U.S. Department of the Interior
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In cooperation with the
Idaho Department of Water Resources

Methods to Determine Pumped Irrigation-Water Withdrawals from the Snake River Between Upper Salmon Falls and Swan Falls Dams, Idaho, Using Electrical Power Data, 1990–95

Water-Resources Investigations Report 99–4175

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By Molly A. Maupin

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FOREWORD

The U.S. Geological Survey (USGS) Water-Use Program is a cooperative program with other Federal, State, and local agencies that began in 1978. The program is designed to collect, store, analyze, and disseminate water-use information. In fiscal year 1995, the program funded nearly $4 million for water-use information activities in all 50 States and Puerto Rico. Goals of the program are to (1) analyze the source, use, and disposition of water resources at local, State, and national levels; (2) document trends in water use in the United States; (3) coordinate with State and local agencies on projects of special interest; (4) devise and apply new standards of data collection, aggregation, and synthesis; (5) develop water-use data bases; (6) reply to water-use information requests from the public; and (7) make local, State, and national water-use information available through publications and access to the World Wide Web.

In Idaho, the USGS has operated the Water-Use Program cooperatively with the Idaho Department of Water Resources (IDWR) and local ground water irrigation districts to gather, interpret, and disseminate water-use information statewide and in localized areas with special water-use interests. This report emphasizes one of the study areas where both the USGS and IDWR share an interest in determining pumped irrigation-water withdrawals from the Snake River.

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FIGURES

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATED UNITS

Multiply	By	To obtain
acre	4,047	square meter
acre-foot (acre-ft)	1,233	cubic meter
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
horsepower (hp)	0.746	kilowatt (kW)
inch (in.)	25.4	millimeter
kilowatthour (kWh)	3,600,000	joule
kilowatthour per acre-foot (kWh/acre-ft)	2,919	joule per cubic meter
mile (mi)	1.609	kilometer
watthour	3,600	joule

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929

The following terms and abbreviations are used in this report:

degrees (D)
energy (Wh, kWh), in watthours or kilowatthours
global positioning system (GPS)
minutes (M)
power-consumption coefficient (PCC)
power demand (kW), in kilowatts
pump sites with canal conveyance systems (Pc)
pump sites with closed-pipe conveyance systems (Pp)
rate of withdrawal (Q), in cubic feet per second
seconds (S)
total head (TH)
withdrawal (V), in acre-feet

Methods to Determine Pumped Irrigation-Water Withdrawals from the Snake River Between Upper Salmon Falls and Swan Falls Dams, Idaho, Using Electrical Power Data, 1990–95

By Molly A. Maupin

Abstract

Pumped withdrawals compose most of the irrigation-water diversions from the Snake River between Upper Salmon Falls and Swan Falls Dams in southwestern Idaho. Pumps at 32 sites along the reach lift water as high as 745 feet to irrigate croplands on plateaus north and south of the river. The number of pump sites at which withdrawals are being continuously measured has been steadily decreasing, from 32 in 1990 to 7 in 1998. A cost-effective and accurate means of estimating annual irrigation-water withdrawals at pump sites that are no longer continuously measured was needed. Therefore, the U.S. Geological Survey began a study in 1998, as part of its Water-Use Program, to determine power-consumption coefficients (PCCs) for each pump site so that withdrawals could be estimated by using electrical power-consumption and total head data.

PCC values for each pump site were determined by using withdrawal data that were measured by the U.S. Geological Survey during 1990–92 and 1994–95, energy data reported by Idaho Power Company during the same period, and total head data collected at each site during a field inventory in 1998. Individual average annual withdrawals for the 32 pump sites ranged from 1,120 to 44,480 acre-feet; average PCC values ranged from 103 to 1,248 kilowatthours per acre-foot. During the 1998 field season, power demand, total head, and withdrawal at 18 sites were measured to determine 1998 PCC values. Most of the 1998 PCC values were within 10 percent of the 5-year average, which demonstrates that withdrawals for a site that is no longer continuously measured can be calculated with reasonable accuracy by using the PCC value determined from this study and annual power-consumption data. K-factors, coefficients that describe the amount of energy necessary to lift water, were determined for each pump site by using values of PCC and total head and ranged from 1.11 to 1.89 kilowatthours per acre-foot per foot.

Statistical methods were used to define the relations among PCC values and selected pump-site characteristics. Multiple correlation analysis between average PCC values and total head, total horsepower, and total number of pumps revealed the strongest correlation was between average PCC and total head. Linear regression of these two variables resulted in a strong coefficient of determination R^2=0.986) and a representative K-factor of 1.463. Pump sites were subdivided into two groups on the basis of total head—0 to 300 feet and greater than 300 feet. Regression of average PCC values for eight pump sites with total head less than 300 feet produced a good correlation of determination (R^2=0.870) and a representative K-factor of 1.682. The second group consisted of 10 pump sites with total head greater than 300 feet; regression produced a correlation of R^2=0.939 and a representative K-factor of 1.405.

Data on pump-site characteristics were successfully used to determine individual PCC and K-

factor values. Statistical relations between pump-site characteristics and PCC values were defined and used to determine regression equations that resulted in good coefficients of determination and representative K-factors. The individual PCC values will be used in the future to calculate irrigation-water withdrawals at sites that are no longer continuously measured. The representative K-factors and regression equations will be used to calculate irrigation-water withdrawals at sites that have not been previously measured and where total head and power consumption are known.

INTRODUCTION

In 1998, as part of its Water-Use Program, the U.S. Geological Survey (USGS) began a cooperative study with the Idaho Department of Water Resources (IDWR). This study assesses the feasibility of using electrical power-consumption and total head data to determine withdrawals from the Snake River at sites between Upper Salmon Falls and Swan Falls Dams where water meters were not installed (fig. 1). The Snake River meanders approximately 140 mi in a westerly direction across the study area. In places, the river serves as the dividing line between Twin Falls and Owyhee Counties on the south, and Gooding, Elmore, and Ada Counties on the north. Between Salmon Falls Creek and Glenns Ferry, the river is deeply entrenched below adjacent plateaus. The uplands are mostly open rangeland covered in grass and sagebrush, except where land is irrigated to produce mostly potatoes, wheat, and hay crops. The semiarid climate provides marginal precipitation for growing crops; mean annual precipitation is 10 in. or less (Molnau, 1995). The average growing season lasts from 120 to 160 days.

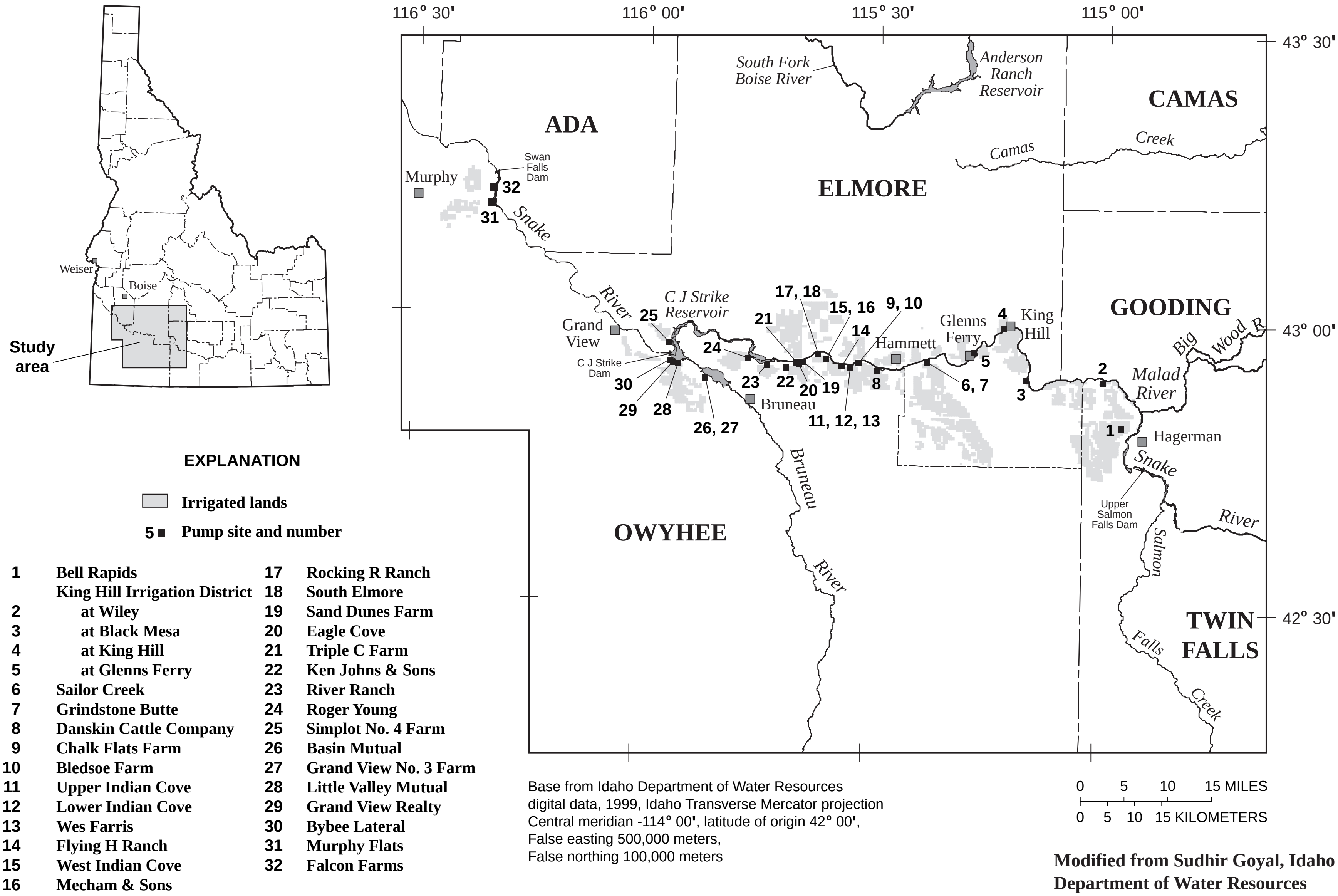
Irrigation water is withdrawn from the Snake River between Upper Salmon Falls and Swan Falls Dams through pumps, some that lift water as high as 745 ft. During the late 1920's and early 1930's, the first pump sites were introduced in the reach; the first three principal sites withdrew water to irrigate about 9,100 acres (Hoyt, 1935, p. 132). In 1980, withdrawals from pumps at 39 sites between Salmon Falls Creek and Swan Falls Dam totaled about 360,000 acre-ft (Kjelstrom, 1991, p. 750). Twenty-eight of the 39 pump sites withdrew water to irrigate 89,750 acres in 1980 (Bob Sutter, Idaho Department of Water Resources, written commun., 1998).

Rationale for Determining Power-Consumption Coefficient Values for Pump Sites

In 1988, flowmeters were installed on 20 pipelines along the Snake River between Upper Salmon Falls and C.J. Strike Dams. Data from the flowmeters were used to define relations among withdrawals, total power consumption, and total head. Kjelstrom (1991) determined a coefficient, called a K-factor, that describes the amount of energy necessary to lift 1 acre-ft of water 1 ft; this K-factor is expressed in units of kilowatthours per acre-foot per foot (see also Goodell, 1988). Kjelstrom used broad estimates of total head for wells and pump sites to determine a K-factor of 1.69. A representative K-factor, such as 1.69, is adequate for general estimates of withdrawals or for sites with similar total head, but for a population of sites with large variances in total head, and especially sites with relatively low total head, individually determined K-factors are best.

K-factors were determined for each site individually by first calculating a power-consumption coefficient (PCC) value. PCC values represent the amount of energy required to lift 1 acre-ft of water, expressed in units of kilowatthours per acre-foot. A PCC value enables estimation of total annual withdrawal for a site when only total annual power consumption is known. Therefore, the advantage of using PCC values rather than K-factors for withdrawal estimations at sites that had been measured historically is that measurements of total head would not be necessary.

The number of pump sites in the study area at which withdrawals are being continuously measured has been steadily decreasing, from 32 in 1990 to 7 in 1998 (table 1). However, future withdrawals can be estimated by using individual PCC values, determined from this study, together with annual power-consumption data. The PCC values are tailored to each site and provide cost savings to monitoring programs because fewer visits and less equipment are needed. In addition, regressions between PCC values and pump-site characteristics demonstrate that future withdrawals can be estimated at sites where only total head and power consumption are known.



1	**Bell Rapids**
	King Hill Irrigation District
2	**at Wiley**
3	**at Black Mesa**
4	**at King Hill**
5	**at Glenns Ferry**
6	**Sailor Creek**
7	**Grindstone Butte**
8	**Danskin Cattle Company**
9	**Chalk Flats Farm**
10	**Bledsoe Farm**
11	**Upper Indian Cove**
12	**Lower Indian Cove**
13	**Wes Farris**
14	**Flying H Ranch**
15	**West Indian Cove**
16	**Mecham & Sons**
17	**Rocking R Ranch**
18	**South Elmore**
19	**Sand Dunes Farm**
20	**Eagle Cove**
21	**Triple C Farm**
22	**Ken Johns & Sons**
23	**River Ranch**
24	**Roger Young**
25	**Simplot No. 4 Farm**
26	**Basin Mutual**
27	**Grand View No. 3 Farm**
28	**Little Valley Mutual**
29	**Grand View Realty**
30	**Bybee Lateral**
31	**Murphy Flats**
32	**Falcon Farms**

Figure 1. Locations of pump sites between Upper Samon Falls and Swan Falls Dams, Idaho.

Table 1. Period of record for U.S. Geological Survey withdrawal measurements at all pump sites between Upper Salmon Falls and Swan Falls Dams, Idaho

[Site locations shown in figure 1; USGS, U.S. Geological Survey; No., number]

Pump site No.	USGS gaging station No.	Pump site name	Period of record, 1985–98													
			85	86	87	88	89	90	91	92	93	94	95	96	97	98
1	1313457010	Bell Rapids														
2	1315377299	King Hill Irrigation District at Wiley														
3	13153778	King Hill Irrigation District at Black Mesa														
4	13154510	King Hill Irrigation District at King Hill														
5	13155074	King Hill Irrigation District at Glenns Ferry														
6	13155750	Sailor Creek														
7	13155800	Grindstone Butte														
8	13157015	Danskin Cattle Company														
9	13157105	Chalk Flats Farm														
10	13157110	Bledsoe Farms														
11	13157120	Upper Indian Cove														
12	13157125	Lower Indian Cove														
13	13157130	Wes Farris														
14	13157160	Flying H Ranch														
15	13157291	West Indian Cove														
16	13157293	Mecham & Sons														
17	13157296	Rocking R Ranch														
18	13157300	South Elmore														
19	13157305	Sand Dunes Farm														
20	13157310	Eagle Cove														
21	13157315	Triple C Farm														
22	13157325	Ken Johns & Sons														
23	13157340	River Ranch														
24	13157370	Roger Young														
25	13161070	Simplot No. 4 Farm														
26	13170300	Basin Mutual														
27	13170350	Grand View No. 3 Farm														
28	13170700	Little Valley Mutual														
29	13170800	Grand View Realty														
30	13170400	Bybee Lateral														
31	13172410	Murphy Flats														
32	13172420	Falcon Farms														
Total number of sites measured during each year			5	10	12	27	31	32	29	29	29	26	24	20	15	7

Purpose and Scope

The purpose of this report is to summarize methods used to establish relations between irrigation withdrawals and power consumption for pump sites along the north and south sides of the Snake River between Upper Salmon Falls and Swan Falls Dams (fig. 1). The study consisted of four primary tasks: (1) Obtain and synthesize a complete inventory of pump-site data; (2) derive average PCCs that relate energy to withdrawals for all sites by using recent (1990–92 and 1994–95) power data; (3) derive K-factors that relate energy to withdrawals and total head by using PCC values and measurements of total head; and (4) determine whether statistical relations exist among PCCs and pump-site characteristics and, if so, derive equations that explain those relations. Also included in this report are new data, collected during the 1998 irrigation season (April to October), on pump-site characteristics and withdrawals. Gravity irrigation diversions at C.J. Strike Dam were not included in this study.

Acknowledgments

The following individuals assisted by providing, collecting, or processing data for this study: Frank Youngkin (USGS) endured one of the hottest summers on record to complete measurements and gather information at all sites in the study area. Sudhir Goyal (Idaho Department of Water Resources), K.C. Duerig (King Hill Irrigation District), Leroy Breshears (South Board of Control), Kent Frish (Bybee Lateral Water Users Association), and Irene Collins (Bureau of Reclamation) provided information and technical support. Quentin Nesbitt and Debra Lehan (Idaho Power Company) answered requests for information and provided invaluable field assistance. Numerous pump owners and operators were very helpful in providing access to and information on their pump sites.

ASSESSMENT OF DATA

Data for the study, collected at 32 pump sites, include annual power consumption, in kilowatthours, and withdrawals, in acre-feet, during a 5-year period (1990–92 and 1994–95). Data for 1993 were excluded because they were incomplete. Pump-site data collected from field inventories during the 1998 irrigation season include measurements of power demand, in kilowatts; withdrawals, in acre-feet; and total head, in feet. The following sections of the report describe aspects of source of data, method of measurement, and accuracy of data used to determine average PCC values for each pump site.

Idaho Power Company Data

Idaho Power Company (IPC) data for each pump site were identified, verified, and associated with USGS field-inventory data by using a variety of comparisons, most important of which were powerpole and meter numbers and the number and size of pumps at each site. During the 5-year period, changes occurred that affected the ability to correctly match IPC and field-inventory data for each site. For example, meter numbers and number of pumps changed, and some accounts were closed and reopened in different names. Consequently, matches between powerpole numbers from USGS field inventories and IPC records were the most reliable method to verify pump sites. IPC reports energy data in monthly and annual kilowatthours. Monthly data were assumed to represent energy usage for only that month; annual data represented energy usage during October of one year through September in the next year.

U.S. Geological Survey Data

Between 1985 and 1998, the USGS measured withdrawals at each of the 32 pump sites. The shortest continuous period of measurement was 4 years; the average continuous period of measurement was 8 years (table 1). Withdrawals at only 2 sites were measured continuously over the entire 14-year period. Most of the data used in this study were from 24 sites that were measured continuously over a 5-year period between 1990 and 1995 (Harenberg and others, 1991, 1992, 1993; Brennan and others, 1995, 1996). Measurements were collected monthly during the irrigation season, which extends from mid-March to mid-October. Withdrawal measurements, in acre-feet, were collected either with inline flowmeters that were attached to the pipeline or with hand-held meters in canals after water was discharged from the pipe. Either way, measurements were obtained before water was discharged from the pipeline or diverted to crops from the canals. The technology and equipment for inline flowmeters were

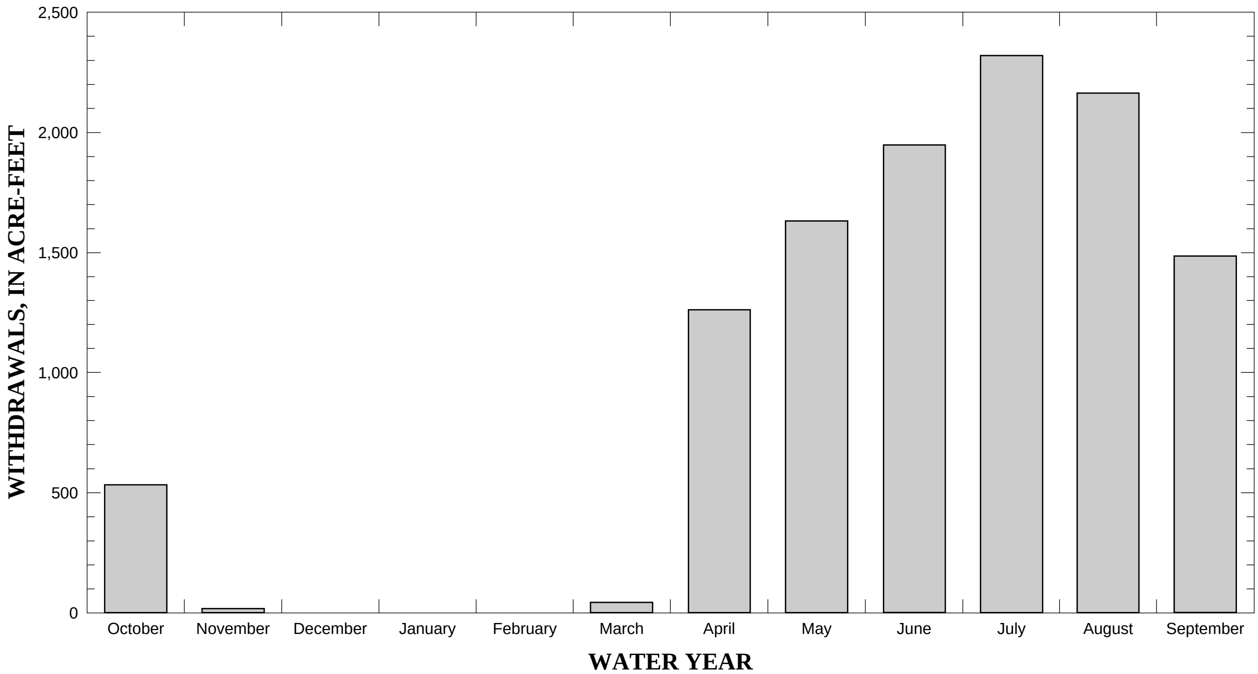


Figure 2. Mean monthly irrigation withdrawals, 1990–92 and 1994–95, from the Snake River at pump sites between Upper Salmon Falls and Swan Falls Dams, Idaho.

designed as part of a study on the pumps in 1987 and are summarized in a report by Kjelstrom (1991). Total annual withdrawals for all sites ranged from 202,790 in 1995 to 288,760 in 1990.

Irrigation and Water User Company Data

Some pump sites are operated by irrigation or water user companies, who provided information on energy, withdrawals, total head, and the number and size of pumps in operation for the period of this study. Energy data from these companies were compared with IPC data; all were exact. Information about the number of acres irrigated with water withdrawn at each pump site was obtained when possible.

DATA COLLECTION

Irrigation Season

During late November to early March, irrigation pumps are not in use. Between late March and early April, depending on the weather, pumps usually are turned on for the first time in the irrigation season, and withdrawals are relatively small. During May through September, most of the withdrawals occur; from June through August, the pumps are usually running at or near full capacity. From mid-October to mid-November, almost all the pumps are in the process of shutting down or have already been shut down, and withdrawals are again small (fig. 2).

Field Inventory

The first of two field inventories was conducted during the latter part of the 1997 irrigation season. Meter and powerpole numbers, meter information, measurement location descriptions, and sprinkler system and owner information were inventoried for all sites, some of which had not been visited for several years. Often, meters and pumps were located near the river, not adjacent to or within sight of the location where withdrawal measurements were made. For sites where pumps and meters were locked in enclosures, arrangements were made to gain access during the 1998 field visits. A copy of the field questionnaire that was used to determine characteristics of pump sites is shown in appendix A. The questionnaire also was used to help plan site visits during the 1998 irrigation season. Site information from the questionnaire and IPC data were examined in the months prior to the 1998 irrigation season to correlate sites with power records. Power records and withdrawal data from annual USGS water-data reports (Harenberg and others, 1991, 1992, 1993; Brennan and others, 1995, 1996) were compiled for each site.

The second round of visits was conducted during the peak of the 1998 irrigation season; a new form (High-Lift Pump Field-Inventory Sheet-Snake River, July 1998, appendix A) was devised and used to record field measurements and conditions. Arrangements were made with pump operators and owners to coordinate visits and ensure that pumps would not be adjusted during the measurements. Field checks on powerpole and meter numbers revealed that new meters had been installed at many sites during the winter of 1997; therefore, new meter numbers were recorded and confirmed with IPC data. Withdrawal, power demand during the withdrawal measurement, total head, and pertinent meter information were recorded during this round of visits.

Pumps lift water from the Snake River and convey it through pipes for some distance before releasing it into an open canal, stock pen, or holding basin (Pc), or continuing to convey the water through a closed-pipe network (Pp). If a Pp system is used, water is maintained under pressure in the pipes and sprinkled directly onto the fields. Information about Pc and Pp systems was recorded and sites were categorized into one of the two types. There are 18 Pc-type sites and 14 Pp-type sites in the study area. Measurements at Pc-type systems were made using standard flowmeters, typically just downstream from the location where water was released from the pipe into the canal, but upstream from any diversion to or confluence with another source. Canal measurements were made using USGS surface-water measuring techniques. Sometimes measurement locations in the canals were not near the river or within sight of the pumps. In these cases, withdrawal measurements were made first and power-demand measurements, meter information, and total head were recorded when the field technician went to the pump site. As stated before, precautions were taken to ensure that no adjustments were made to pumps during withdrawal and power-demand measurements.

Measurements on Pp-type systems were made using ultrasonic flowmeters to check instantaneous discharge measurements recorded with inline flowmeters, if they were installed. The inline flowmeters remain in the pipe throughout the irrigation season and relay data electronically to a datalogger that stores, and later downloads, the data to a laptop computer during field visits. Ultrasonic flowmeters are used to check, and correct if necessary, the inline flowmeter data during monthly visits. If no inline flowmeter was present, a one-time ultrasonic meter reading was made.

Pump-site characteristic data included number and horsepower of each pump. These data enabled correlations to be made among total horsepower, total power demand, and withdrawals. Measurements of total head were determined from pressure gages that were already installed on pipes near the pumps. A measure of pressure in the pipe, in pounds per square inch, was converted to feet of water using the conversion factor 2.311. If a pressure gage was not available and the operator of the pump site did not provide a pressure reading, no K-factor was calculated.

Locations from a Global Positioning System (GPS) receiver were used to create a data layer within a geographic information system (GIS) so that IDWR could map and catalog pump sites. GPS readings, consisting of latitude and longitude coordinates in degrees, minutes, and seconds (DMS), usually were taken next to the powerpole that held the meter for the pumps. The military-grade GPS receivers used in this study are capable of collecting locational data with accuracies of ±15 m (50 ft). Locations of powerpoles were used because (1) they were in close proximity to the pumps and river, (2) the poles offered a perfect location to apply the IDWR GPS metal identification tag, and (3) it was not safe for the field technician to climb down to the exact location where water was withdrawn from the river. One GPS coordinate location for each pump site was sufficient because individual coordinates for each pump on a platform were not necessary. Furthermore, the hand-held GPS unit that was used did not have sufficient accuracy to warrant individual pump location readings. A few very large pump sites, owned by different individuals, were located close together along the river. These sites were located with one GPS coordinate reading. The GPS coordinates were taken near the midpoint between pump sites; therefore, for a few sites, identical latitude and longitude values are given for both sites (table 2).

All field data, historical withdrawal measurements, and photographs are organized using the GIS software package ArcView, which integrates the geographic coordinates and tabular data-base information, as well as scanned images of pump sites. Site information can be retrieved in table format by using interactive links with pictures and data-base spreadsheets.

METHODS TO DETERMINE POWER-CONSUMPTION COEFFICIENTS AND IRRIGATION-WATER WITHDRAWALS

Equation 1 describes how power demand (P) was determined for sites visited in 1998. P subsequently was used in equation 2 to determine the 1998 PCC values that later were compared with average PCC values for the same sites. Average PCC values were calculated from annual PCC values, which were determined from equation 3 by using total annual withdrawal and power-consumption data for 1990–92 and 1994–95. Withdrawals for a site can be calculated with equation 4 by using total annual power-consumption and PCC values. In this report, withdrawals were not calculated because measured withdrawals already were available; equation 4 is provided for reference only. Equation 5 explains how a K-factor for each site was determined by using PCC values and total head. After discussions about the equations, pump-site characteristic data are summarized with explanation of the K-factor variable. Finally, statistical comparisons are provided of pump-site characteristics and the feasibility of calculating future withdrawals using PCC or K-factor values from sites grouped by characteristics.

Equations

The rate of energy used by a pump site, called the power demand, and the associated withdrawal measurement were used to calculate 1998 PCC values. The variables used to determine power demand were measured according to methods described by Hurr and Litke (1989, p. 10). Power demand is calculated as:

$$P = rate \times Kh \times 3.6, \qquad (1)$$

where

P = power demand of running pumps, in kilowatts;
$rate$ = average time of disk revolutions or blinking light, in revolutions per second;
Kh = electric meter disk constant, in watthours per revolution; and
3.6 = factor to convert kilowatt seconds to watthours.

The rate variable in equation 1 was the observed rate at which the power meter was recording power demand. Rate was measured by timing the intervals of a blinking light or rotating disk in the power meter. The average of three readings was used in equation 1. The Kh variable represents the watthour per revolution of the meter disk, which was listed on the faceplate of the meter.

A PCC represents the amount of energy required to lift 1 acre-ft of water; concurrent power demand and withdrawal measurements collected during the 1998 field inventory were used to determine a 1998 PCC by using the following equation:

$$1998\ PCC = P / Q \times 12.1, \qquad (2)$$

where

P = power demand of running pumps, in kilowatts;
Q = rate of withdrawal, in cubic feet per second; and
12.1 = factor to convert kilowatts per cubic foot per second to kilowatt-hours per acre-foot.

Annual PCC values were determined using equation 3 for all sites that had related annual power-consumption and withdrawal data:

$$PCC = E / V, \qquad (3)$$

where

E = energy consumption, in kilowatt-hours; and
V = volume of withdrawal, in acre-feet.

The 1998 and average PCC values in table 3 show that most of the 1998 values were within 10 percent of the average. Only a few sites were running

Table 2. Pump-site characteristics and field-inventory data for pump sites between Upper Salmon Falls and Swan Falls Dams, Idaho

[Site locations shown in figure 1; USGS, U.S. Geological Survey; No., number; DMS, degrees, minutes, seconds; Pc, canal; Pp, closed-pipe; ft, feet; nd, no data]

Pump site No. (fig. 1)	Pump site name	USGS gaging station No.	County name	Location coordinates in latitude/longitude (DMS/DMS)	Type of convey-ance system (Pc, Pp)	Total head (ft)	All pumps at a site: Total horse-power	All pumps at a site: Total No. of operable pumps	All running pumps, 1998: Total horse-power	All running pumps, 1998: Total No. of pumps	Average annual withdrawal (1990–95), in acre-ft
1	Bell Rapids	1313457010	Twin Falls	42°49'14"/114°55'55"	Pc	625	20,100	14	13,500	9	44,480
	King Hill Irrigation District										
2	at Wiley	1315377299	Twin Falls	42°54'50"/114°59'05"	Pc	200	1,100	6	600	3	7,380
3	at Black Mesa	13153778	Elmore	42°54'57"/115°09'44"	Pc	266	5,500	7	3,000	4	25,480
4	at King Hill	13154510	Elmore	43°00'04"/115°12'32"	Pp	180	700	4	600	3	5,125
5	at Glenns Ferry	13155074	Elmore	42°57'36"/115°16'48"	Pc	174	3,100	7	2,400	6	25,100
6	Sailor Creek	13155750	Elmore	42°56'40"/115°22'53"	Pp	901	7,950	6	3,750	3	11,720
7	Grindstone Butte	13155800	Elmore	42°56'40"/115°22'53"	Pc	682	24,000	16	7,500	5	28,840
8	Danskin Cattle Company	13157015	Owyhee	42°55'34"/115°30'02"	Pp	610	1,400	4	800	2	2,695
9	Chalk Flats Farm	13157105	Elmore	42°56'35"/115°32'26"	Pp	663	2,000	4	1,400	3	2,495
10	Bledsoe Farm	13157110	Elmore	42°56'35"/115°32'26"	Pc	nd	1,000	4	600	2	1,185
11	Upper Indian Cove[1]	13157120	Owyhee	42°56'05"/115°33'31"	Pc	60	350	2	350	2	([1])
12	Lower Indian Cove[1]	13157125	Owyhee	42°56'05"/115°33'31"	Pc	([2])	([2])	([2])	([2])	([2])	([1])
13	Wes Farris	13157130	Owyhee	42°56'04"/115°33'31"	Pp	356	450	2	250	1	1,580
14	Flying H Ranch	13157160	Elmore	42°56'18"/115°34'42"	Pp	693	2,150	4	1,550	3	3,785
15	West Indian Cove[1]	13157291	Owyhee	42°56'48"/115°36'50"	Pc	100	280	4	190	3	([1])
16	Mecham & Sons	13157293	Owyhee	42°56'49"/115°36'51"	Pc	693	1,050	3	800	2	1,690
17	Rocking R Ranch	13157196	Elmore	42°57'26"/115°37'49"	Pc	511	4,800	7	3,400	5	10,710
18	South Elmore	13157300	Elmore	42°57'26"/115°37'49"	Pc	495	10,300	6	10,300	6	15,775
19	Sand Dunes Farm	13157305	Owyhee	42°56'35"/115°40'00"	Pp	425	1,000	3	600	2	1,460
20	Eagle Cove[3]	13157310	Owyhee	42°56'24"/115°40'38"	Pp	nd	1,400	4	800	2	3,100
21	Triple C Farm[4]	13157315	Elmore	42°56'36"/115°40'47"	Pp	369	1,600	4	1,000	3	3,535
22	Ken Johns & Sons[4]	13157325	Owyhee	42°55'54"/115°42'12"	Pp	231	425	3	300	2	1,515
23	River Ranch	13157340	Owyhee	42°56'01"/115°45'00"	Pp	242	600	3	600	3	2,640
24	Roger Young	13157370	Owyhee	42°56'45"/115°47'40"	Pp	502	3,000	5	2,400	5	6,065
25	Simplot No. 4 Farm	13161070	Elmore	42°58'11"/115°58'26"	Pc	273	1,200	3	1,200	3	7,350
26	Basin Mutual	13170300	Owyhee	42°54'45"/115°53'32"	Pc	370	882	4	200	1	1,120
27	Grand View No. 3 Farm	13170350	Owyhee	42°54'46"/115°53'33"	Pp	nd	450	2	400	2	2,980
28	Little Valley Mutual	13170700	Owyhee	42°56'04"/115°56'50"	Pc	224	3,000	5	1,800	3	12,835
29	Grand View Realty	13170800	Owyhee	42°56'10"/115°57'29"	Pp	229	650	3	650	3	7,170
30	Bybee Lateral	13170400	Owyhee	42°56'22"/115°58'12"	Pc	74	1,025	10	826	7	18,475
31	Murphy Flats	13172410	Owyhee	43°11'46"/116°23'15"	Pc	600	4,200	6	700	1	9,575
32	Falcon Farms	13172420	Owyhee	43°13'17"/116°23'03"	Pc	745	2,160	3	1,400	2	0

[1] USGS measurement only in 1990.

[2] Included in Upper Indian Cove.

[3] Measurements discontinued from 1994 to 1995.

[4] Data exclude 1991.

above average, and field notes indicated that most of these sites were operating with few pumps turned on. Because few pumps were running, more energy was consumed to withdraw the same amount of water than if more pumps had been running. Therefore, the 1998 PCC values were higher than the 5-year average PCC value. Conversely, 1998 PCC values for some sites were less than the 5-year average value because all or nearly all the pumps at the sites were running, and less energy was consumed to withdraw water.

Withdrawals for a pump site can be calculated using annual power-consumption data and the PCC value in equation 4:

$$V = E / PCC, \quad (4)$$

where

V = volume of water pumped, in acre-feet; and

E = power consumption, in kilowatt-hours.

A K-factor reflects the amount of energy that is necessary for a particular pump site to lift 1 acre-ft of water 1 ft. Equation 5 shows how K-factors are determined for each site by using the average PCC value and total head that was measured during the 1998 field visit:

$$K = PCC / TH, \quad (5)$$

where

K = K-factor, in kilowatthours per acre-foot per foot; and

TH = pressure that a pump must exert, in feet, to lift and possibly pressurize water.

Strong correlations among withdrawals, power consumption, and total head were reported by Kjelstrom (1991, p. 754); the coefficient of determination (R^2) exceeded 0.99. For this study, power-consumption data (1990–92, 1994–95) were regressed with withdrawals for all pump sites, and an equally strong relation was determined (R^2=0.99). Kjelstrom explained that a K-factor determined from site data might be used to estimate withdrawals at unmeasured pump sites, but withdrawals are sensitive to total head, especially when total head is small (1991, p. 754–755). He concluded that improved estimates could be determined if a K-factor were determined for each pump site. Because estimating withdrawals at sites that are no longer measured was a primary objective of this study, individual K-factors were determined using equation 5 (table 3). Further discussions of relations among withdrawals, power consumption, and total head are presented in the "Statistical Comparisons" section.

Table 3. Power-consumption coefficients for pump sites between Upper Salmon Falls and Swan Falls Dams, Idaho

[Values in order of descending amount; PCC, power-consumption coefficient; kWh, kilowatthours; acre-ft, acre-foot; ft, foot; nd, no data]

Average PCC (1990–92, 1994–95), in kWh per acre-ft	1998 PCC, in kWh per acre-ft	Average K-factor (1990–92, 1994–95), in kWh per acre-ft/ft	Approximate efficiency (1.02/average-K) x 100, in percent
1,248	1,012	nd	nd
1,049	773	1.54	66
1,025	989	1.48	68
1,015	920	1.47	69
997	nd	1.11	91
995	nd	1.50	68
931	804	1.89	53
922	1,129	1.54	66
857	nd	1.37	74
793	740	1.55	65
752	761	1.23	82
709	657	1.67	61
692	689	1.38	73
687	623	1.86	54
530	492	1.49	68
468	nd	1.72	59
394	nd	1.47	69
391	380	1.60	63
376	338	1.68	60
375	nd	nd	nd
333	nd	1.44	70
308	nd	1.54	66
295	nd	1.29	79
287	245	1.65	61
267	287	1.51	67
229	294	1.32	77
103	105	1.40	72

Pump-Site Characteristics

Each site was inventoried and total head, horsepower (from faceplates on pumps), and number of pumps were recorded. Median total head for 28 sites was about 370 ft, median total horsepower for 31 sites was 1,400, and median average K-factor for 25 sites was 1.49 kWh/acre-ft/ft. Goodell (1988) and Kjelstrom (1991) reported a representative K-factor of 1.69 by using linear regression of data for 72 wells and 7 pump

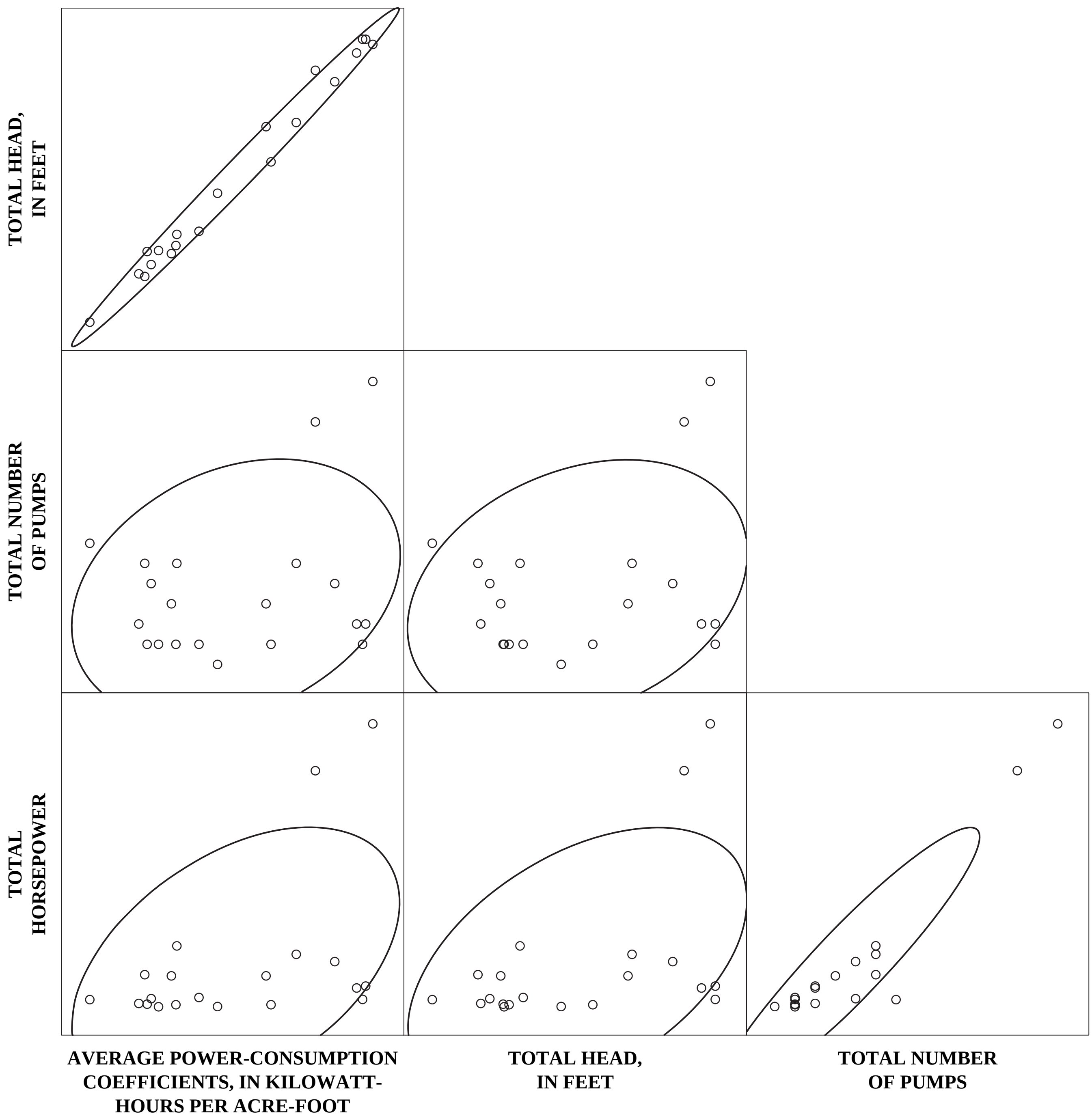


Figure 3. Correlations among average power-consumption coefficients and total head, total number of pumps, and total horsepower at pump sites between Upper Salmon Falls and Swan Falls Dams, Idaho.
(Ellipses show 75-percent confidence)

Table 4. Mean values for selected pump-site characteristics at two types of pump sites between Upper Salmon Falls and Swan Falls Dams, Idaho

Characteristic	Canal (Pc)	Pipe (Pp)
Number of pump sites in group	18	14
Mean values for:		
Total head, in feet	351	410
Total horsepower	4,787	1,698
Total number of pumps	6	3
K-factor, in kilowatthours per acre-foot per foot	1.61	1.64
Power consumption, in millions of kilowatthours	7.93	2.54
Total annual withdrawal, in thousands of acre-feet	22.77	3.95

sites in the early 1980's. The median value for average PCCs at 28 sites was about 630 kWh/acre-ft/ft.

Pump sites were divided into two groups—those that pumped into canals (Pc) and those that pumped into closed systems (Pp) (table 2). Pump sites that deliver water through closed systems (Pp) have significantly higher total head than sites that deliver water to canals (Pc) because of the added pressurization needed to operate the sprinkler system. Sailor Creek and Grindstone Butte are neighboring pump sites. Sailor Creek, a Pp site, has a total head almost 220 ft more than that at Grindstone Butte, a Pc site. Similarly, comparisons between the Upper and Lower Indian Cove and neighboring Wes Farris pump sites illustrate large differences in total head. Mean values for selected pump characteristics at the two types of sites are summarized in table 4.

Although mean total head values for Pp-type sites are higher, mean total horsepower and power-consumption values are low because these sites, on average, have fewer pumps than Pc-type sites. Because Pc-type sites are prevalent in the study area and have more pumps (resulting in higher horsepower per site) than Pp-type sites, Pc-type sites deliver much more water.

Statistical Comparisons

Relations among average PCC values and pump-site characteristics were examined using multiple-correlation analysis (fig. 3). Average PCC and total head are strongly correlated, as reflected by the linearity of points in the matrix. The correlation between average PCC and total number of pumps is not well defined, as reflected by the randomly scattered points. Average PCC and total horsepower are also poorly correlated, but the scatter is slightly more elongate than that for average PCC and total number of pumps. Total horsepower and total number of pumps are strongly correlated, which would be expected because more pumps at a site mean more horsepower. From the correlations between average PCC and total head, and between average PCC and total horsepower, regression models were developed to describe the strengths of the relations in the expression of an equation. From those models, future withdrawals could be determined at sites where only total head, total horsepower, and power consumption are known.

Regression of average PCC values and total head for 20 sites (fig. 4) produced a strong coefficient of determination (R^2=0.986). The equation of the regression line is PCC=1.463 (TH) + 16.66 (where PCC is in kilowatthours per acre-foot and TH is in feet). The slope of the regression line, 1.463 in this case, is referred to by Goodell (1988) as the representative K-factor. Goodell (1988) concluded that such correlations and resulting K-factors could be used for estimates of withdrawal in the future at sites where total head and power consumption are known. However, Kjelstrom's (1991) conclusions about weakening correlation with low total head values also apply to this correlation. Also, because the y-intercepts of the regression lines in the correlation analyses (figs. 4–6) are not at the origin, use of the line equations with known total head and

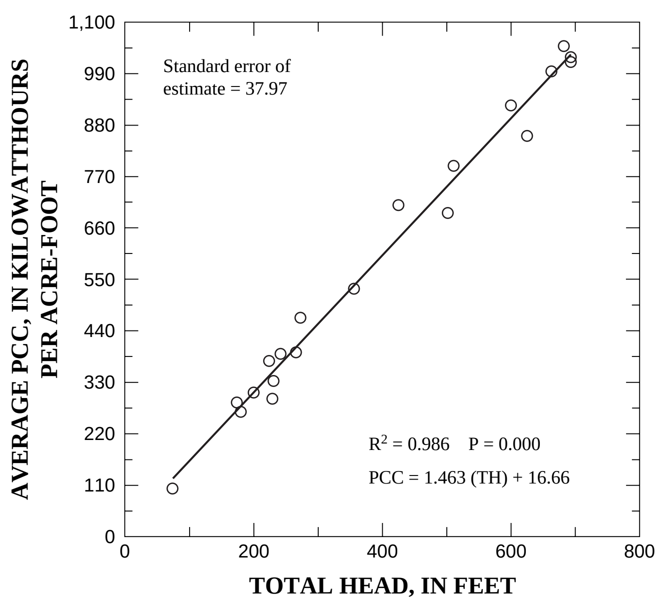


Figure 4. Relation between power-consumption coefficients and total head at 20 pump sites between Upper Salmon Falls and Swan Falls Dams, Idaho. (PCC, power-consumption coefficient; TH, total head)

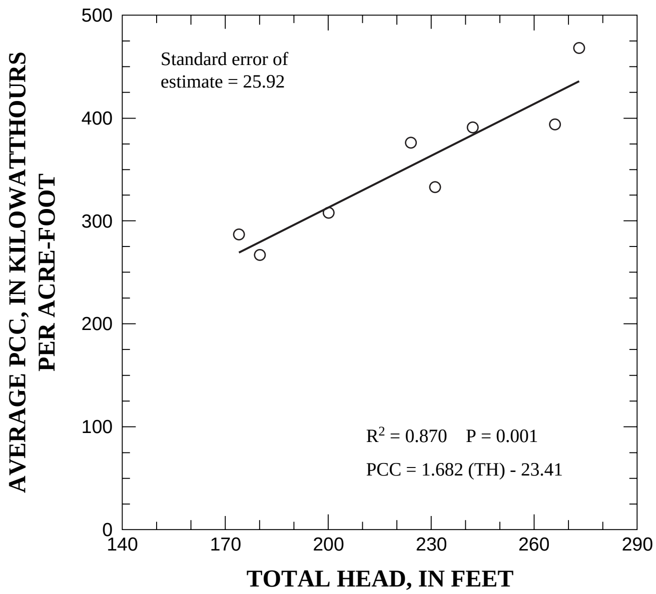


Figure 5. Relation between power-consumption coefficients and total head less than 300 feet at eight pump sites between Upper Salmon Falls and Swan Falls Dams, Idaho. (PCC, power-consumption coefficient; TH, total head)

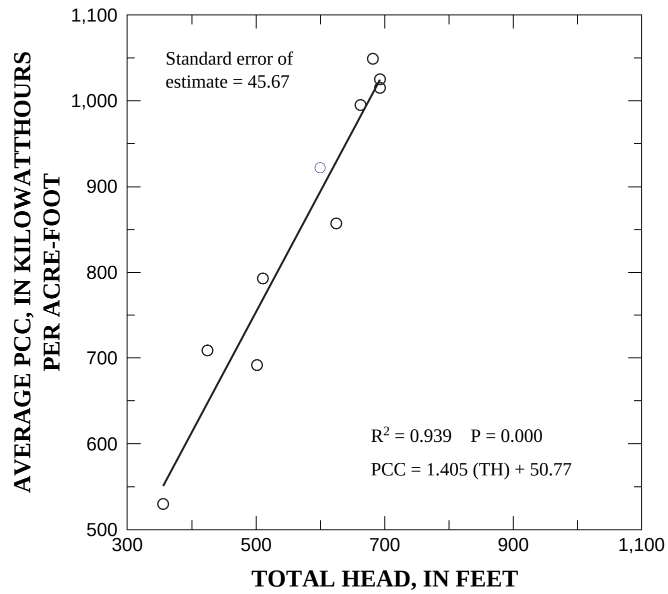


Figure 6. Relation between power-consumption coefficients and total head greater than 300 feet at 10 pump sites between Upper Salmon Falls and Swan Falls Dams, Idaho. (PCC, power-consumption coefficient; TH, total head)

power consumption may yield a more accurate estimate of withdrawals. The data points shown in figure 4 were subdivided into two groups: pump sites with total head less than 300 ft and pump sites with total head greater than 300 ft. Average PCC values for eight pump sites with total head less than 300 ft were regressed with total head, which produced a coefficient of determination of $R^2 = 0.870$ (fig. 5). The equation of the regression line for those data was PCC=1.682 (TH) - 23.41, where the slope of the line, or representative K-factor, is equal to 1.682. This K-factor and equation will be most useful for estimating withdrawals at low-head pump sites in other reaches of the Snake River. Similarly, 10 pump sites with total head greater than 300 feet were regressed and the coefficient of determination was also strong (R^2=0.939). The regression line equation was PCC = 1.405 (TH) + 50.77, where the slope of the line, or representative K-factor, is equal to 1.405 (fig. 6).

FUTURE STUDIES

The final phase of this study entails inventory and field data-collection efforts at pump sites along the Snake River between Swan Falls Dam and the confluence of the Weiser River. No field inventories or withdrawal measurements at pump sites along the approximately 100-mi reach have been made since the early 1980's. Of the hundreds of pump sites along this reach, only 27 have been specifically identified as candidates for inventory. An assessment of sparse USGS withdrawal data and current IPC energy data would be conducted in the same manner as described in this report. A one-time field inventory would be conducted during the irrigation season and would entail the same types of visits and data-collection activities as outlined in this report. From these data, individual pump-site PCC and K-factor variables would be calculated for each of the 27 pump sites. Without the benefit of many historical withdrawal measurements, PCC values would be based on one-time field measurements of power demand, withdrawal, and total head. From this information, a K-factor representing mid-season operating conditions would be calculated and compared with either of the representative K-factors determined in this report.

SUMMARY

During the 1998 irrigation season, 32 pump sites were inventoried, and power demand and withdrawal were measured at 18 of them. The pump sites are located along the Snake River between Upper Salmon Falls and Swan Falls Dams in Idaho. Coordinates obtained with Global Positioning System equipment

were used to develop a geographic information system data set that stores and depicts locations, tables, and pictures of the sites. Pump-site characteristic data collected during 1998 included total head, horsepower, number of pumps, and meter and measurement location information. Power-consumption coefficient (PCC) values were successfully determined using measured withdrawal data (1990–92, 1994–95), power-consumption data for the same period, and total head data collected during the 1998 inventory. Average PCC values for 1998 also were calculated using power demand, withdrawal, and total head measurements. PCC values for 1998 were within 10 percent of the 5-year average PCC values. K-factors for most sites were determined from average PCC values by dividing the PCC value by total head for each site.

Multiple-correlation analysis and linear regression were used to describe relations between average PCC values and pump-site characteristics. A strong relation exists between average PCC and withdrawal (R^2=0.99); an equally strong relation was identified between average PCC and total head (R^2=0.99). Average PCC values were regressed with total head and the coefficient of determination was 0.986; the slope of the regression line was equal to a representative K-factor of 1.463 kilowatthours per acre-foot per foot. Pump sites were subdivided further into two groups on the basis of total head. Average PCC values for eight pump sites with total head less than 300 feet were regressed with total head and the coefficient of determination was 0.870; the representative K-factor for that relation was 1.682 kilowatthours per acre-foot per foot. Regression of 10 pump sites with total head greater than 300 feet resulted in a strong coefficient of determination (R^2=0.939) and a representative K-factor of 1.405 kilowatthours per acre-foot per foot. Both regression models substantiate the strong linear correlation between total head and average PCC values. Results of regression models demonstrate that future withdrawals could be determined at unmeasured sites where total head and power consumption are known.

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APPENDIX A

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HIGH-LIFT PUMP FIELD QUESTIONNAIRE

Site No. ____________________ **Date** ____________ **Quad** ______________

Site name ____

Is this measurement site a CANAL or a closed PIPE? (Circle one)

Canal Questions

If a canal, was the water pumped from the river through closed PIPES and delivered to the canal, or GRAVITY diverted? (Circle one)

If the water was pumped through closed PIPES, can you locate on a topographic map the point on the river where water is diverted and a point where water is dumped into the canal? (yes/no)

Please list the powerpole number(s) and meter number(s) for the pump site that delivers water to the canal. If there is more than one pole and meter, please associate pump(s) and horsepower to powerpole and meter numbers.

Pole number	Meter number	Number of pumps and horsepower of each (i.e. 600 total, with 3 pumps @ 200 hp each)

Are there any additional pumps (with separate powerpoles and meters attached) between the river and the point where water is measured in the canal? If so, please list those powerpole and meter numbers.

Pole number	Meter number	Number of pumps and horsepower of each (i.e. 600 total, with 3 pumps @ 200 hp each)

Closed Pipe Questions

Please list the powerpole number(s) and meter number(s) for the pump site. If there is more than one pole and meter, please associate the pump(s) and horsepower to the powerpole and meter numbers.

Pole number	Meter number	Number of pumps and horsepower of each (i.e. 600 total, with 3 pumps @ 200 hp each)

Are there additional pumps between the river and sprinklers for repressurizing? (yes/no)

If yes, locate on a topographic map where the extra pump(s) is/are.

Irrigation System Questions

What types of irrigation systems are used to distribute water diverted from this site?

Center pivot   Sprinklers (all other types)   Mix

Is it possible to delineate a general polygon that shows where water is applied? (yes/no) If so, please mark on the topographic map.

General Description / Notes

NOTES: Give any descriptions that would be helpful to explain how water is diverted from the river and delivered to the fields.

HIGH-LIFT PUMP FIELD-INVENTORY SHEET — Snake River, July 1998

Date ______________________ **Time** __________ **Inventory crew** ______________________________

Station name ____

GPS Location and Information

Tag identification number ____

GPS tagged location description ____

____

____

Latitude (DMS) _______________________ Longitude (DMS) _______________________

Elevation at tag location (m) ______________________________

Pump Information

Total # of pumps ______________________ Total horsepower of pumps ______________________________

Number of pumps running _____________ Total horsepower of running pumps _______________________

Meter No. ____________________ Watthour per disk revolution (from faceplate) (Kh) ___________________
Meter No. ____________________ Watthour per disk revolution (from faceplate) (Kh) ___________________
Meter No. ____________________ Watthour per disk revolution (from faceplate) (Kh) ___________________

POWER CONSUMPTION: Take 3 readings of the time for the disk to make 10 revolutions (in seconds):

Meter No. ____________________ (1) _____________ (2) _____________ (3) _____________
Meter No. ____________________ (1) _____________ (2) _____________ (3) _____________
Meter No. ____________________ (1) _____________ (2) _____________ (3) _____________

Meter Configuration with Pumps

Is/are the meter(s) configured in the standard fashion? Y / N

If not, what is/are the type(s) and ratios of the transformers? CT / PT

Pressure

PSI reading ______________________ (lbs/in²)

Location of PSI reading ______________________

Notes ______________________

____

____

Photograph Description(s) ______________________

____

Ownership Information

Owner Name ______________________ Phone ______________________

Manager Name ______________________ Phone ______________________

Remarks

If the pumps supply water through a closed system to sprinklers, enter the types and number of sprinklers that you know are running at the time of measurements. Draw a schematic diagram of the pump and pipe configurations at the site.