Eastern Snake River Plain Surface and Ground Water Interaction

This page provides a description of physical characteristics and activities most important to understanding surface and ground water interaction on the eastern Snake River Plain. The section focuses on the eastern Snake River Plain because of the intensive water use in the area and the significant surface and ground water interaction.

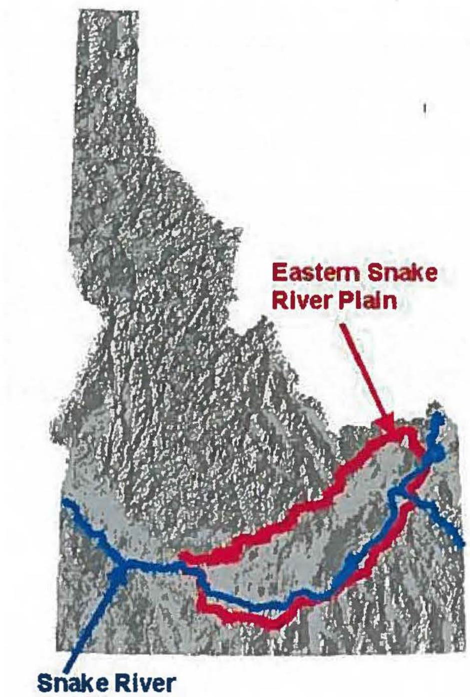


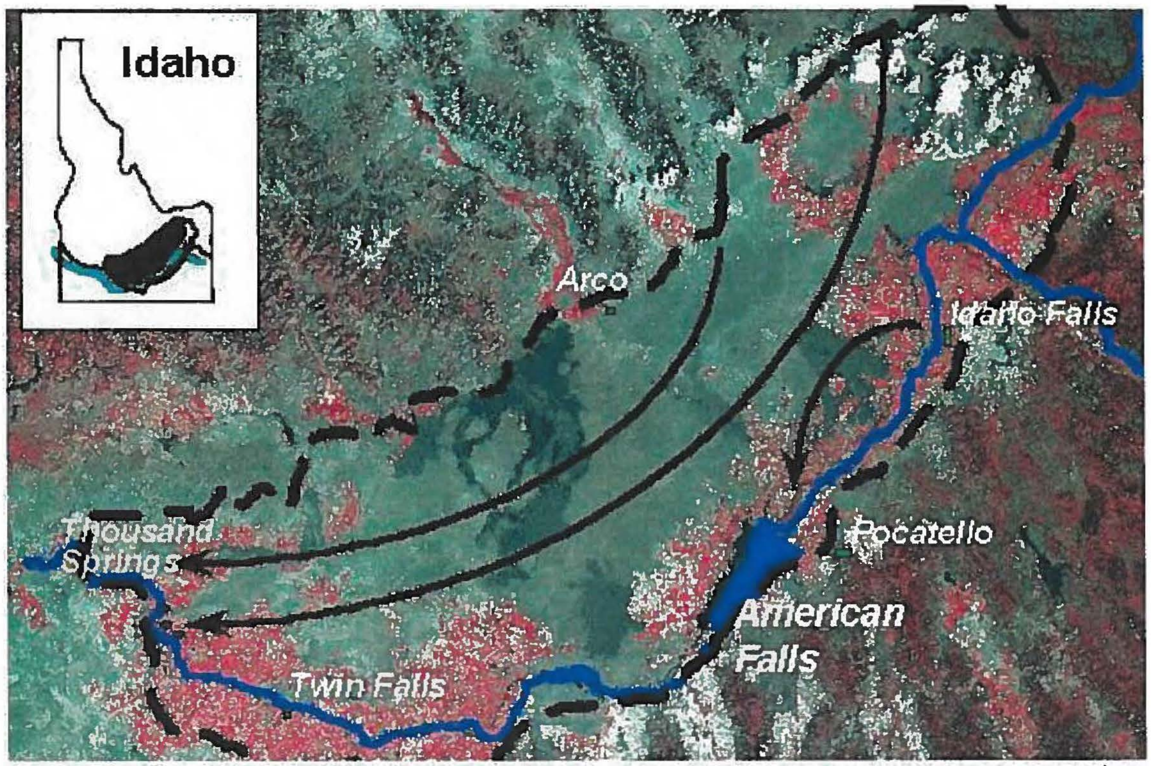
Table of Contents

:Physical Description

The eastern Snake River Plain extends as a two hundred mile long arc, about 60 miles in width, across southeast Idaho. This plain was formed by the deposition of basaltic lava extruded from numerous vents across the plain. Wind and water deposited sediments overlie the basalt in most areas and are also found interbedded with basalt flows in the subsurface. A more detailed geologic description can be found in the sections on Hydrogeology and Origin of the Snake River Plain.

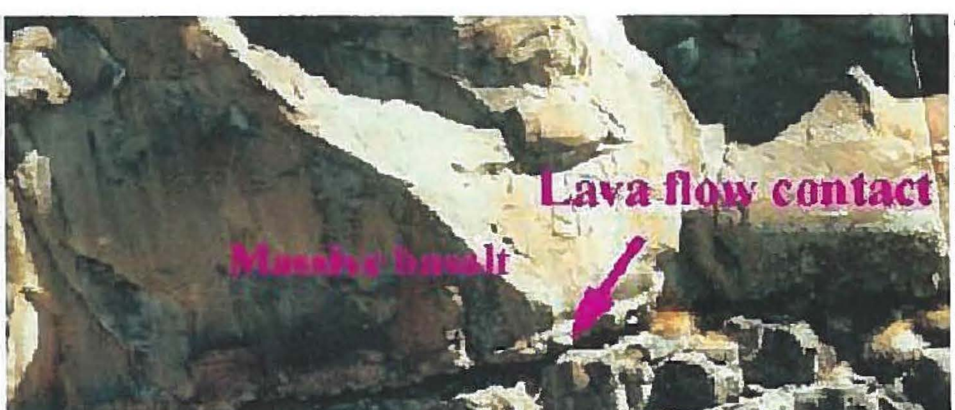
Precipitation ranges from about 8 inches/year in the lower elevations in the west to about 14 inches/year in the higher elevations in the northeast. The majority of the water supply originates in mountains on the north and east sides of the basin, including the southern portion of Yellowstone National Park. Within the boundaries of the Snake River Plain, rainfall is insufficient to support commercial levels of agriculture without irrigation that requires substantial diversions from surface and ground-water systems. The Snake River flows along the southern margin of the plain, fed by tributaries flowing out of the mountains on the south and east side of the plain. A few tributaries from the northern valleys flow into the Snake River, but many disappear through seepage into the permeable Snake River Plain basalts.

Hydrogeology



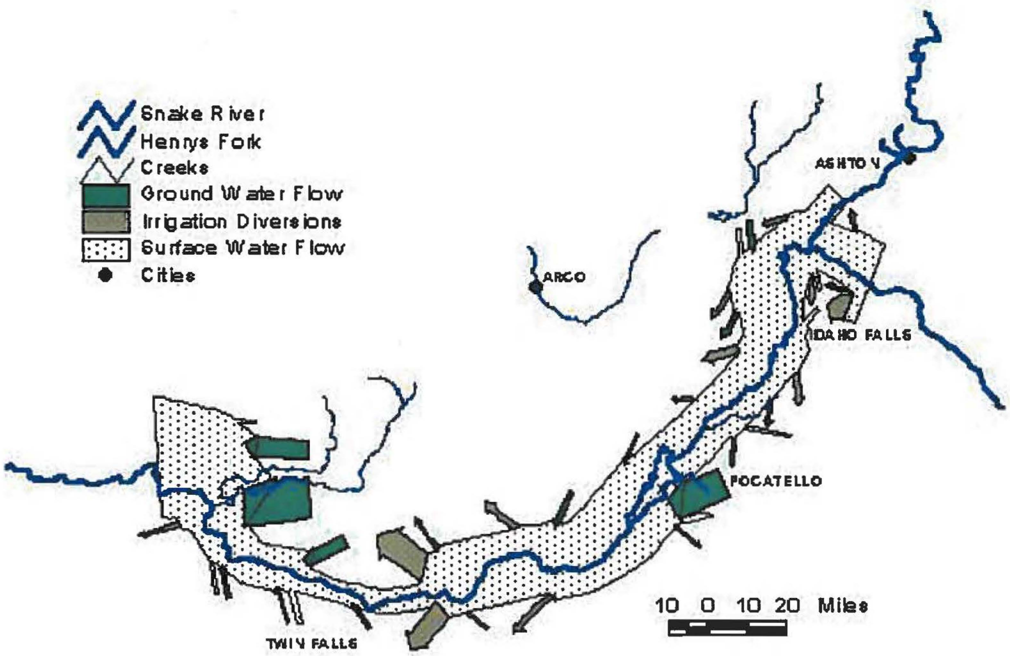
Flow in the Snake River Plain aquifer is generally from recharge areas in the north and east, to springs in the American Falls and Thousand Springs reaches of the Snake River.

The highly productive Snake River Plain aquifer underlies the eastern Snake River Plain. It has been declared a sole source aquifer by the U.S. Environmental Protection Agency, due to the nearly complete reliance on the aquifer for drinking water supplies in the area.



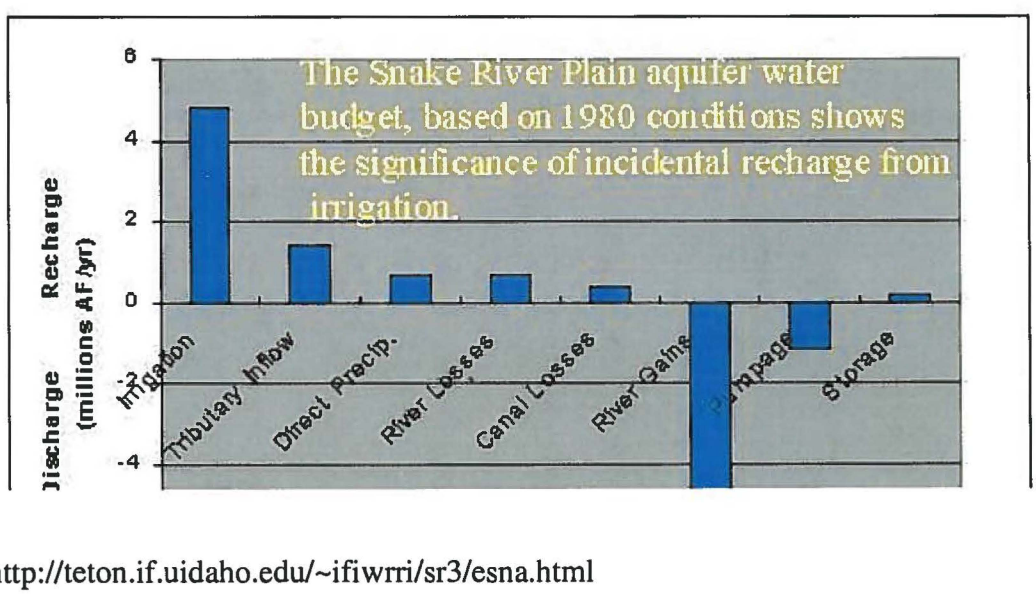
The aquifer is hosted in layered basalts with sediment occasionally deposited between layers. Highly fractured rubble zones at the contacts between layers provide the primary conduit for ground-water flow. The aquifer is considered to be unconfined but may locally respond as a confined aquifer during short duration pumping. This is presumably due to vertical stratification and the presence of lower permeability sediments interbedded among the basalt layers.

Aquifer recharge occurs mainly in the north and east portions of the plain, resulting in generally southwest trending flow lines. Natural discharge from the aquifer occurs primarily along two reaches of the Snake River: 1) near American Falls Reservoir, in which spring discharges total about 2,600 cfs; and 2) in the Kimberly to King Hill reach (Thousand Springs reach), where the collective discharge is about 5,200 cfs.

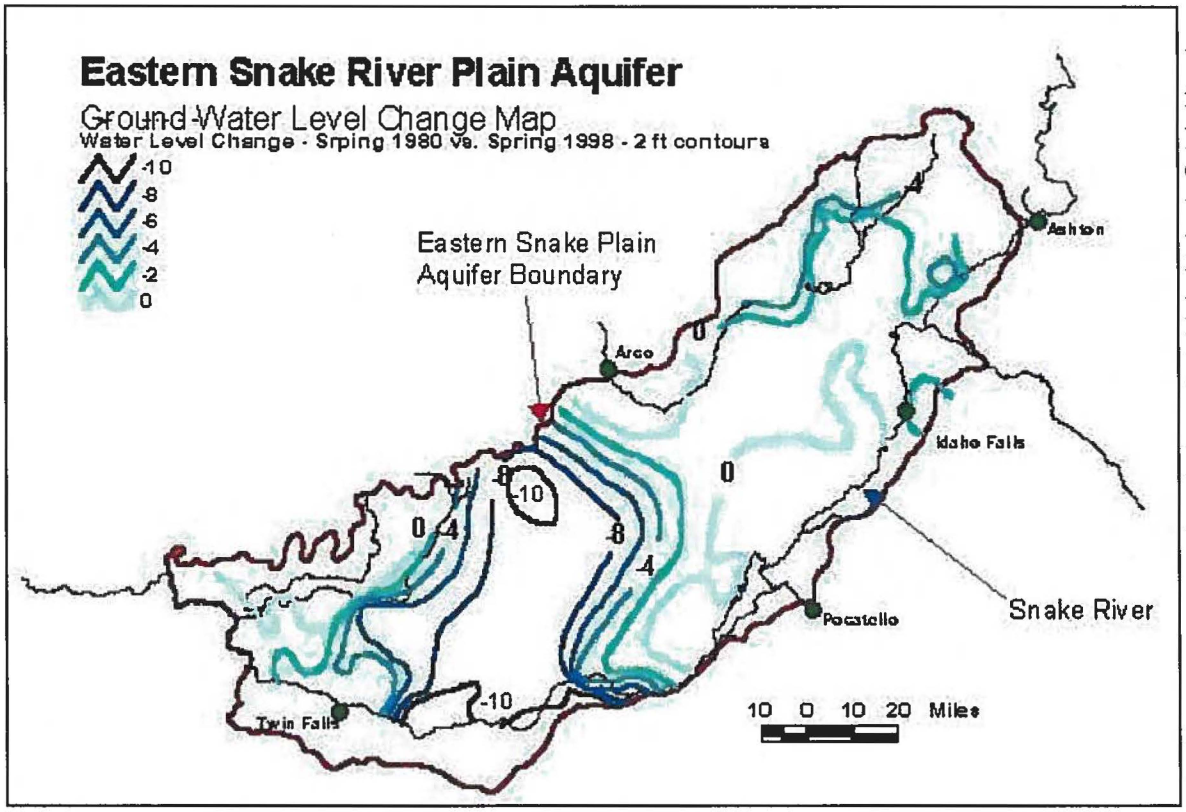


Flow in the Snake River is strongly affected by irrigation diversions and by inflow from springs.

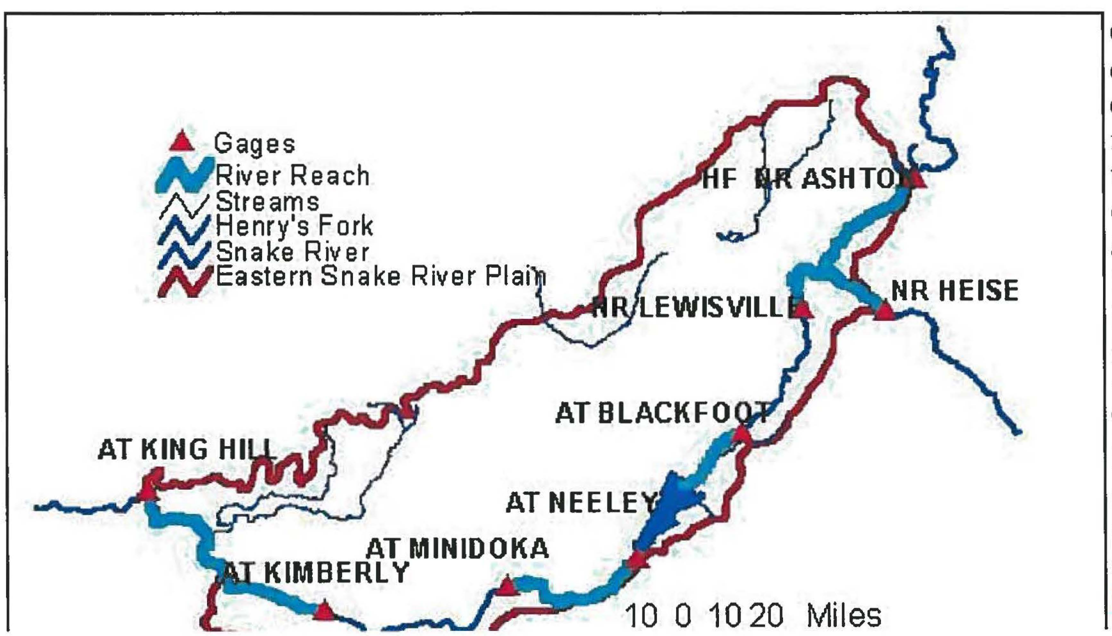
During summer, the spring flows provide the majority of the flow in the Snake River below the irrigation diversions of Milner Dam. The Snake River basin contains 15 of the Nation's 65 first magnitude springs (discharge greater than 100 cfs).



The graph to the left is a water budget for the Snake River Plain aquifer representing 1980 conditions. Surface water irrigation is by far the largest component of aquifer recharge, with smaller contributions from tributary valley underflow and seepage from rivers. During the past several decades, ground water storage has been depleted, causing water levels to drop.



Variations in weather patterns and changes in irrigation practices on the Snake River Plain have caused changes in aquifer water levels. The map to the left shows changes in water levels from Spring 1980 to Spring 1998. Some areas of the aquifer have experienced drops in water levels where other areas have experienced slight increases in water levels. (Map provided by the Idaho Department of Water Resources.)



One of the major concerns of conjunctive management is the identification of river reaches or surface water bodies that are hydraulically interconnected with an aquifer. The conceptual basis for this concern is described in the section on "Surface Water and Ground Water Interaction". In some cases it is difficult to determine the degree of interconnection because of uncertainties in river bottom conditions and water table depth and because conditions vary with time. A river reach that at one time is hydraulically connected to the aquifer may be perched at another time when aquifer water levels are lower. The State's computer model of the Snake River Plain aquifer treats four major reaches (bounded by gaging stations) of the Snake River as interconnected with the aquifer (illustration above).

1) The Kimberly to King Hill reach (Thousand Springs reach), in which the river is deeply incised in a canyon and springs discharge along the canyon wall and in the bottom of the river. Total spring discharge in this reach is about 5,200 cfs. The discharge in this reach varies seasonally and also has shown long term variations reflecting weather and irrigation patterns.

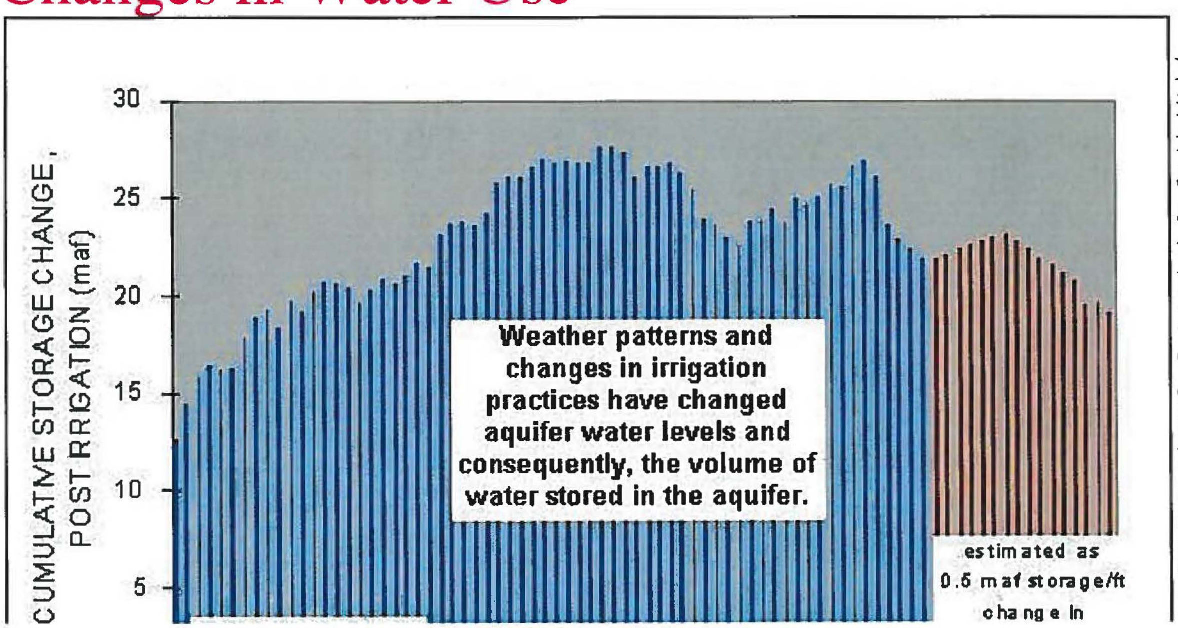
2) The Neeley to Minidoka reach which may alternately gain and lose water depending upon water table elevation. The U.S. Geological Survey estimated that this reach had a net gain of 180 cfs in 1980 (Garabedian, 1992).

3) The Blackfoot to Neeley reach in which springs contribute about 2,600 cfs to the flow of the river. Spring discharges in this reach exhibit seasonal variation (graph), but have not shown the long-term variation like the Kimberly to King Hill reach (graph). The reason for the long-term stability in this reach is not known.

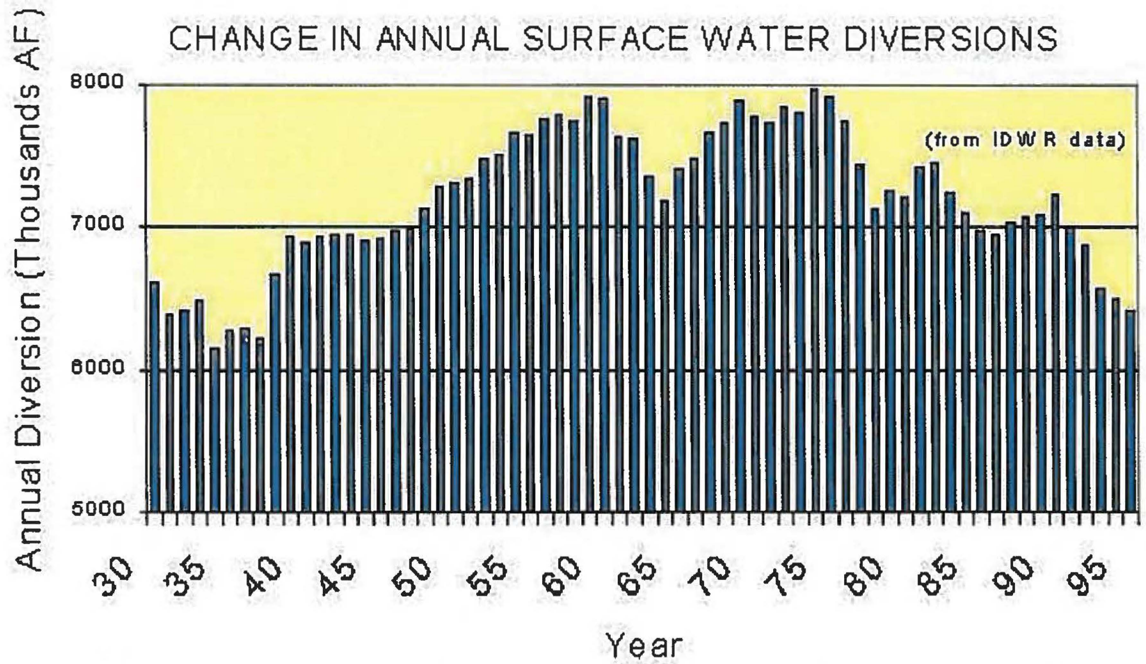
4) The Henrys Fork and Upper Snake River reaches which were estimated to jointly gain approximately 260 cfs in 1980 (Garabedian, 1992).

Changes in water table elevation, due to natural causes or man caused activities, result in changes in river gains and losses in these reaches. Although the effects of ground water pumping cannot be measured or separated from effects of natural events, ground water models can provide estimates of individual and collective pumping effects.

Changes in Water Use



Extensive irrigation from the Snake River and its tributaries began in the late 1800s on the eastern Snake River Plain. Gravity irrigation systems typically divert more than twice the amount of water necessary to meet crop requirements (Goodell, 1985). The remainder of the water returned to the Snake River or infiltrated to the aquifer. The incidental recharge from the approximately 900,000 acres of surface water irrigated land resulted in increased elevation of ground water levels. The volume of water stored in the aquifer, as shown in the above graph, increased by about 15 million acre-feet between 1915 and 1955. On the average, 340,000 acre-feet of water were being added to aquifer storage annually during this period. Spring discharge, especially in the Thousand Springs reach, also increased dramatically during this period due to higher water levels. Cumulative discharge in the Thousand Springs reach increased from about 4,800 cfs in 1915 to about 6,800 cfs in 1955. An infrared image of the plain shows the approximate extent of irrigated lands in the early 1990s for areas that appear in red adjacent to the Snake River.

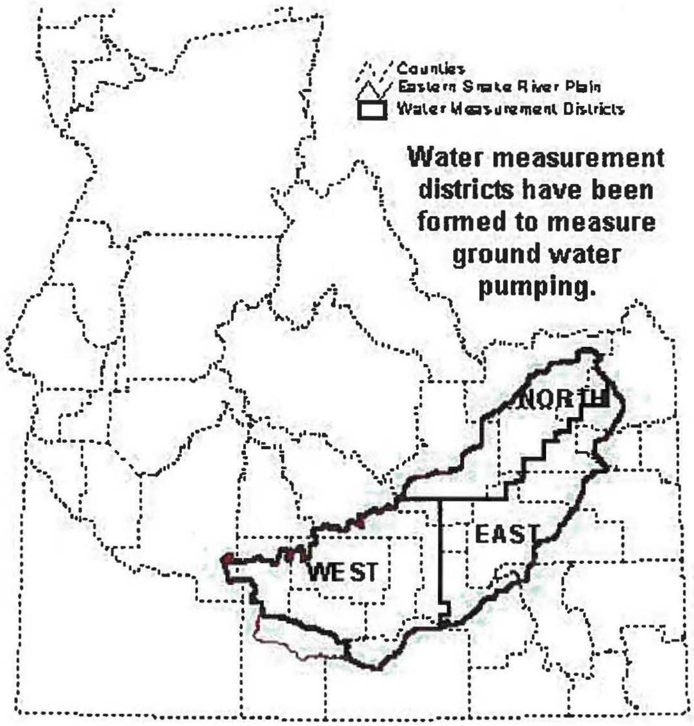


Surface water diversions have varied in response to weather patterns, number of acres irrigated, and irrigation technology.

In the mi - 19 irri tec on the eas Sn Ri Pla be to ch Ar inc wa use eff res fro co

of additional surface water storage facilities, water conservation programs, and, probably most importantly, increased use of sprinkler irrigation. Surface water diversions for irrigation began decreasing in the early 1970s (see above graph). The increased efficiency of the system led to decreased ground-water recharge that has contributed to the decline of ground water levels and spring discharge. In addition, ground-water withdrawals for irrigation increased dramatically during the last half of the century. About 800,000 acres of ground water irrigated land have been brought into production since the 1950s. At an average estimated irrigation demand of 1.8 acre-feet/acre, the total aquifer withdrawal is about 1.5 million acre-feet/year. The combined effects of decreased recharge from surface water irrigation and increased ground-water withdrawals, along with weather variation, are apparent in the declines in ground-water storage and spring discharge since the mid-1950s. The average rate of decline in ground-water storage between 1975 and 1995 is about 350,000 acre-feet/year. Changes in the collective discharge of springs in the Blackfoot to Neeley and Kimberly to King Hill reaches of the Snake River are shown by a hydrograph.

Recent Challenges in System Management



The State of Idaho administers water rights according to the Prior Appropriation Doctrine (see Water Rights and Conjunctive Management). Idaho fully recognized the need to implement conjunctive management of its water resources in 1984 when the Idaho Supreme Court determined that hydropower water rights of Idaho Power Company at Swan Falls Dam were not subordinated to junior upstream irrigation rights. The case alerted water users in the basin that ground water pumping for irrigation was impacting spring discharge and flow in the Snake River, and that surface and ground water rights were to be jointly administered. In 1992, a moratorium was imposed on new irrigation pumping on the eastern Snake River Plain (Idaho Department of Water Resources, 1996), which is still in place. Subsequently, IDWR promulgated conjunctive management rules to provide a mechanism to stem conflicts between surface and ground water users when water supplies are limited. IDWR has also formed water measurement districts in the Eastern Snake River Plain (see above figure) that require the measurement and reporting of ground-water pumping at rates exceeding 0.24 cfs, or irrigating areas greater than 5 acres.

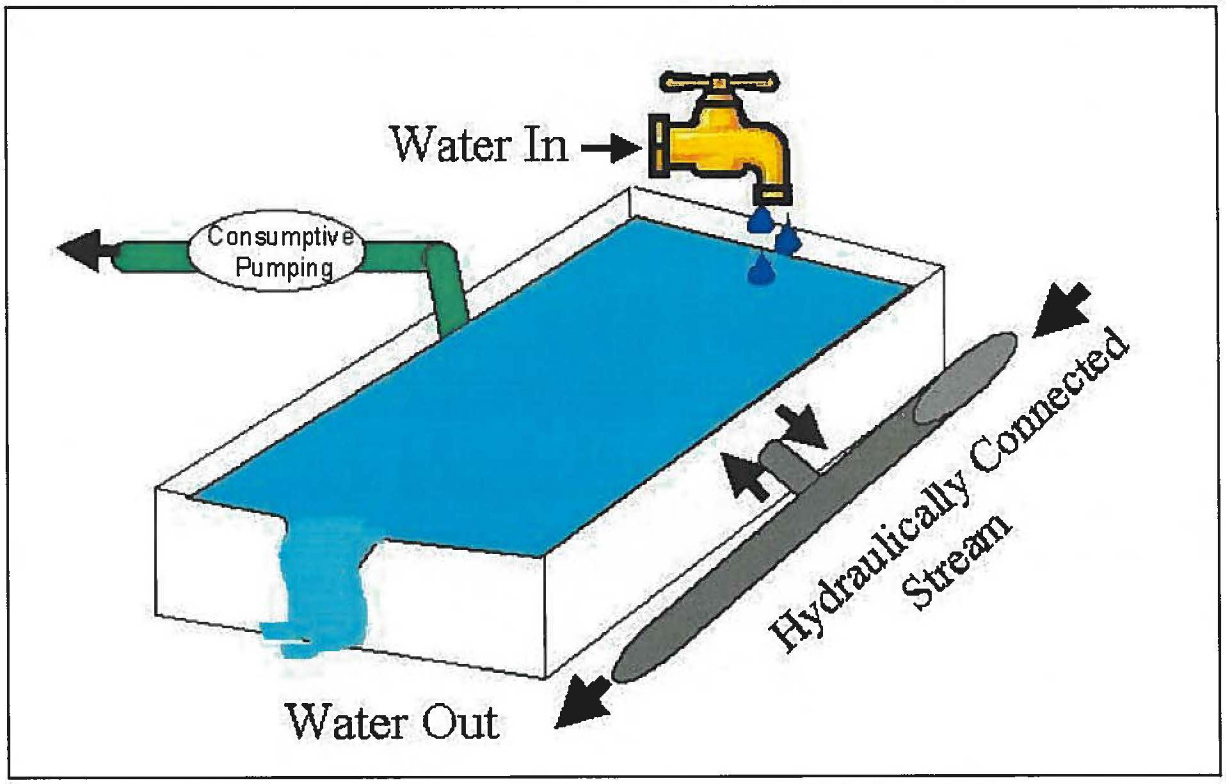
Depletion of spring flows and declining ground-water levels are a collective effect of drought, changes in surface-water irrigation acreage and practices, and ground-water pumping. A recent model study (IDWR, 1997) indicates that the collective effects of all ground-water pumping within the boundaries of the eastern Snake River Plain depletes spring discharge and flow of the Snake River by about 900,000 acre-feet per year (1,200 cfs). The same study projects that changes in surface water irrigation practices have depleted the spring discharge by about 500,000 acre-feet per year (700 cfs). IDWR and the courts are placed in the position of determining the degree to which junior ground-water users have injured senior surface-water users. Isolating cause and effect relationships on a case by case basis will be difficult and costly.

Although most water users and managers accept the concept that ground water use depletes surface water supplies, it is not necessarily accepted that depletion constitutes legal injury. The conjunctive management rules provide for weighing the time of year in which depletion is experienced, the efficiency of use of the senior water users, and the maximum economic benefits of all uses, against the possibility of "futile call".

The State's conjunctive management rules allow junior priority water users to mitigate injury to senior surface and ground water users. One of the mechanisms is to provide supplemental recharge to the aquifer. Both surface and ground water users have embraced artificial or managed recharge as a means of avoiding future conflicts and litigation.

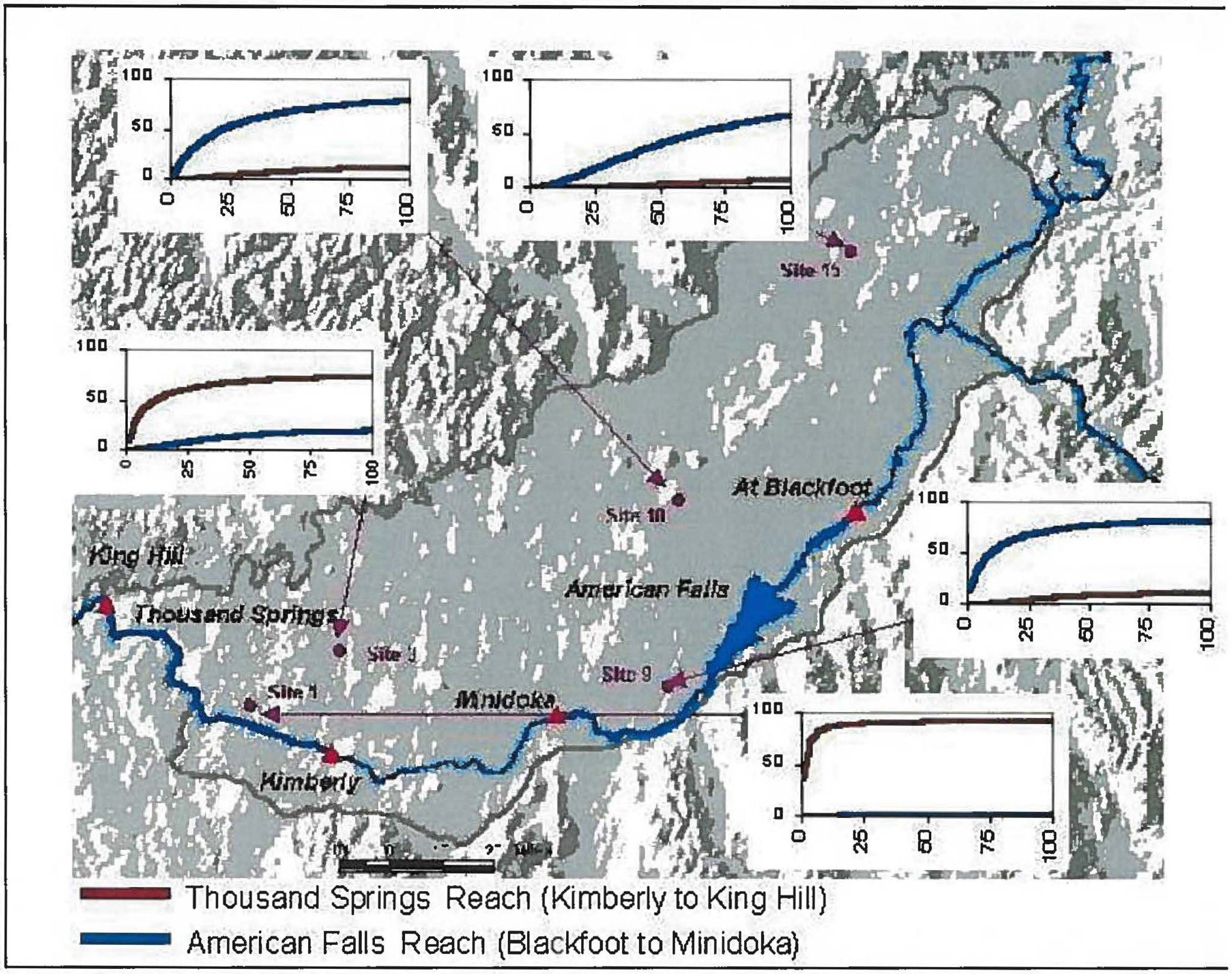
Estimates of Surface and Ground Water Interaction

There are several reaches of the Snake River, as well as small streams, that are hydraulically connected with the Snake River Plain aquifer. Ground water pumping from the aquifer initially causes a localized decline in the water table. That decline, or cone of depression, propagates progressively outward until it encounters hydraulically connected surface water bodies. The surface water bodies are subsequently depleted as a result of the pumping. There are four primary points to recognize about the effects of pumping on surface water in the eastern Snake River Plain. The reader should recognize that throughout this discussion the focus is on ground water pumping, but the same concepts, in reverse, apply to aquifer recharge. For more information on these concepts consultSurface Water and Ground Water Interactions.



Aquifer Inflows in Balance with Outflows.

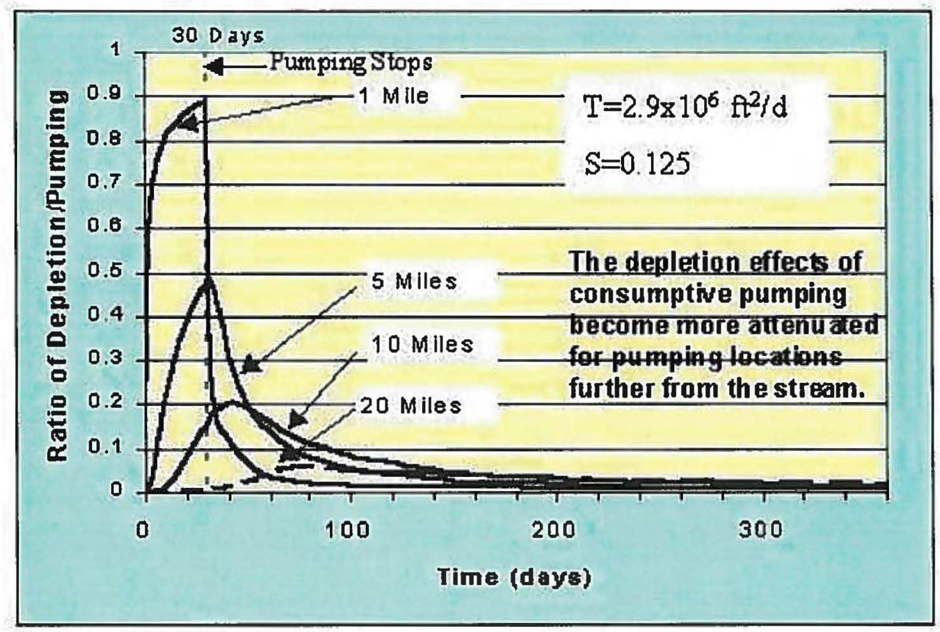
1) Pumping effects propagate in all directions through the aquifer, not just down-gradient. This means it is possible for a down-gradient water user to affect stream flow in the upper reaches of the plain. This appears to be in contrast to the logic that "water flows downhill", but in fact it is not. Consider the analogy of an water tank in which water is entering from two sources on one end and continuously discharging from an overflow weir on the other end, as shown in the illustration. The water in the tank represents the Snake River Plain aquifer. The one source of fill is a faucet that does not make direct contact with the water level in the tank, therefore it cannot siphon. This represents recharge to the aquifer resulting from perched streams, precipitation, and irrigation sources. If the water level in the tank (i.e. aquifer) changes, it has no effect on this recharge. The second source of fill is a pipe connected below the water surface in the tank. This source represents hydraulically connected stream and river channels. If the water level in the tank drops, more water will flow out of the pipe and into the tank. If a pump is introduced to extract water from the middle of the tank, what will happen? Water levels in the tank will decline, causing the outflow over the weir to be reduced (similar to Thousand Springs). In addition, the inflow from pipe connected beneath the water surface will increase or outflow will decrease (similar to river connection in the Henrys Fork and the upper Snake River). This increase occurs despite the fact that water is flowing through the tank from the inlet to the outlet sides. In the Snake River Plain aquifer, if water is pumped, or recharged, in the center of the plain, gains and losses of the Snake River may be affected at many locations, not just along the flow lines. Flow lines in an aquifer have limited meaning when evaluating the propagation of pumping or recharge effects; they are significant with respect to water quality considerations.



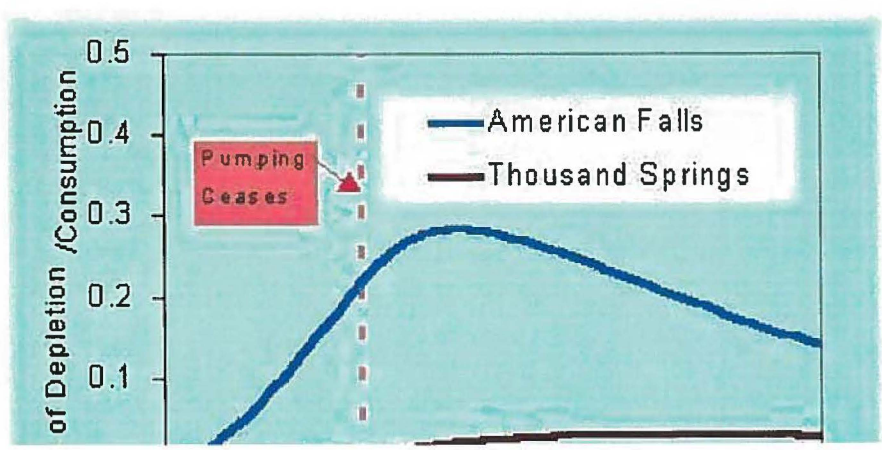
Ground water pumping at different locations results in different degrees of depletion of theSnake River. The
above show the percentage of ground water pumping (vertical axis) that is estimated to be depleted from spri
either the Thousand Springs reach or the American Falls reach. The horizontal scale represents time of conti
pumping from 0 to 100 years.

The radial propagation of pumping effects is evident from depletion graphs generated from a numerical model of the Snake River Plain aquifer. It is apparent from the graphs superimposed on the map of the Snake River Plain that effects do not preferentially propagate along the flow lines in the aquifer (see figure). Although pumping sites in the upper portion of the basin are aligned with flow lines that discharge near Thousand Springs, the majority of the impact is expected near American Falls. The simulations did not include effects of the hydraulic connection of the Henrys and upper Snake River, although they may be significant.

2) The total volume of water pumped and consumptively used from the Snake River Plain aquifer will ultimately be depleted from surface water sources and cause a reduction in ground water storage. It is obviously true that water pumped and consumptively used is water that would otherwise have gone somewhere else. If we again consider the water tank above, when our pump is taking water out of the tank, the discharge of the tank is diminished and the inflow from the submerged pipe is increased. The pumping has not exceeded the rate of recharge to the tank, but it has impacted outflow (analogous to springs) and inflow (analogous to a hydraulically connected river reach). In the Snake River Plain aquifer, the entire volume of water pumped and consumptively used will either be depleted from spring discharge, cause a corresponding increase in river losses, or cause a corresponding decrease in river gains. We can neither create nor destroy water in the process of pumping.



3) Pumping and aquifer recharge effects on surface water are often greatly attenuated. Even though the entire volume of water consumptively pumped throughout the Snake River Plain aquifer will ultimately be drawn from surface water sources and ground water storage, that depletion may be distributed over time periods ranging from days to decades. The attenuation of the effects is related to the proximity of the pumping location and surface water body, and the hydraulic properties of the aquifer and stream. The expected approximate attenuation of pumping or recharge effects within about 25 miles of the Snake River in the Thousand Springs area is illustrated graphically. The effects of a 30 day pumping or recharge event are seen to become more attenuated as the site becomes progressively more distant from the river. The illustration uses aquifer properties typical of the Thousand Springs area that may not be representative of other locations within the Snake River Plain aquifer. At greater distances, the effects are much more attenuated. The effects of a 30 year pumping event in the northeast portion of the plain are expected to continue for decades even after the pumping ceases (see graph below).



4) Our ability to estimate ground water pumping impacts on surface water resources is limited. Although this page has presented many illustrations that quantitatively relate consumptive ground water pumping or recharge to surface water depletion, these illustrations are approximate. They are the result of analytical and numerical models, but those models are the current representations of our limited knowledge about the real system. More detail can be found in the section on "Evaluation Methods".

The above points are extremely significant to water management in the Snake River and the Snake River Plain aquifer. Some of the primary management considerations are:

1) Negative impacts can result from consumptive ground water pumping, even though the rate of pumping does not exceed natural recharge. This is because other users or system needs are dependent on the aquifer.

2) There is no "no-impact" consumptive pumping. Every gallon of water consumptively used is not available somewhere else in the system where it would otherwise have existed.

3) Conjunctive administration of water rights under the Prior Appropriation Doctrine will be an involved process. Complication results from the propagation of effects to changes in consumptive ground water pumping or managed recharge in all directions and the attenuation of those effects in the aquifer and to the stream, and due to our limited knowledge about the aquifer.

4) Managed aquifer recharge can offset some of the adverse economic and environmental impacts of consumptive ground water pumping.

Evaluation Methods

Several methods may be applied to estimate the impact of ground water pumping or recharge on surface water resources. General application of these methods is discussed in the section on "Surface Water and Ground Water Interaction". The primary method used for the Snake River Plain aquifer has been numerical modeling. Numerical modeling allows us to use as much information about the system physical characteristics as we have available; however, our knowledge of the system is never complete.

Several models have been constructed of the Snake River Plain aquifer, or portions of the aquifer. The two most complete models were constructed by the University of Idaho for the Idaho Department of Water Resources (IDWR) and the U.S. Geological Survey (USGS). These two models have similar boundaries and employ the same computer code. They differ, however, in their purpose for construction and, consequently, their design. The USGS model was constructed largely as an investigative tool to explore concepts of the regional ground water flow and improve our scientific understanding of the system. The IDWR model was designed primarily as an aquifer planning and management tool. The IDWR model presents a more simplified concept of the aquifer in that it uses a single model layer. The single layer was used because it was felt that data were inadequate to develop the multi-layer approach used by the USGS. Nevertheless, extremely sophisticated concepts can be simulated with each model. Our development of models is limited by data availability and our understanding of the real system. A comparison of predictions from these two models is currently being explored as part of the Bureau of Reclamation's SR3 project. More information on these models can be found in Cosgrove and others (1999) and Garabedian (1992).

The model developed for the IDWR is the tool that has been, and probably will continue to be, used for evaluating ground water and surface water relationships. Click here for a view of the IDWR State model grid and boundaries. The model was used to perform the Upper Snake River Basin Study (IDWR, 1997) and was used to develop response functions for the river and aquifer (Johnson and Cosgrove, 1999, to be supplied).

The models of the Snake River Plain aquifer described above have been used for many years and presently are accepted to represent the effects that consumptive ground water pumping and managed recharge have on ground water storage and on interactions between the river and the aquifer. However, it is important to recognize that these models are not precise. Although our models will never be perfect, they can always be improved. For example, more ground water-level measurements are needed near the Snake River to better understand and represent the interconnection between the river and the aquifer.

Top