per year as recharge (as long as the water is available) to numerous sites, and that the best opportunities to deliver artificial recharge is in the months of November, April and October; followed by March, May and September. The study indicates that there was widespread support for artificial recharge activities, except for during the winter months (December-January) due to adverse weather and icing conditions. Managed recharge during peak capacity periods is made more difficult because of the canal system capacities required. IWRRI recommended that existing and pilot artificial recharge projects be continually monitored and developed, and recommends further investigation of the effectiveness of recharge from a hydrogeologic perspective. It was also recommended to evaluate water availability in order to produce estimates of recharge potential.		
Hydrologic and Water-Quality Data for the Southwest Irrigation District's High Plains States Groundwater Recharge Demonstration Project, South-Central Idaho (Open-File Report 97-820)	1997	USGS
Hydrologic and water-quality data were collected from 1992 through June 1997 as part of the Southwest Irrigation District's High Plains States Groundwater Recharge Demonstration Project. The study area encompassed parts of northeastern Twin Falls County and parts of northwestern Cassia County in south-central Idaho, and comprised seven recharge sites that received water from three sources. The combined capacity of all seven recharge sites was about 27,700 gallons per minute (61.5 cubic feet per second), or about 122 acre-feet per day. The data consists of measurements of depth to water, streamflow, and rates of injection; and analysis of water-quality characteristics.		

Period where initial evaluation and fact finding was prevalent

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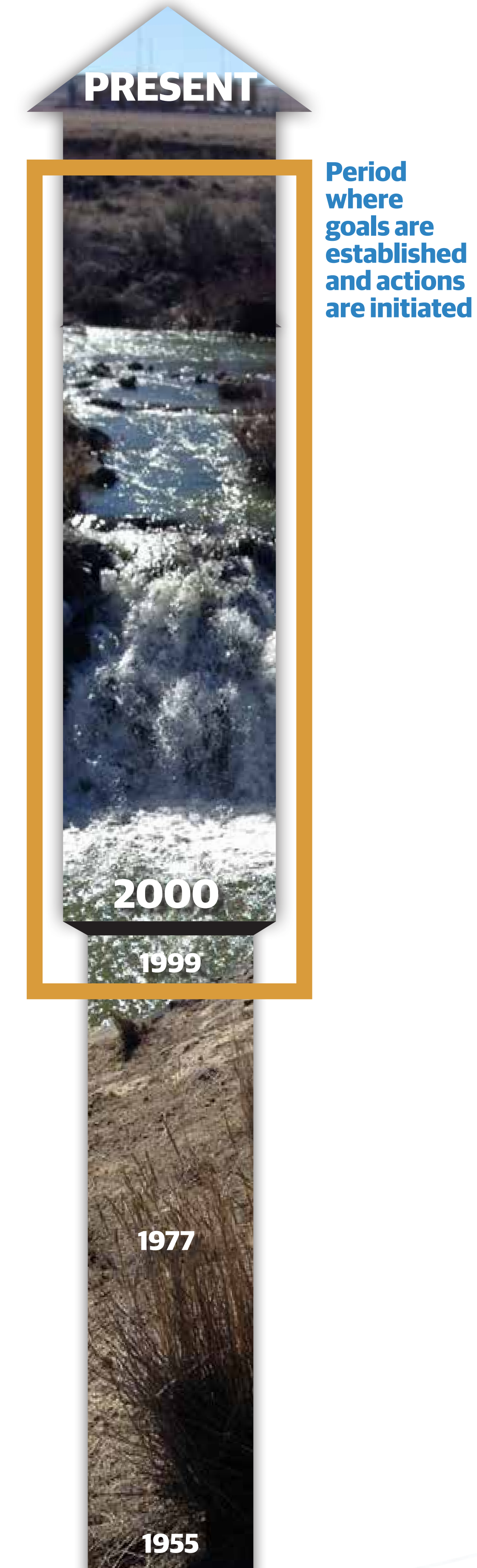
TITLE	DATE	AUTHOR
Feasibility of Large-Scale Managed Recharge of the Eastern Snake Plain Aquifer System	December 1999	IDWR
This report documents the evaluation of the potential of a large-scale managed recharge program to enhance the management of water resources in the ESPA, with restoration of groundwater levels and spring discharges being two key hydrologic objectives of said program. Recharge would typically include diversion of surface water from the Snake River (or tributaries) during times of surplus flow, and delivery of the water through irrigation systems to locations where the water would infiltrate into the ground to the underlying aquifer. The increased groundwater levels would in turn produce increased return flows back to the Snake River. The report highlights both hydrologic and institutional constraints on managed recharge, as well as potential environmental impacts of managed recharge on fish and wildlife in the Snake River and on groundwater quality in the aquifer. A numerical groundwater model predicted hydrologic benefits from four different scenarios, the most effective being the "Thousand Springs" scenario, which uses excess capacity in the Milner-Gooding and North Side Canals to recharge the ESPA. The report suggests that there is strong motivation to conduct the recharge during winter months due to flow availability, excess canal capacity, and instream flow requirements during these months. The findings of the report provide a new perspective on the longstanding assumption that aquifer recharge conducted higher up in the basin would have the greatest net benefit, and points out that there is substantial aquifer compartmentalization in terms of the influence of managed recharge activities. Economic costs are discussed both qualitatively and quantifiably. The report concludes that a large-scale managed recharge program is feasible, but not without potential institutional, operational, and environmental challenges.		
Phase II of Managed Recharge on the ESRP Development of Recharge Facilities	April 2005	IDWR
As a follow-up to the December 1999 report, this evaluation indicates that estimates of recharge potential documented in the previous feasibility report were likely excessively high. This report outlines a strategy for developing recharge sites with adequate recharge capacity to provide higher likelihood of long-term success for a managed recharge program. Modified estimates of recharge capacity for proposed sites are provided by using soil permeability instead of infiltration rates, and potential recharge sites are further refined based on soil properties. Potential construction costs of engineered recharge facilities are also discussed, and benefits of engineered facilities (that is, maintenance concerns, etc.) over "natural basins" are discussed and recommended.		
Groundwater-Aquifer Recharge Demonstration Project Fox Creek Area, Teton Valley, Idaho, Driggs, Idaho.	2005	Friends of the Teton River
Due to concerns about the condition of the alluvial aquifer in the Teton Valley, the Friends of the Teton River initiated a demonstration recharge project in the Fox Creek watershed, which is a tributary of the Teton River. The purpose of the project was to develop a more detailed understanding of the impact of recharge from streams and irrigation activity on groundwater levels and spring discharges in the area, as well as to identify "practical considerations" associated with recharge efforts for that aquifer. In addition to conducting a geologic analysis in order to understand the subsurface geology in the area, the project selected a demonstration test site to maximize groundwater infiltration in a relatively limited area, averaging approximately 3 cfs over a 35-acre area from May-July 2004. Through field data collection and numerical groundwater model calibration, the results suggested that a positive effect on groundwater levels in the aquifer was achieved by the concentrated recharge effort that utilized flood/sprinkler irrigation methods. However, because most of the maximum amount of potentially achievable groundwater recharge is already occurring in the area, it was also concluded that there was little advantage to implementing supplemental groundwater recharge except during the peak runoff season when stream flows are high. As a result, the study suggests that recharge efforts in the Fox Creek area will produce only minor increases in groundwater levels, and thus likely have a limited positive benefit in the lower elevation portions of the Fox Creek area.		
Eastern Snake Plain Aquifer (ESPA) Comprehensive Aquifer Management Plan	January 2009	IWRB
Documents the Comprehensive Aquifer Management Plan (CAMP) for the ESPA, which was developed at the direction of the Idaho State Legislature. In general, the Plan establishes a long-term program for managing the water supply and demand in the ESPA. This is done through a phased approach, and in an adaptive manner to allow for adjustments over time during the implementation of the plan. Specifically, the long-term objective of the Plan is to incrementally achieve an increase in the net water budget of the ESPA of 600,000 acre-feet per year. The plan projects that this goal can be achieved through various actions, one of which is groundwater recharge. The target increase in the water budget during the initial phase (1-10 years) includes ground to surface water conversions, managed aquifer recharge, and demand reduction, as well as a pilot weather modification program and minimizing losses of incidental recharge. The CAMP is presented in a way so as to allow for adjustments and improvements as new information and technologies are developed over the course of implementing all phases of the Plan, and costs are estimated to be between $7-10 million annually.		
The potential for recharge at Jensen Grove (IDWR Open File Report)	April 2009	IDWR
Jensen's Grove is a city park, located approximately one mile northwest of downtown Blackfoot, about one-quarter mile east of the Snake River and immediately east of Interstate Highway 15. This report provides data suggesting that the Snake River and Jensen's Grove are somewhat insulated from the aquifer by sediments, and also from one another, leading to the potential for recharging the aquifer at this site, leading to an initial immediate effect on the river, but with much of the impact to the Snake River being delayed and realized at locations distant from Jensen's Grove. The report suggests that available data supports Jensen's Grove being a viable recharge site, rather than reacharge water at the site immediately impacting the river without reacharging the aquifer.		
Prioritization of Aquifer Recharge Sites Based on Hydrologic Benefits	April 2012	IWRRI
This report summarizes the evaluation of seven objectives for prioritizing recharge at 19 different potential sites in the Eastern Snake River Plain. The evaluation utilizes the ESPAM numerical model (ESPAM1.1) to quantitatively assess the ability to achieve the seven recharge objectives. The report suggests that each potential recharge site provides varying benefit, depending on which recharge objective is considered. For example, potential recharge sites below Milner Dam increase spring discharge below the dam, as expected. In a similar way, recharge sites upstream of Minidoka can increase river reach gains in the Snake River above Minidoka. Model simulations suggest that recharge at the Lake Walcott site, Southwest Irrigation District, and the potential sites downstream of Milner Dam increases aquifer water levels more than other potential recharge sites. The report provides quanitiative results (for example, river reach gains, change of recharge volume retained in the aquifer and discharged to the Snake River over time) for each of the 19 potential recharge sites. IDWR revised this report in 2015, updating results using the latest version of the numerical model of the Eastern Snake Plain Aquifer (ESPAM2.1).		
Enhanced Snake Plain Aquifer Model Version 2.1 Final Report	January 2013	IDWR
Documents the development and calibration of the most recent version of the state's numerical model of the Eastern Snake Plain Aquifer.		



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APPENDIX B

Detailed Figures and Tables

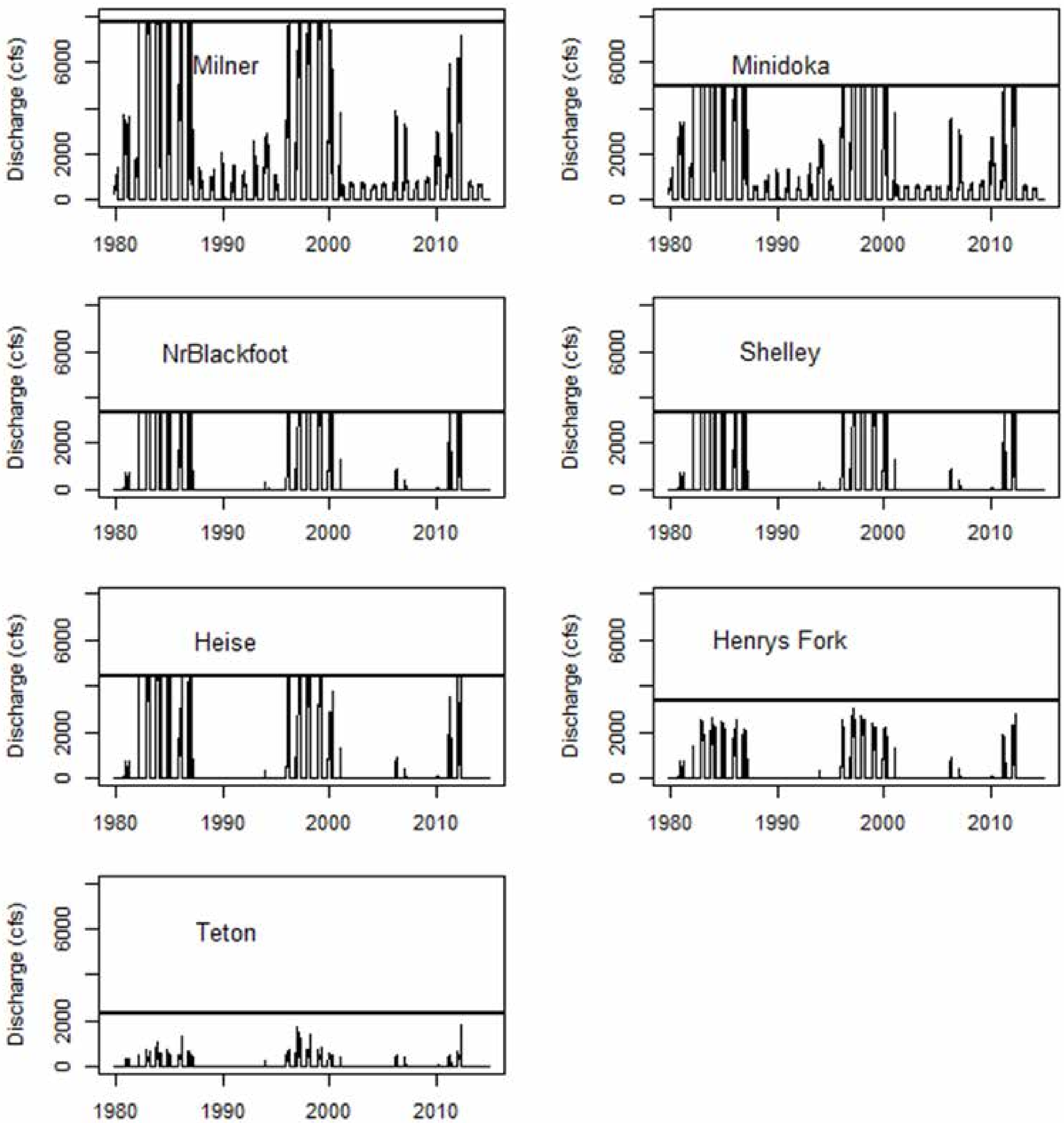

FIGURE B-1. Daily winter recharge availability, by stream reach, irrigation years 1980-2014.

The horizontal line on each graph is the maximum diversion rate of IWRB recharge rights. Every year there is generally water available for recharge below Minidoka, and the Minodoka power right limits the recharge volume. When there is water available in the Henrys Fork and Teton, there is not enough water to fill the entire water right.

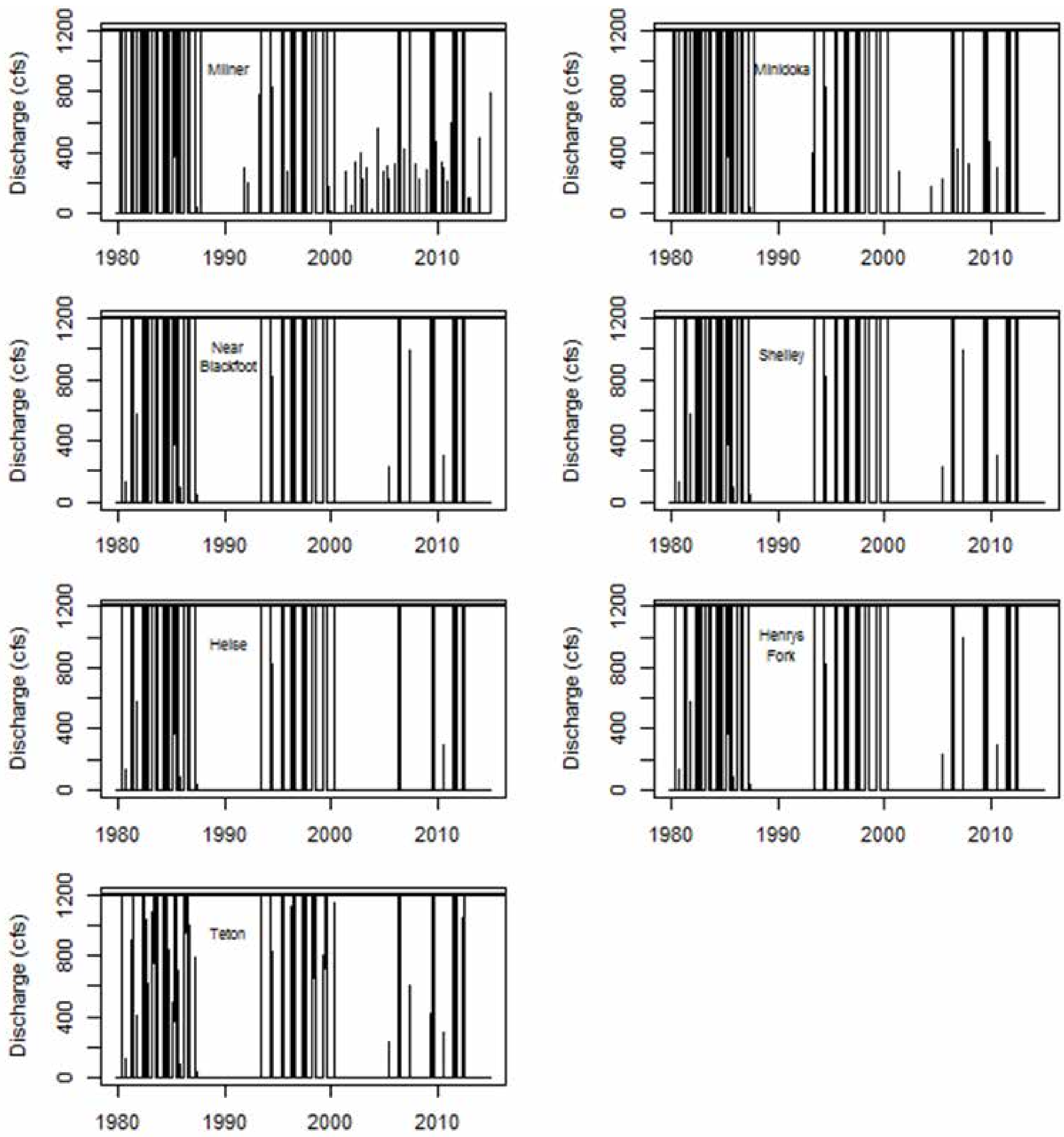

FIGURE B-2. Daily summer recharge availability under IWRB 1980 recharge right, by stream reach, irrigation years 1980-2014.

The horizontal line on each graph is the maximum diversion rate of the IWRB's 1980 recharge right. When there is water available for recharge, there is usually sufficient water to fill the entire 1980 water right.

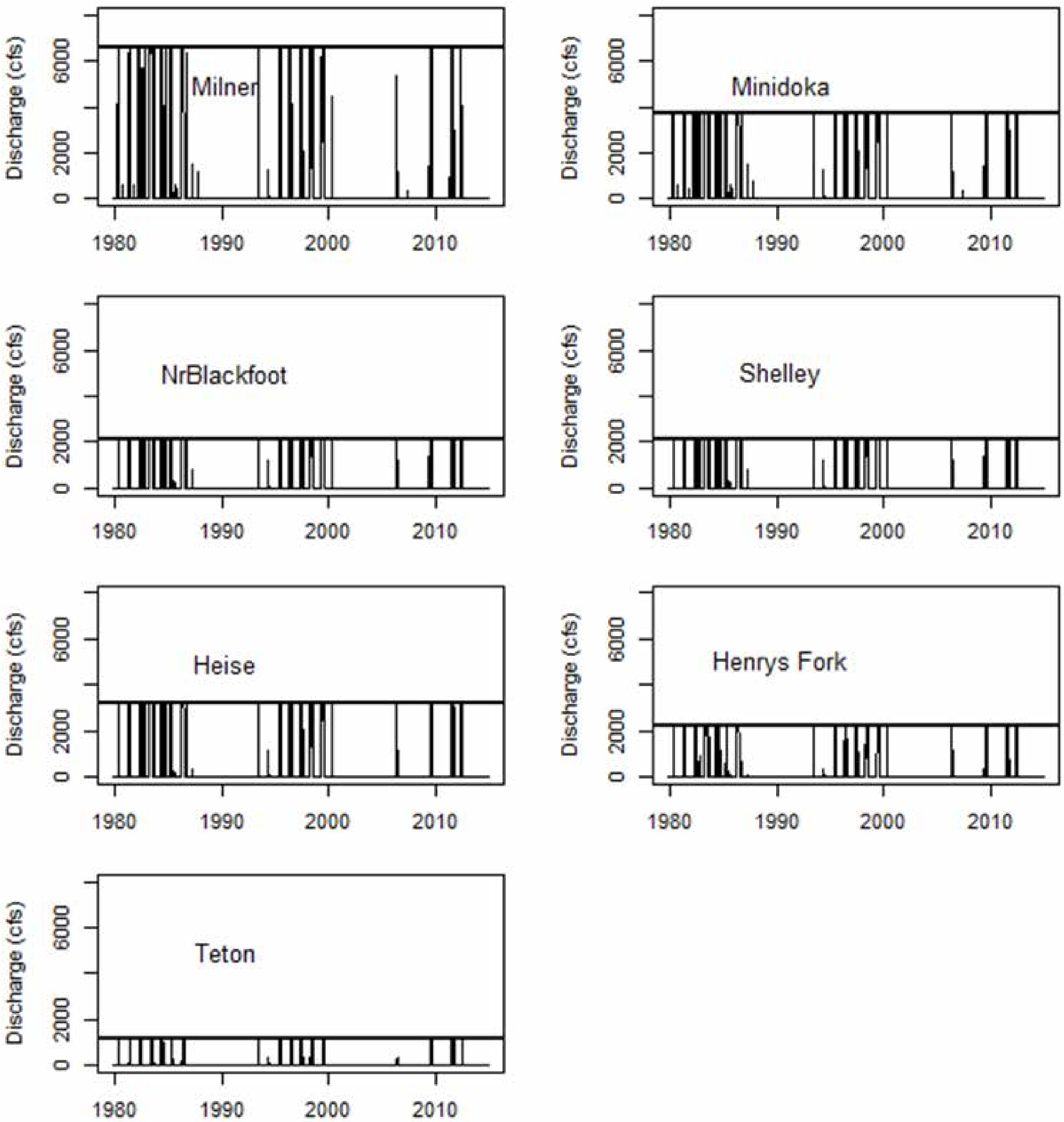

FIGURE B-3. Daily summer recharge availability under IWRB 1998 recharge rights, by stream reach, irrigation years 1980-2014.

The horizontal line on each graph is the maximum diversion rate of the IWRB's 1998 recharge rights. When there is water available for recharge, there is usually sufficient water to fill the entire 1998 water right.

TABLE B-1. Summary of all water rights in the upper Snake River and tributary basins that list groundwater recharge as a beneficial use. List is ordered by administrative basin, then by priority date within each basin.

Type	Basin	Sequence	Priority Date	Div. Rate (cfs)	Source	Owner
WR Permit	1 Upper Snake	7054	8/25/1980	1200.00	Snake River	State of Idaho
WR App	1 Upper Snake	7142	3/20/1998	2831.00	Snake River	State of Idaho
WR App	1 Upper Snake	10609	3/20/1998	3738.00	Snake River	State of Idaho
WR App	1 Upper Snake	10612	3/20/1998	2106.00	Snake River	State of Idaho
WR App	1 Upper Snake	10613	3/20/1998	3206.00	Snake River, SF Snake River	State of Idaho
WR Permit	1 Upper Snake	10566	9/28/2009	50.00	Snake River	Southwest Irrigation District
WR App	1 Upper Snake	10597	4/1/2011	300.00	Snake River	Idaho Irrigation District
WR App	1 Upper Snake	10598	4/1/2011	300.00	Snake River	New Sweden Irrigation District
WR Permit	1 Upper Snake	10625	6/19/2013	350.00	Snake River	Peoples Canal & Irrigation Co
WR Permit	1 Upper Snake	10626	6/19/2013	585.00	Snake River	Snake River Valley Irrigation District
WR App	1 Upper Snake	10629	4/14/2014	1200.00	Snake River	Aberdeen Springfield Canal Co
WR App	21 Henrys Fork	7577	3/20/1998	399.00	Henry's Fork	State of Idaho
WR App	21 Henrys Fork	7578	3/20/1998	568.00	Henry's Fork	State of Idaho
WR App	21 Henrys Fork	7580	3/20/1998	94.00	Henry's Fork	State of Idaho
WR App	21 Henrys Fork	13160	3/20/1998	1130.00	Fall River, Henry's Fork, Teton RiverR	State of Idaho
WR App	21 Henrys Fork	13144	5/10/2012	1200.00	Fall River, Henry's Fork, Teton RiverR	Fremont Madison Irrigation District
WR Permit	22 Teton	13689	5/4/2006	12.00	North Leigh Creek	Smith Teton Ranch LLC
WR Permit	22 Teton	13690	5/4/2006	12.00	South Leigh Creek	Smith Teton Ranch LLC
WR	31 Sinks	12181	5/5/1969	617.00	Camas Creek	Mud Lake Waters Users Inc.
WR	31 Sinks	7650	6/11/1997	113.00	Camas Creek	Mud Lake Waters Users Inc.
WR	33 Little Lost	2133	6/22/1949	9.88	Big Spring Creek, Little Lost River	Pancheri Brothers LLC. Pancheri Inc.
WR	34 Big Lost	14089	4/22/1884	0.08	Big Lost River	Karen Place Broussard
WR	34 Big Lost	14091	6/1/1894	0.13	Big Lost River	Karen Place Broussard
WR Permit	34 Big Lost	7571	2/3/1995	270.00	Antelope Creek, Big Lost River, South Fork Antelope Creek	Water District No. 34

Type	Basin	Sequence	Priority Date	Div. Rate (cfs)	Source	Owner
WR Permit	34 Big Lost	7573	4/11/1995	530.00	Alder Creek, Antelope Creek, Big Lost River, Parsons Creek, Pass Creek, Warm Springs Creek	Water District No. 34
WR App	36 Snake Plain	17011	3/17/2014	50.00	Waste Water	Magic Valley Groundwater District; North Snake Groundwater District; Southwest Irrigation District
WR	37 Wood	282	4/1/1877	1.00	Little Wood River	City of Gooding
WR	37 Wood	271	6/30/1882	0.32	Little Wood River	City of Gooding
WR	37 Wood	262	2/22/1883	3.16	Little Wood River	City of Gooding
WR	37 Wood	709	2/22/1883	0.74	Little Wood River	City of Gooding
WR	37 Wood	22313	3/24/1883	1.33	Big Wood River	Dry Lot, LLC
WR	37 Wood	22318	3/24/1883	0.16	Big Wood River	Dry Lot, LLC
WR	37 Wood	22323	3/24/1883	0.17	Big Wood River	Dry Lot, LLC
WR	37 Wood	577	3/24/1883	1.20	Big Wood River	The Valley Club, Inc.
WR	37 Wood	577	3/24/1883	1.69	Big Wood River	The Valley Club, Inc.
WR	37 Wood	960	4/1/1883	0.57	Little Wood River	City of Gooding
WR	37 Wood	662	6/15/1885	1.42	Little Wood River	City of Gooding
WR	37 Wood	494	5/1/1886	2.0	Big Wood River	The Valley Club, Inc.
WR	37 Wood	495	7/1/1892	2.8	Big Wood River	The Valley Club, Inc.
WR	37 Wood	833	11/12/1936	0.75	Big Wood River	The Valley Club, Inc.
WR Permit	37 Wood	7842	8/25/1980	800.00	Big Wood River, Little Wood River	State of Idaho
WR Permit	37 Wood	20653	12/21/2000	25.00	Waste Water	Thomas M O Gara Family Trust
WR Permit	37 Wood	20654	12/21/2000	25.00	Waste Water	Thomas M O Gara Family Trust
WR App	37 Wood	22682	2/10/2012	154.00	Big Wood River	Innovative Mitigation Solutions, LLC
WR App	37 Wood	22852	10/21/2013	10.00	Big Wood River	Innovative Mitigation Solutions, LLC
WR App	37 Wood	22851	10/23/2013	3.00	Adams Gulch Creek	Innovative Mitigation Solutions, LLC
WR App	37 Wood	22853	11/18/2013	3.00	Oregon Creek	Innovative Mitigation Solutions, LLC
WR App	37 Wood	22854	11/18/2013	5.00	Big Wood River	Innovative Mitigation Solutions, LLC
WR	43 Raft	4106	3/15/1878	1.00	Warm Creek	Todd Powers; Tyler Powers

Type	Basin	Sequence	Priority Date	Div. Rate (cfs)	Source	Owner
WR	43 Raft	4106	3/15/1878	0.40	Warm Creek	Ann L Rigby; Steven Gene Rigby
WR	43 Raft	4106	3/15/1878	0.70	Warm Creek	Larry Walker
WR	43 Raft	13107	1/13/1958	80 AFA	Almo Creek, Stines Creek	Cordell Sheridan; Patricia Sheridan
WR	43 Raft	13106	1/13/1958	940 AFA	Almo Creek, Stines Creek	State of Idaho (Parks and Recreation)
WR Permit	43 Raft	13731	2/14/2013	25.00	Raft River	Raft River Groundwater District
WR Permit	43 Raft	13732	2/14/2013	25.00	Raft River	Raft River Groundwater District
WR Permit	43 Raft	13733	2/14/2013	25.00	Raft River	Raft River Groundwater District
WR Permit	43 Raft	13734	2/14/2013	25.00	Raft River	Raft River Groundwater District
WR Permit	43 Raft	13735	2/14/2013	25.00	Cassia Creek	Raft River Groundwater District
WR Permit	43 Raft	13736	2/14/2013	25.00	Cassia Creek	Raft River Groundwater District
WR Permit	43 Raft	13737	2/14/2013	25.00	Cassia Creek	Raft River Groundwater District
WR	45 Goose	7567	2/27/1985	20.00	Big Cottonwood Creek	Southwest Irrigation District
WR	45 Goose	7588	1/7/1986	15.76	Dry CreekK	Southwest Irrigation District
WR	45 Goose	14194	3/10/2009	0.20	Howell Creek	Earl L Warthen
WR Permit	45 Goose	14446	12/10/2012	24.00	Land Creek, Willow Creek	Lambert Produce, Inc.
WR App	45 Goose	14455	2/25/2014	0.40	Howell Creek	Norman E Dayley
WR App	45 Goose	14456	4/7/2014	2.00	Howell Creek	ALBION12 Investments, LLC

TABLE B-2. Central-tendency statistics for annual volume of available recharge and number of days per year on which recharge could occur, irrigation years 1980-2014.

	Metric	Statistic	Milner	Minidoka	NrBlack-foot	Shelley	Heise	Henrys Fork	Teton
Winter	Vol. (ac-ft)	Median	401,542	361,475	693	693	693	693	693
		Mean	769,036	593,368	234,640	234,652	275,855	161,016	47,388
	No. days	Median	151	151	3	3	3	3	3
		Mean	151	151	50	50	50	50	50
Summer	Vol. (ac-ft)	Median	134,064	122,418	102,533	102,533	83,695	101,181	46,055
		Mean	473,566	347,243	234,170	233,715	287,174	210,108	123,162
	No. days	Median	39	37	30	30	30	30	30
		Mean	55	51	47	46	45	45	45
TOTAL	Vol. (ac-ft)	Median	627,183	550,572	149,024	149,024	130,185	147,671	85,780
		Mean	1,242,602	940,611	468,811	468,366	563,029	371,124	170,549
	No. days	Median	190	188	55	50	42	45	45
		Mean	205	202	97	97	95	96	96

TABLE B-3. Annual volume (acre-feet) of recharge availability.

Year	Milner	Minidoka	NrBlackfoot	Shelley	Heise	Henrys Fork	Teton
1980	804,448	638,172	245,680	245,680	321,887	239,843	137,109
1981	1,243,191	1,083,236	280,065	281,772	336,739	257,378	144,649
1982	1,730,635	1,398,383	472,093	472,155	531,218	394,479	235,673
1983	4,114,624	2,739,049	1,798,725	1,798,725	2,315,513	1,333,510	533,232
1984	3,956,862	2,695,897	1,738,862	1,738,862	2,230,478	1,384,281	631,915
1985	3,011,142	2,068,227	1,348,564	1,348,564	1,683,226	924,298	350,410
1986	3,290,865	2,514,804	1,390,960	1,390,960	1,596,173	1,134,184	514,382
1987	1,541,697	1,099,456	550,979	550,979	700,726	337,865	100,370
1988	197,982	132,838	0	0	0	0	0
1989	203,641	142,301	0	0	0	0	0
1990	265,876	228,675	0	0	0	0	0
1991	197,951	166,225	0	0	0	0	0
1992	233,256	175,953	0	0	0	0	0
1993	398,884	292,187	105,760	105,760	128,158	107,647	80,674
1994	724,320	693,308	71,315	71,315	71,315	64,285	46,748
1995	535,910	476,955	286,143	286,143	230,396	290,137	217,301
1996	2,436,533	1,971,242	1,102,623	1,102,635	1,351,966	869,415	427,488
1997	3,151,476	2,208,981	1,365,674	1,365,674	1,734,335	1,169,725	556,546
1998	3,278,690	2,336,033	1,573,913	1,573,913	1,944,736	1,232,262	513,724
1999	3,277,970	2,257,347	1,457,478	1,457,874	1,748,564	1,081,120	413,089

Year	Milner	Minidoka	NrBlackfoot	Shelley	Heise	Henrys Fork	Teton
2000	1,528,153	1,327,594	617,790	617,790	615,367	456,184	151,302
2001	205,070	184,150	7,366	7,366	7,366	7,366	2,580
2002	196,525	169,518	0	0	0	0	0
2003	177,002	161,738	0	0	0	0	0
2004	168,058	148,471	0	0	0	0	0
2005	193,680	156,376	1,378	1,378	0	1,378	1,378
2006	535,606	483,893	149,024	149,024	130,185	147,671	85,780
2007	502,759	467,584	15,957	15,957	11,920	15,957	15,194
2008	167,925	145,932	0	0	0	0	0
2009	673,278	550,572	263,686	245,314	264,142	219,916	177,306
2010	627,183	587,153	8,826	8,826	8,826	8,826	8,826
2011	1,733,142	1,396,024	707,750	707,750	813,672	669,364	381,345
2012	1,830,510	1,554,237	847,758	848,411	929,115	642,246	242,207
2013	174,533	129,597	0	0	0	0	0
2014	181,711	139,261	0	0	0	0	0
MINIMUM	167,925	129,597	0	0	0	0	0
Q1	200,812	167,871	0	0	0	0	0
MEDIAN	627,183	550,572	149,024	149,024	130,185	147,671	85,780
MEAN	1,242,602	940,610	468,811	468,366	563,029	371,124	170,549
Q3	1,781,826	1,476,310	777,754	778,080	871,394	655,805	296,309
MAXIMUM	4,114,624	2,739,049	1,798,725	1,798,725	2,315,513	1,384,281	631,915

TABLE B-4. Duration of the longest period of contiguous days over which recharge was available, reported by irrigation year in which the period of contiguous days ended.

Year	Milner	Minidoka	NrBlackfoot	Shelley	Heise	Henrys Fork	Teton
1980	168	168	38	38	38	38	38
1981	205	205	57	57	57	57	57
1982	205	205	51	51	51	56	56
1983	306	306	171	171	171	166	166
1984	288	288	163	163	163	163	163
1985	256	256	177	177	177	177	177
1986	297	297	124	124	124	124	124
1987	207	207	91	91	91	91	91
1988	168	167	0	0	0	0	0
1989	151	151	0	0	0	0	0
1990	151	151	0	0	0	0	0
1991	151	151	0	0	0	0	0
1992	154	152	0	0	0	0	0
1993	166	151	24	24	24	24	24
1994	166	166	16	16	16	16	16

Year	Milner	Minidoka	NrBlackfoot	Shelley	Heise	Henrys Fork	Teton
1995	151	151	41	41	41	41	41
1996	193	191	154	154	154	154	154
1997	251	251	208	208	208	208	208
1998	255	255	255	255	255	255	255
1999	243	243	243	243	243	243	243
2000	184	182	100	100	100	100	100
2001	152	152	3	3	3	3	3
2002	163	151	0	0	0	0	0
2003	164	151	0	0	0	0	0
2004	156	152	0	0	0	0	0
2005	155	151	3	3	0	3	3
2006	161	151	34	34	34	34	34
2007	160	156	21	21	21	21	21
2008	164	155	0	0	0	0	0
2009	157	151	43	43	43	43	43
2010	156	155	15	15	15	15	15
2011	156	151	74	74	74	74	74
2012	187	187	187	187	187	187	187
2013	142	142	0	0	0	0	0
2014	160	145	0	0	0	0	0
MINIMUM	142	142	0	0	0	0	0
Q1	156	151	0	0	0	0	0
MEDIAN	164	155	34	34	34	34	34
MEAN	187	184	66	66	65	66	66
Q3	205	205	112	112	112	112	112
MAXIMUM	306	306	255	255	255	255	255

TABLE B-5. Central-tendency statistics for number of days per year recharge availability is limited by the given constraint, irrigation years 1980-2014. The constraint "Flow at Milner" refers to available natural flow at Milner.

		Constraint	Statistic	Milner	Minidoka	NrBlackfoot	Shelley	Heise	Henrys Fork	Teton
Winter (151 days)	Recharge Not Possible	Flow at Milner	Median	0	0	0	0	0	0	0
			Mean	0	0	0	0	0	0	0
		Minidoka power right	Median	NA	NA	145	145	145	145	145
			Mean	NA	NA	100	100	100	100	100
	Recharge Possible	Flow at Milner	Median	151	29	0	0	0	0	0
			Mean	131	33	0	0	0	0	0
		Minidoka power right	Median	NA	NA	3	3	3	3	0
			Mean	NA	NA	23	23	25	16	6
		Flow at POD	Median	NA	98	0	0	0	0	0
			Mean	NA	87	0	0	9	34	45
		IWRB rights div. rate	Median	0	0	0	0	0	0	0
			Mean	20	31	27	27	16	0	0

		Constraint	Statistic	Milner	Minidoka	NrBlackfoot	Shelley	Heise	Henrys Fork	Teton
Summer (214 days)	Recharge Not Possible	Water rights priorities	Median	151	158	163	163	167	163	163
			Mean	155	158	162	162	164	163	163
		Flow at Milner	Median	0	0	0	0	0	0	0
			Mean	4	4	4	4	3	4	4
		Minidoka power right	Median	NA	NA	0	0	0	0	0
			Mean	NA	NA	1	1	1	1	1
	Recharge Possible	Flow at Milner	Median	31	23	11	11	13	10	5
			Mean	37	24	14	14	16	12	9
		Minidoka power right	Median	NA	NA	0	0	0	0	0
			Mean	NA	NA	2	2	3	2	1
		Flow at POD	Median	NA	0	0	0	0	2	5
			Mean	NA	1	0	0	2	14	22
		IWRB rights div. rate	Median	0	4	6	6	3	1	0
			Mean	18	26	30	30	25	18	14

The tables above are flow charts that lead from left to right through mutually exclusive choices to the median and mean number of days per year when a particular constraint either prevents or limits rate of diversion for managed recharge. The first choice is winter versus summer. The second choice is whether recharge is possible or not. The final choice level presents all possible constraints that could apply. Constraints under "Recharge Not Possible" are those that prevent recharge from occurring at all. Constraints under "Recharge Possible" are those that limit the diversion rate for recharge, if recharge can occur. Means add to 365 days per year (up to rounding), whereas medians do not.

For example, consider "Winter, Recharge Possible" at Milner. When winter recharge is possible at Milner, flow at Milner limits diversion rate on an average of 131 days per year. Diversion rates allowed under the IWRB rights limits diversion at Milner on an average of 20 days per year. The sum of these is 151 days, which accounts for all 151 days during the winter season.

As a second example, consider "summer" at the Henrys Fork PODs. Water-rights priorities prevent recharge diversion from the Henrys Fork on an average of 163 days per year, lack of natural flow at Milner prevents recharge on an average of 4 days per year, and the Minidoka power right prevents recharge on an average of 1 day per year. Continuing down the Henrys Fork column, when recharge is available there, diversion rate is limited by flow at Milner on an average of 12 days per year, by the Minidoka power right on 2 days per year, by physical flow in the Henrys Fork itself on 14 days per year, and by diversion rates under the IWRB water rights on 18 days per year. The sum of these is 214 days, accounting for all days during the summer season.