ASSESSMENT OF THE IMPACT OF REDUCED STREAM FLOWS ON GROUND WATER RECHARGE AND SPRING DISCHARGE IN THE LITTLE SNAKE RIVER DRAINAGE BASIN, WYOMING

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Wyoming Water Development Commission
Cheyenne, Wyoming
and
Wyoming Water Resources Center
University of Wyoming
Laramie, Wyoming

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PURPOSE

The objective of this investigation was to assess the impacts on ground water systems in the upper part of the Little Snake River Basin that result from diversion of water from tributaries to the Little Snake River by the Cheyenne Stage I and II diversion system. The location of the project area is shown on Figure 1.

The methods used to carry out this phase of the study included (1) an assessment of the hydraulic interconnection between the impacted streams and the sedimentary rocks comprising their beds, (2) visual observation of stream flows in the tributaries below the diversion system periodically during 1991, and (3) correlation of the stratigraphy between the upper Little Snake Basin and Dixon, Wyoming, in order to determine if there is good hydraulic communication between these locations within the ground water system.

FINDINGS

The entire western flank of the Sierra Madre Range, on which the Little Snake Drainage Basin is eroded, has endured a record drought between 1987 and this year. The dry conditions reduced both streamflows in the tributaries within the basin, and discharge from seeps and small springs within the upland parts of the basin that derive their waters from local precipitation. The drought was partially broken by above normal precipitation during the summer of 1991 leading to recovery of many of the upland seeps. This in turn resulted in recharge to shallow alluvial aquifers under the lowlands along the Little Snake River or its tributaries, in part mitigating recent water level declines in the alluvial aquifers. However, dry conditions through September and October have again exacerbated natural water supply shortages in the basin.

Table 1 shows the 1991 diversion of water from the Little Snake drainage through the tunnel to Hog Park Reservoir. This data indicates that water in the tributaries was diverted during snow melt runoff in May and June. Field observations made by Huntoon and McCormack during the course of the summer and fall of 1991 also indicated that: (1) the largest flows in tributaries downstream from the various Stage I and II collector structures occur during the peak of the snow melt runoff period in May and June, and (2) discharges in the tributaries of the Little Snake Basin decline over the summer as snow melt becomes minimal so that in August and September, flows in the Little Snake River are near there low point as indicated by Figures 7-10.

There is minimal stream-aquifer interaction in the Little Snake Basin in the area considered by this report. The Paleozoic and Mesozoic sediments that are present have very small permeabilities and exhibit minimal reservoir responses. These tight rocks are in turn mantled by the Tertiary Browns Park Formation which is comprised of tuffaceous sandstone underlain by a basal conglomerate. The Browns Park Formation occurs as an elevated tabular deposit that unconformably covers the older strata. It is usually dissected by fairly deep canyons in the project area so the many seeps and very small springs that discharge from the conglomerate at its base usually occur along the canyon walls. The unit usually lies above the surface streams and is largely hydraulically isolated from them. Consequently, the Browns Park Formation does not derive significant recharge from the streams, as recharge to the unit originates from local precipitation or upland runoff.

The only strata in significant hydraulic connection with the streams is alluvium which floors the channels. The permeable alluvium generally has limited thickness and aerial extent so it does not serve as a large volume reservoir within the total hydrologic system. Some wells are developed in the alluvium, and those wells along the streams derive most of their water in some manner from the streams. Other alluvial wells, such as one owned by Patrick O'Toole at the mouth of a dry tributary canyon along the Little Snake River, are sufficiently shallow that they draw significant amounts of water from sources other than the streams. Thee types of wells rely on recharge from snow melt on outcrops of the alluvium upstream in the dry gulches. The prolonged recent drought adversely impacted the yields from such wells, a circumstance that is, of course, independent of the operation of the Stage I and II system.

WATER RIGHTS AND STAGE I and II DIVERSION POINTS

Figure 1 shows the locations of recorded ground water rights in the upper part of the Little Snake Basin. Most of these are spatially distant from the diversion points for the Cheyenne Stage I and II project which are also shown on Figure 1.

GROUND WATER GEOLOGY

The geologic data contained on Figure 2 reveals that most of the land surface in the upper part of the Little Snake Basin is mantled by the Browns Park Formation of Tertiary age. Underlying this tabular unit is a beveled succession of southwesterly dipping Paleozoic and Mesozoic strata which overlie the Precambrian crystalline basement rocks comprising the core of the Sierra Madre Range. As shown on Figure 3, successively younger units underlie the Browns Park Formation to the west, and their dips decrease basinward.

The hydrostratigraphy of these rocks is summarized on Figure 4. The units present in the project area are dominantly classified as confining strata because they possess small permeabilities.

The rocks in the project area are deformed by folds and faults that pre-date deposition of the Browns Park Formation (See Figure 2). These structures owe their origin to compressional tectonism, and they were emplaced during the main period of uplift of the Sierra Madre Range. The ensuing erosion caused the beveling of the surface upon which the Browns Park Formation is deposited. Late Tertiary extensional tectonism produced numerous normal faults with displacements of less than 1,000 feet that offset the Browns Park Formation and older rocks throughout the project area. In addition to the normal faulting, the extensional tectonism caused regional and local warping of the Browns Park and older strata.

Volcanism occurred simultaneously with or post-dated the normal faulting and was responsible for the emplacement of intrusive feeder dikes and plugs, and deposition of extrusive rocks in the southern part of the area. The volcanic rocks are now mostly confined to outcrops above the Browns Park Formation such as those that cap Battle Mountain.

None of the faults in the sedimentary strata, either of extensional or compressional origin, serve as hydraulic conduits based on the lack of spring discharges from them along streams in the area. The volcanic rocks are hydrologically unimportant sources for ground water owing to the fact that they are elevated and well drained.

PRECAMBRIAN ROCKS

Precambrian crystalline rocks comprise the core of the Sierra

Madre Range. These rocks are impermeable unless fractured. Small seeps discharge from fractures in the crystalline rocks in the uplands producing wet spots in meadows that are important for livestock and wildlife watering. However, the Precambrian crystalline rocks have not proven to be an important developable source for large volumes of ground water in the area.

PALEOZOIC AND MESOZOIC ROCKS

The Paleozoic and Mesozoic strata are predominantly comprised of interbedded shales, siltstones and sandstones. These fine-grained clastic rocks have small permeabilities. The result is that, at best, the aquifers present are minor. Evidence supporting this statement is the fact that large springs do not discharge from the section and large capacity irrigation wells have not been successfully drilled into it. A few seeps discharge from the coarser clastic rocks. The Paleozoic and Mesozoic rocks that elsewhere in Wyoming are important aquifers, such as the Madison Limestone and Tensleep Sandstone, are very thin or absent in the headwaters of the Little Snake Basin.

There is very little hydraulic interaction between the Paleozoic and Mesozoic rocks in the Little Snake Basin and the Stage I and II project, primarily because these rocks have such small permeabilities. In addition, most of the exposed Paleozoic and Mesozoic outcrops are topographically separated from live streams draining from the Stage I and II intakes.

There is minimal basinward recharge from the upper Little Snake River Basin through the Paleozoic and Mesozoic strata to the area underlying Dixon. The primary reason for this is the small hydraulic conductivities of the rocks in this section. Also, the channels downstream of the Little Snake River and its tributaries become floored by successively younger Cretaceous confining strata. As shown on Figure 3, this basinward younging sequence is as follows: Steele Shale, Mesaverde Group, Lewis Shale and Lance Formation, each of which has minimal permeabilities.

TERTIARY BROWNS PARK STRATA

The Browns Park Formation is a tuffaceous sandstone with a prominent basal conglomerate. Most of the springs and seeps that occur in the area are small and discharge from the basal conglomerate or thin sandstone interbeds within the Browns Park section. Most notable are the seeps that occur along the walls of canyons and in areas of low topography that emerge from the base of the unit. These sources were minor, having yields ranging from seeps to a few gallons per minute at best during the wettest months of the summer of 1991. Most of the permitted water wells in the area are developed in the Browns Park Formation. These are typically about 100 feet deep and are completed in the basal conglomerate.

Some Browns Park springs have been developed as stock watering supplies and some even support small constructed ponds in the upland areas. No attempt was made to inventory these sources because they derived their waters from snow melt and precipitation on outcrops directly upgradient and thus are unaffected by developments associated with the Stage I and II project. The importance of these sources should not be underestimated, however, because they are important for stock watering. They are highly sensitive to climatic variability.

UNCONSOLIDATED ALLUVIUM

The most permeable rocks in the basin are the alluvial deposits which floor the valleys. These occur along both the live streams in the Little Snake system and in dry gulches that drain to the live streams. In the typical setting, the underlying Mesozoic strata from which the gulches are eroded are largely impermeable. The alluvium is saturated along the live streams and experiences modest water level fluctuations that track the stages of the streams.

The alluvial aquifers in the dry gulches have proven to be highly sensitive to recent prolonged drought conditions. The elevated position of these aquifers above the streams causes them to be dependent on recharge from ephemeral runoff in the gulches in which they occur and snow melt directly above or on them. Patrick O'Toole has an alluvial well located in the floor of such a gulch close to but slightly above the flood plain of the Little Snake River (Figure 1). A significant fraction of the water in the well is derived from circulation of water in the alluvium originating upgradient in the gulch. This setting was common in the area so Huntoon and McCormack carefully studied the headwaters of the gulch to identify the sources of water for the well.

The gulch is eroded into shaly bedrock and its headwaters are topographically isolated from other sources. Consequently, the water in the alluvium is derived entirely within the gulch, with most of the sustained yield being water taken into storage below a large snow bank during spring snow melt. This combines with water that infiltrates into the bed of the gulch from melting snow or rainfall, and these waters circulate down the gulch through the alluvium to the site of the well. Obviously, the well is sensitive to the precipitation over the gulch, but is hydraulically disconnected from any streams impacted by the Stage I and II diversions.

1987-1991 DROUGHT

The severity of the recent drought in the Little Snake River Basin is dramatically revealed by the precipitation data shown on Figure 5. The 1987 through 1990 precipitation is the lowest on record.

Figure 6 shows the mean daily discharge of the Little Snake River near Slater. Figures 7 through 10 show comparisons between the mean daily discharge by month for the years 1987 through 1990, and mean daily discharge by month for the period of record. Table 1 indicates the diversions of Little Snake River basin water during 1991 as a result of Stage I and II diversion structures through the tunnel into Hog Park Reservoir. The decreased streamflows during these four years are believed to represent the cumulative impacts of both the drought and Stage I and II diversions. Although the relative impacts of the drought and Stage I and II diversions have not been separated on these plots, the impact of the drought is severe. This fact is revealed qualitatively on Figures 8 and 10 by the proportionately small winter runoffs in 1988 and 1990, during periods when Stage I and II diversions are not operating.

OBSERVED STREAM DISCHARGES

Huntoon and McCormack visited the project area periodically during the months May through September of 1991 to qualitatively observe the discharges of the creeks draining to the Little Snake River. The primary purpose of these site visits was to identify any obvious hydraulic interactions between the streams and the strata comprising the floors and the walls of the channels. They were particularly interested in locating large springs or reaches that were losing noticeably to the beds. These types of occurrences were not found along the reaches below the Stage I and II diversions.

In the process of these investigations Huntoon and McCormack observed the variable discharge characteristics of the principal tributaries to the Little Snake River during the summer months. Discharges were particularly high during June, accompanying the snow melt, and releases were occurring through the Stage I and II diversion structures. There was water in the creeks that barely covered the rocks of the channel during our August and September visits, and the Little Snake River was at a low stage. As expected under this condition, water temperatures were elevated and algae was flourishing in the Little Snake itself as a result.

INTERVIEWS WITH RESIDENTS

Huntoon was given a tour of the upper Little Snake Basin by Patrick O'Toole on August 10, 1991. During this site visit, Mr.

O'Toole, Terry Reidy of the Focus Ranch, and Rick Barnes of the Three Forks Ranch were asked about hydrologic conditions in the upper part of the Little Snake River Basin in general and about impacts resulting from the Stage I and II project in particular.

Each person interviewed agreed that it was difficult to separate the relative impacts of the recent severe drought from the impacts of the Stage I and II diversion project. Mr. Reidy was especially careful to note that the sheepman he knew had told him that seeps and springs on the flanks of the Sierra Madre Range outside the influence of the Stage I and II project had dried up similarly to those in the project area as a result of the drought. He had noticed that many formerly reliable springs which issue from the Browns Park Formation dipslopes above his ranch were now dry. He assumed this was the result of the drought.

CONCLUSIONS

The drought between 1987 and 1990, which has only now been partially broken by the heavy 1991 summer precipitation, has severely reduced the water supply in the upper part of the Little Snake River drainage basin. The drought has diminished both surface runoff and spring discharges throughout the area.

There is minimal exploitable ground water storage in the Mesozoic and Paleozoic rocks under the Little Snake River because these rocks have small permeabilities. For the same reason, there is little basinward circulation of ground water through the Mesozoic and Paleozoic rocks to the region underlying Dixon.

Small late season stream flows have been an historical problem even before Stage I and II diversions, particularly in drought years.

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LIST OF ILLUSTRATIONS

8 Comparison between the long term average mean daily discharge (1943-1990) and the 1988 mean daily discharge by month for the Little Snake River near Slater, Colorado. Data: U. S. Geological Survey station 09253000.

9 Comparison between the long term average mean daily discharge (1943-1990) and the 1989 mean daily discharge by month for the Little Snake River near Slater, Colorado. Data: U. S. Geological Survey station 09253000.

10 Comparison between the long term average mean daily discharge (1943-1990) and the 1990 mean daily discharge by month for the Little Snake River near Slater, Colorado. Data: U. S. Geological Survey station 09253000.

Table

1 1991 Stage I and II diversion amounts (cfs). The amounts shown are the flow measured after passing through the tunnel into the Hog Park drainage.

Geologic Age	Lithology	Thick-ness (ft)	Formation	Hydrologic Character
Quaternary		0-50	Alluvial deposits	local aquifer
Tertiary		0-1600	Browns Park Formation	local aquifer
		0-1700	Fort Union Formation	minor aquifer
Upper Cretaceous		0-1400	Lance Formation	leaky confining layer
		0-2500	Lewis Shale	confining layer
		0-2000	Mesaverde Group	minor aquifer
		3100 & 1200	Steele and Niobrara Shales	confining layer
		690	Frontier Formation	minor aquifer
Lower Cretaceous		130	Mowry Shale Thermopolis Shale	confining layer
		84	Cloverly Formation	minor aquifer
Jurassic		216	Morrison Formation	minor aquifer/ locally confining
		138	Sundance Formation	
		398	Nugget Sandstone	
Triassic		750	Chugwater Formation	leaky confining layer
Permian		<100	Dinwoody Formation	minor aquifer
		84	Phosphoria Formation	
Pennsylvanian		<100	Tensleep Formation	
		<100	Amsden Formation	confining layer
Mississippian		<100	Madison Limestone	minor aquifer
Precambrian			Precambrian Rocks	minor local aquifer

igneous and metamorphic — sandstone — shale — coal

limestone — siltstone — conglomerate

Figure 4. Geologic and hydrologic characteristics of the rocks in the Little Snake River Basin, Carbon County, Wyoming.

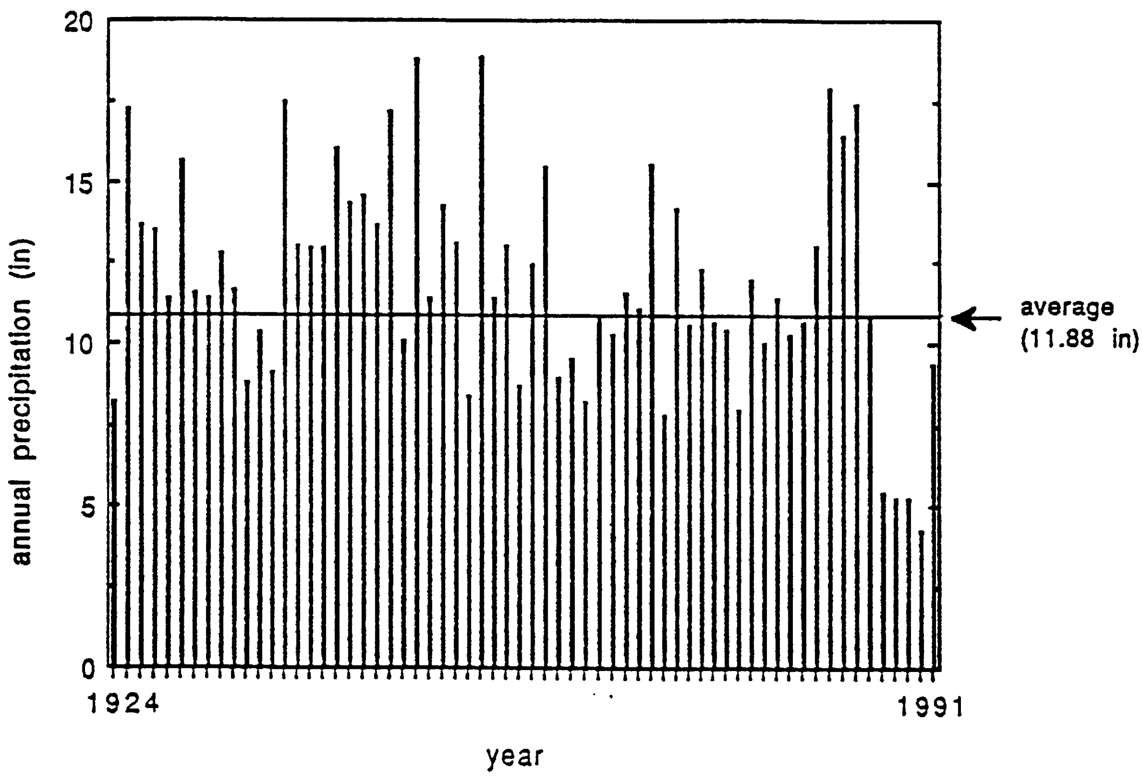

Figure 5. Annual precipitation in the vicinity of the Little Snake River Basin, Carbon County, Wyoming. Data: Dixon, U.S. Geological Survey station 482610 (1922-1978); Baggs, U. S. Geological Survey station 480484 (1979-1991).

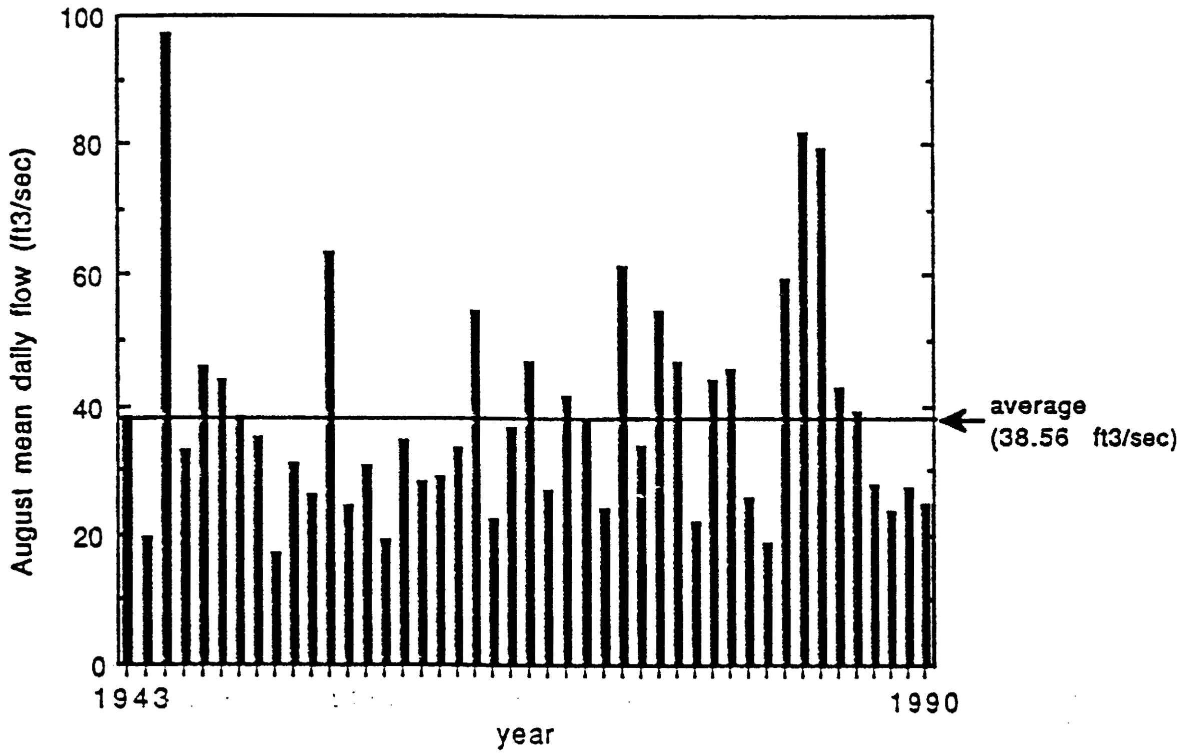

Figure 6. Mean daily discharge of the Little Snake River, 1943-1990, near Slater, Colorado. Data: U. S. Geological Survey station 09253000.

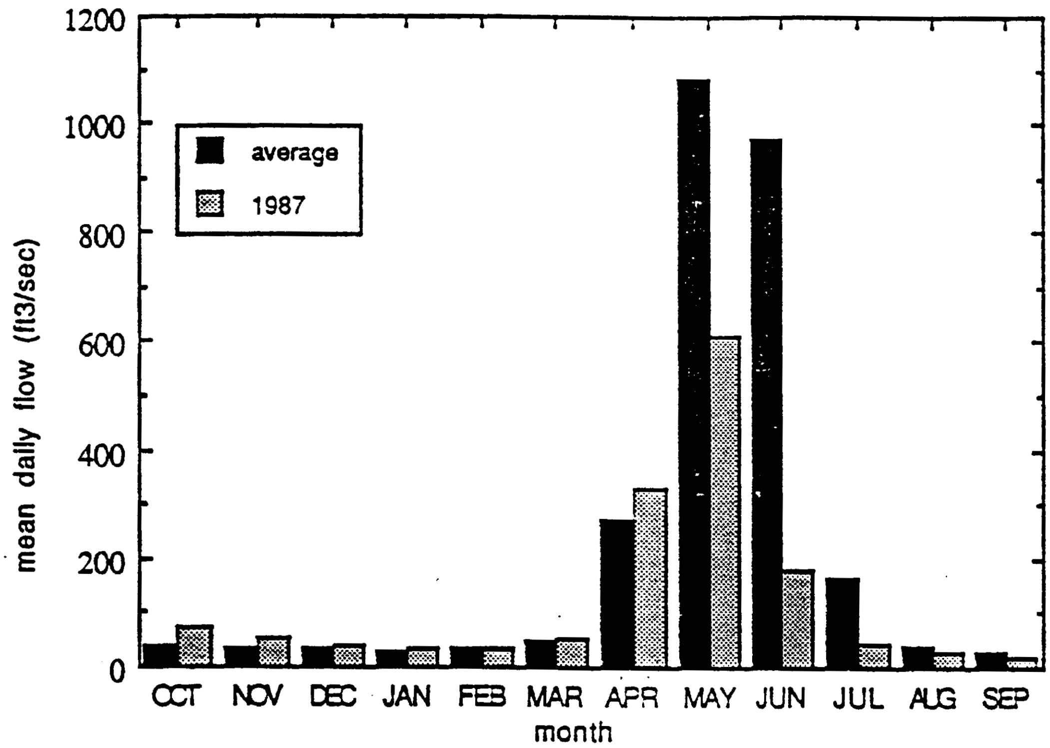

Figure 7. Comparison between the long term average mean daily discharge (1943-1990) and the 1987 mean daily discharge by month for the Little Snake River, 1943-1990, near Slater, Colorado. Data: U. S. Geological Survey station 09253000.

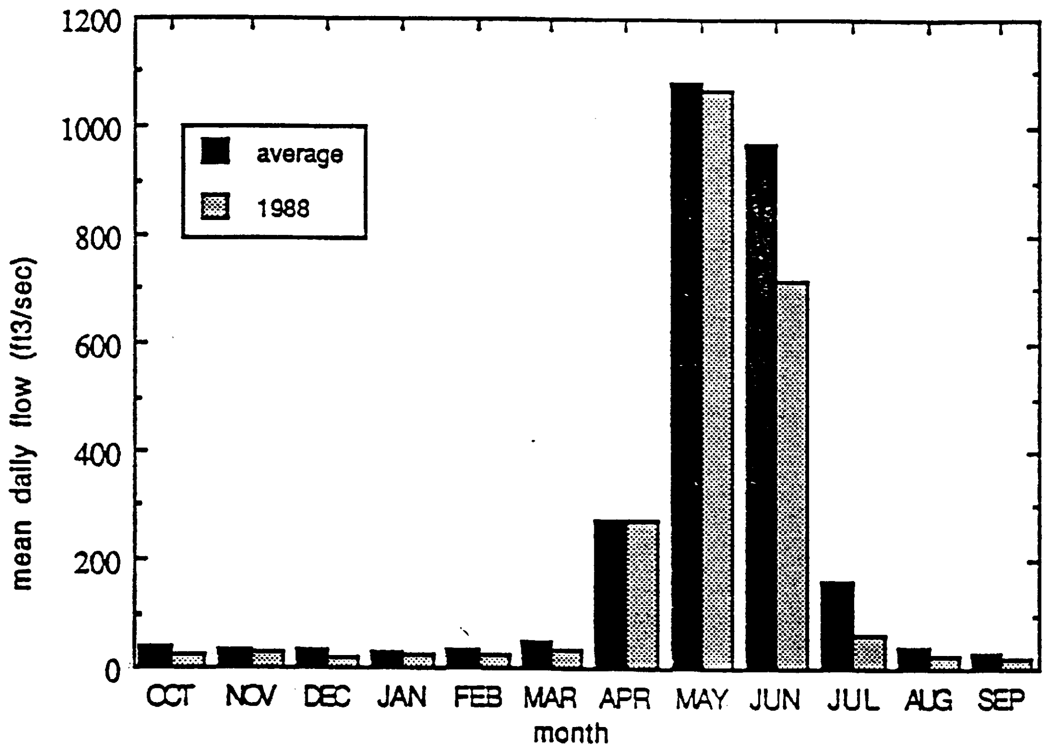

Figure 8. Comparison between the long term average mean daily discharge (1943-1990) and the 1988 mean daily discharge by month for the Little Snake River, 1943-1990, near Slater, Colorado. Data: U. S. Geological Survey station 09253000.

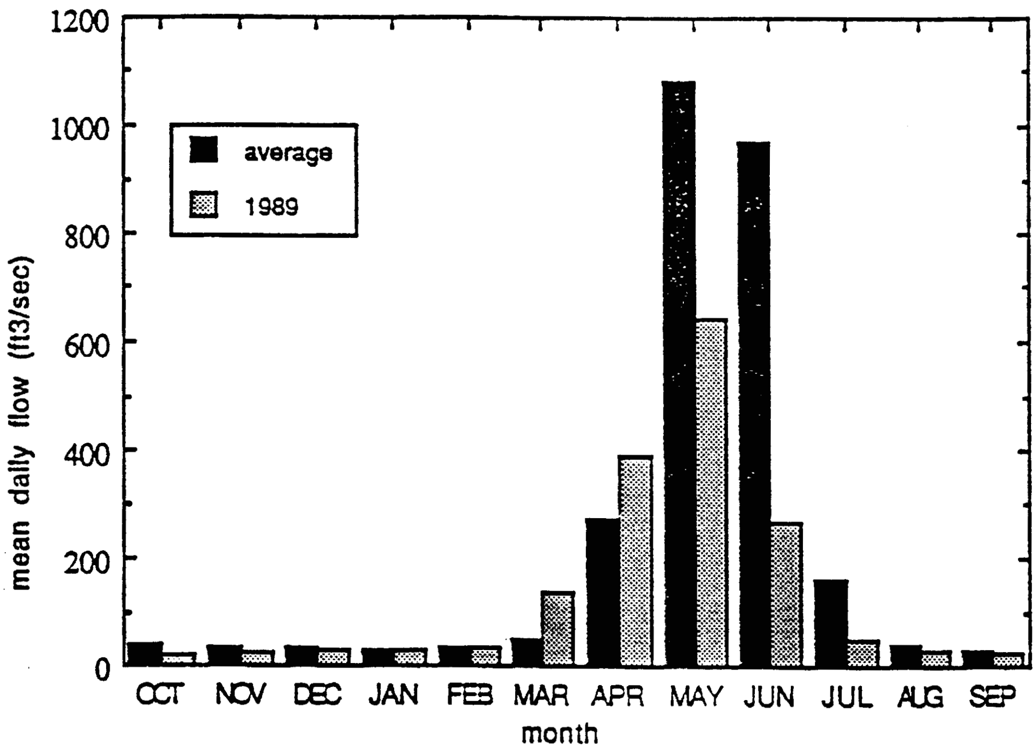

Figure 9. Comparison between the long term average mean daily discharge (1943-1990) and the 1989 mean daily discharge by month for the Little Snake River, 1943-1990, near Slater, Colorado. Data: U. S. Geological Survey station 09253000.

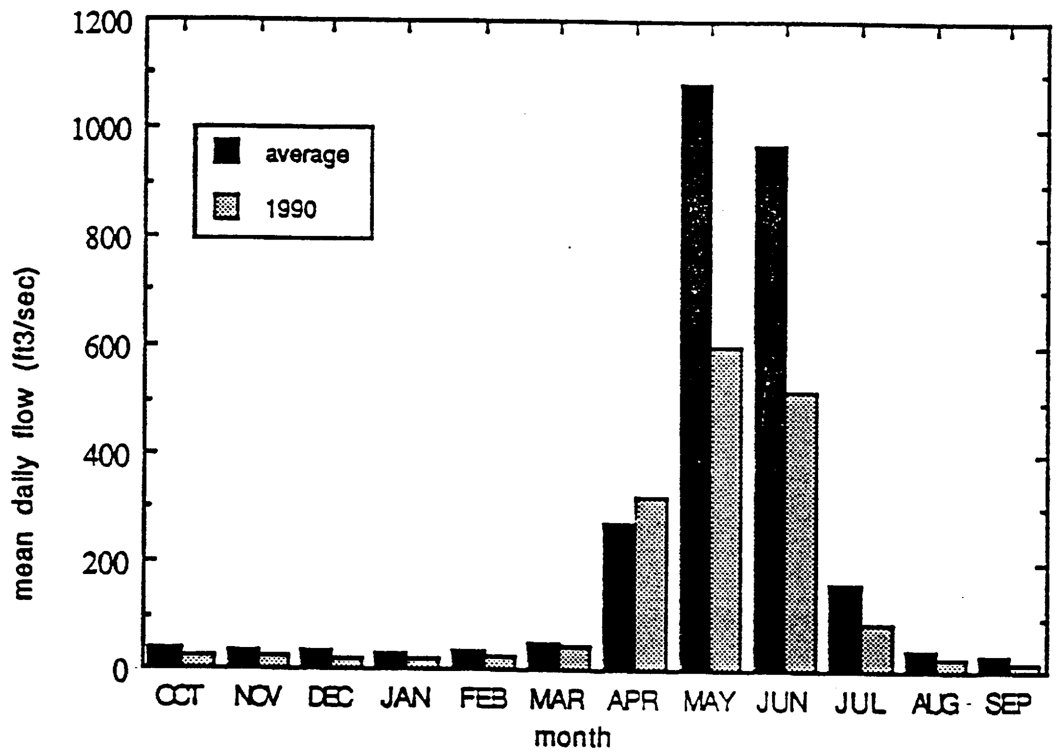

Figure 10. Comparison between the long term average mean daily discharge (1943-1990) and the 1990 mean daily discharge by month for the Little Snake River, 1943-1990, near Slater, Colorado. Data: U. S. Geological Survey station 09253000.

Table 1. 1991 Stage I and II Diversion Amounts (cfs)

Day	Apr	May	Jun	Jul	Aug	Sep	Oct
1	1	3	212	22	1	1	1
2	1	3	208	5	1	1	1
3	1	3	232	2	1	1	1
4	1	3	197	2	1	1	1
5	1	3	199	1	1	1	1
6	1	3	196	1	1	1	1
7	1	4	207	1	1	1	1
8	1	7	208	1	1	1	1
9	1	23	243	1	1	1	1
10	1	47	248	1	1	1	1
11	1	73	239	1	1	1	1
12	1	62	248	1	1	1	1
13	1	52	249	1	1	1	1
14	1	78	236	1	1	1	1
15	1	79	230	1	1	1	1
16	1	56	190	1	1	1	1
17	1	67	168	1	1	1	1
18	1	116	148	1	1	1	1
19	1	168	138	1	1	1	1
20	1	198	120	1	1	1	1
21	1	210	102	1	1	1	1
22	1	223	89	1	1	1	1
23	1	208	77	1	1	1	1
24	3	173	67	1	1	1	1
25	3	189	59	1	1	1	1
26	3	230	51	1	1	1	1
27	3	250	44	1	1	1	1
28	3	253	40	1	1	1	
29	3	239	36	1	1	1	
30	3	208	35	1	1	1	
31		175		1	1		

Values of 1 cfs are seepage in the tunnel diversion.