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DISCHARGE OF THE INDIAN RIVER AND DIVERSIONS, SITKA, ALASKA

National Park Service
Water Resources Division
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INTRODUCTION

The Indian River flows through Sitka National Historical Park (SITK) in southeastern Alaska. See Figures 1 and 2 for locations. SITK is a unit managed by the National Park Service (NPS) and is located along the edge of Sitka Sound.

Four species of Pacific salmon use the river for spawning in the SITK or as a corridor to access upper reaches of the river from July through November. Maintaining stream discharge in the park is also important for the incubation of salmon eggs, supporting alevins (hatched salmon with egg sac attached) during winter, and rearing juvenile coho salmon before they head to sea.

Diversion structures upstream from SITK are used to supply river water for salmon incubation, rearing, and egg/milt extraction facilities in the Sage Building at the edge of Sitka Sound. These hatchery facilities were originally built and operated by Sheldon Jackson College (SJC), but the college closed in June 2007. Former SJC professors organized the Sitka Sound Science Center (SSSC) to operate the hatchery and diversions from the river.

During very low flows, water in the river within SITK is sometimes insufficient for salmon to spawn or move upstream, delaying spawning and possibly causing premature death of salmon before spawning can take place. It is believed that diversions sometimes increase the severity of low flows.

This report contains analyses describing streamflow characteristics of the Indian River and historical diversions by SJC. It also contains estimations of diversions from the Indian River by SSSC as well as an analysis of the diversions.

SALMONIDS

The Indian River is important habitat for many anadromous fish species, including coho salmon (*Oncorhynchus kisutch*), pink salmon (*O. gorbuscha*), chum salmon (*O. keta*), chinook salmon (*O. tshawytscha*), steelhead trout (*Oncorhynchus mykiss*), and Dolly Varden (*Salvelinus malma*) and nonanadromous species such as resident rainbow trout (*Oncorhynchus mykiss)*, threespine stickleback (*Gasterosteus aculeatus*), and coastrange sculpin (*Cottus aleuticus*). Anadromous fish use the river as habitat for migration, spawning, incubation of eggs, and rearing of young. From mid-July through September, adult pink and chum salmon enter the Indian River to spawn. Their fry emerge and migrate to the ocean from late February through mid-May. Coho salmon

return to the Indian River from late September through November and spawn in the upper portion of the watershed. Numbers of pink salmon in the Indian River greatly outnumber those of other salmon species. The Indian River has had some spawning chinook salmon every year since at least 2000, and successful spawning has occurred. Because the Sitka area is not known to have had any existing wild populations of chinook salmon, these fish are considered to be strays from area hatcheries (Eckert and others, 2006, p. 29).

In Alaska Department of Fish and Game (2010a), SSSC described its planned activities at the hatchery in an application to obtain a permit for private nonprofit salmon hatchery. SSSC plans to raise and release coho, pink, and chum salmon — species that are found in the Indian River. SSSC no longer plans to raise and release chinook salmon. Some hatchery-raised fish stray into the Indian River to spawn (Nic Medley, National Park Service, oral commun., 2010).

The Alaska Department of Fish and Game (2010b) provided the following information regarding spawning periods of salmonids.

Salmonid	*Spawning period*
Chinook salmon	May to July
Chum salmon	Not listed
Coho salmon	July to November
Dolly Varden (char)	September to November
Pink salmon	Late June to mid-October
Steelhead trout	Mid-April to early June
Rainbow trout	Late March to early July, dependent on location and severity of winter

John Wullschleger (NPS, oral commun., 2010) noted that hatcheries tend to release all smolts at the same time, so that they return at approximately the same time. The returning salmon arrive initially as a "dribble" of individuals. Later they arrive in larger masses. Then the numbers dribble out, somewhat similar to a Bell curve.

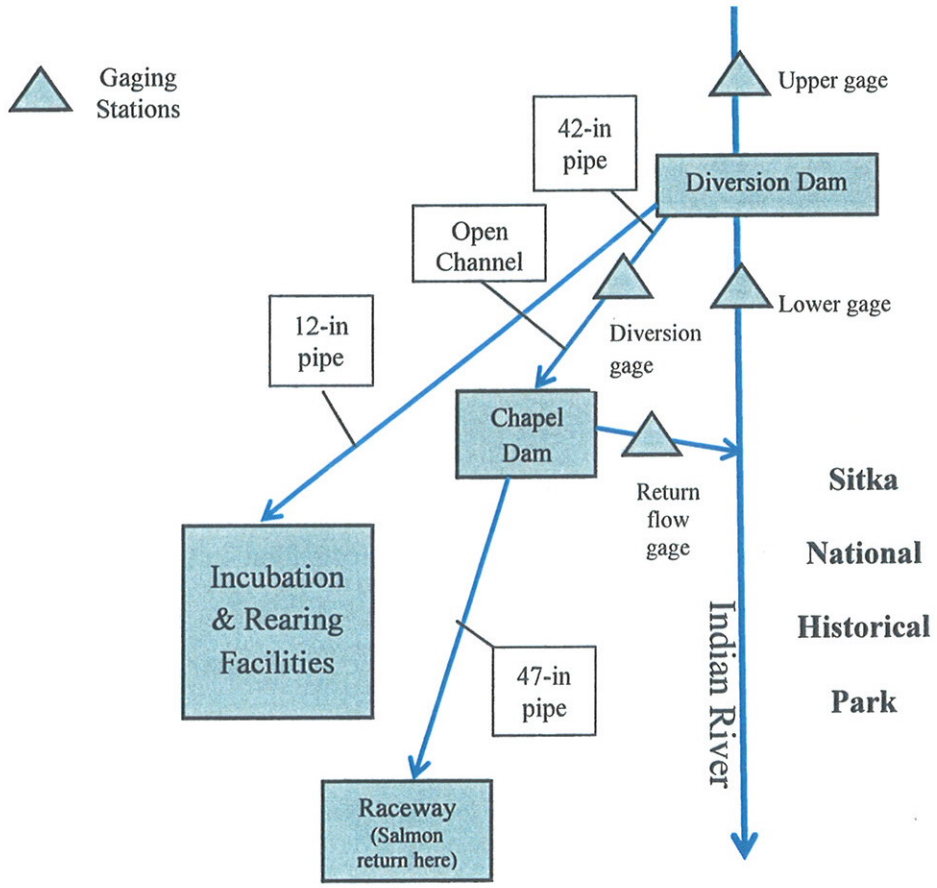
DIVERSIONS FROM THE INDIAN RIVER

There are five known water rights on the Indian River. Basic information on the water rights are shown in the table below[1]:

[1] The information on the state water rights came from Alaska Department of Natural Resources (2010). ADL stands for Alaska Division of Lands, and LAS for Land Administration System. CBS's water rights for emergency use only are not included in the analyses.

Type of water right	*Number*	*Year of priority date*	*Owner*	*Status*	*Duty*	*Notes*
Federal reserved	—	1890	National Park Service	Not adjudicated	Not quantified	
ADL (state)	43671	1914	SSSC	Certified	30 ft^3/s	Under review.
ADL (state)	43672	1914	City and Borough of Sitka (CBS)	Certified	3.87 ft^3/s	For emergency use only.
ADL (state)	101686	1980	CBS	Received	5.41 ft^3/s	For emergency use only.
LAS (state)	12236	1989	Alaska Department of Fish and Game (ADFG)	Certified	35-101 ft^3/s	See Neal and others, 2004, p. 20, for diversion schedule.

A schematic of the river, diversions, facilities, and other features associated with SSSC and SITK is shown below. The schematic is not drawn to scale.



The 42-in diameter pipe carrying diverted water from the diversion dam on the Indian River to SJC and is composed of steel coated with some type of plastic or rubber material. The diverted water then moves out of the pipe into an open channel that leads to a dam (Chapel Dam) on the SJC campus. From there water flows into a buried pipe (47-in diameter and composed of wooden staves). At the Chapel Dam, however, some of the diverted water is returned to the Indian River inside SITK. The 47-in pipe delivers water to the power plant in the Sage Building and eventually flows out into the penstocks and raceways, where hatchery-reared salmon, returning from the seas on their spawning run, are collected. The Sage Building is not shown in the schematic.

There is a second pipe (12-in diameter and composed of HDPE) that runs from the diversion dam on the Indian River directly to the incubation and rearing facilities. This pipe reportedly delivers about 5 ft^3/s.

Table 1 contains the proposed diversion schedule for SSSC hatchery (Alaska Department of Natural Resources, 2010). The annual mean diversion rate is 11 ft^3/s. SSSC proposes to divert between 15.4 to 16.3 ft^3/s between June 15 and November 30, 46 percent of the year.

Table 2 shows the water use of the SSSC hatchery. A maximum monthly water use of 4.4 ft^3/s occurs in August. The annual mean water use is 2.1 ft^3/s. Table 3 contains a comparison of SSSC's proposed diversions and SSSC's water use. It is unknown what the uses shown in the "Other" column in Table 3 are for. Thus, a maximum monthly water use of 4.2 ft^3/s was calculated (4.367-0.212, rounded).

The incubation and rearing diversions are supplied through the 12-in HDPE pipe. It is understood that 5 ft^3/s is needed to pass through the wooden stave pipe to maintain the wooden pipe. From June 16 through November 30, an additional 10 ft^3/s diversion is proposed for the raceway, reportedly as attractant flows and to fill penstocks, where the salmon are kept, before they are milked for roe and milt. This time period mostly coincides with the period when salmon spawn in the Indian River. Part of the returning salmon is harvested by fisherman at sea.

In 2009, the Alaska Department of Natural Resources (2010) measured discharge four times in the water delivery system of SSSC.

Site	*Date*	*Discharge, ft^3/s*	*Comments*
Upstream of Chapel Dam	August 7, 2009	7.1	
Downstream of Chapel Dam	August 7, 2009	6.5 to 6.9	
Hydroelectric raceway	August 8, 2009	7.7	Corrected for surging; discharge value before correction was 23.2 ft^3/s.
Hydroelectric and fish pen raceway (same as "hydroelectric raceway"?)	October 5, 2009	11.7	Not corrected for surging; actual discharge value probably was smaller.

Surging flows (unstable flows) occurred at the raceway measurement site. The unstable flows were apparently caused by debris (e.g., leaves and sticks) clogging the bottom of the raceway. It

appears that SSSC was using about half of its proposed diversion rate for August and October (about 16 ft^3/s).

It appears that diverting 10 ft^3/s can deplete instream flows during July and September or in unusual drought, which may result in delayed spawning and premature death of salmon. The last such event occurred in the first weeks of September 2010. Salmon require a large enough discharge rate to swim upstream and to spawn. A sufficient discharge rate is required for incubation of the eggs that are laid in the streambed gravel. Flowing water is required in the gravel to bring dissolved oxygen is to the eggs and alevins and to carry away waste products.

DATA

Available sources of continuous streamflow and precipitation data include:

Type of Data	*Station Name*	*Source*	*Start*	*End*
Daily and monthly mean flow	15087690 Indian River nr Sitka AK	USGS[2]	8/28/1980	09/30/1993
			10/1/1998	3/31/2006
		Geoffrey Smith (NPS)	6/15/2007	9/30/2009
Daily and monthly mean flow	15087700 Indian River at Sitka AK	USGS	10/1/1998	9/30/2003
		Geoffrey Smith (NPS)	6/15/2007	9/30/2009
Daily and monthly mean flow	15087730 Indian R Div to SJC at Sawmill C Rd at Sitka AK	USGS	10/1/1998	9/30/2000
Daily and monthly mean flow	15087735 Indian R Div Return Flow from SJC at Sitka AK	USGS	10/1/1998	9/30/2000
Hourly precipitation	508490 USGS Magnetic Observatory Sitka 1 NE Experimental	Geoffrey Smith (NPS)	6/1/2007	10/1/2009
Daily precipitation	508494 Sitka Japonski FAA Airport	NOAA[3]	9/1/1944	11/30/1996
			3/1/1999	1/31/2010
Monthly precipitation		DRI[4]	09/1949	04/2010
Daily precipitation	508503 Sitka Magnetic Obsy	NOAA	8/1/1899	12/31/1989
Daily precipitation	508505 Sitka Wtr Trtmnt Plt	NOAA	7/1/2008	1/31/2010

The following stations with the overlapping periods of record were used in these analyses:

Station Name (abbreviation in this report)	*Start*	*End*
15087690 Indian River nr Sitka AK (upper gage)	8/28/1980	09/30/1993

[2] United States Geological Survey (2010a).
[3] National Oceanic and Atmospheric Administration (2010)
[4] Desert Research Institute (2010).

Station Name (abbreviation in this report)	*Start*	*End*
	10/1/1998	3/31/2006
	6/15/2007	9/30/2009
15087700 Indian River at Sitka AK (lower gage)	10/1/1998	9/30/2003
	6/15/2007	09/30/2009
15087730 Indian R Div to SJC at Sawmill C Rd at Sitka AK (diversion)	10/1/1998	9/30/2000
15087735 Indian R Div Return Flow from SJC at Sitka AK (return flow)	10/1/1998	9/30/2000
508494 Sitka Japonski FAA Airport (precipitation)	8/28/1980	9/30/1993
	3/1/1999	9/30/2009

Geoffrey Smith (NPS, written commun., 2010) noted that the most critical time for salmon runs in the Indian River generally occurs in July, August, and September (i.e., for pink and chum salmon). Several periods of record are addressed in the analyses in this report, and these were given names for use in this report, as shown in the table below.

Name of period of record	*Start*	*End*
Common period for upper gage and precipitation	8/28/1980	9/30/1993
	3/1/1999	9/30/2009
Earlier period	10/1/1998	9/30/2003
Later period	6/15/2007	9/30/2009
Combined period	10/1/1998 6/15/2007	9/30/2003 9/30/2009
Measured diversion period[5]	10/1/1998	9/30/2000
Combined summer period[6]	7/01/1999 7/01/2000 7/01/2001 7/01/2002 7/01/2003 7/01/2007 7/01/2008 7/01/2009	9/30/1999 9/30/2000 9/30/2001 9/30/2002 9/30/2003 9/30/2007 9/30/2008 9/30/2009

Between the upper gage and the lower gage, no tributaries are shown on topographic maps. However, during major precipitation events, much water flows in several tributaries between the two gages. During periods with little or no rainfall, there is little or no flow in these tributaries (Geoffrey Smith, NPS, written commun., 2010). The discharge in the tributaries is described below in the section titled "Measured Diversions and Return Flows."

[5] Five days are missing for diversions, 09/07/2000 through 09/11/2000.
[6] Critical period for spawning salmon in Indian River.

Basic information about the gages are shown below.

Station Name (abbreviation in this report)	*Elevation, ft above sea level*	*Drainage area, mi²*	*Accuracy of discharge record*
15087690 Indian River nr Sitka AK (upper gage)	125	10.1	Fair
15087700 Indian River at Sitka AK (lower gage)	30	12	Fair
15087730 Indian R Div to SJC at Sawmill C Rd at Sitka AK (diversion)	70	---	Good to fair
15087735 Indian R Div Return Flow from SJC at Sitka AK (return flow)	60	---	Good to fair
508494 Sitka Japonski FAA Airport (precipitation)	10-70	---	---

The drainage area of the lower gage is 19 percent larger than that of the upper gage. Regarding the accuracy of discharge records, "excellent" means that about 95 percent of the daily discharges are within 5 percent of the true; "good," within 10 percent; and "fair," within 15 percent. Records that do not meet the criteria mentioned, are rated "poor." Different accuracies may be attributed to different parts of a given record (U.S. Geological Survey, 2010b).

It is assumed that all daily discharge records examined in this report are "fair," that is, about 95 percent of the daily discharges are within 15 percent of true discharge. The daily discharge records can be as much as 15 percent larger or smaller than true discharge.

Smith (2010) described the recent discharge monitoring efforts on the Indian River. SITK, ADFG, and CBS formed a partnership to fund and reestablish the upper and lower stream gages on the Indian River. A cooperator was contracted to process data measured by the gages. The NPS Southeast Alaska Inventory and Monitoring Network (SEAN) funds the cooperator's work as part of their Vital Signs monitoring program. SITK staff are responsible for developing the contract, maintaining the gages, downloading discharge data from the recorders, transferring data to the cooperator, and manually measuring stream discharge for quality control.

METHODS

Correlations (r and r^2) between selected data sets were calculated. Statistics were also calculated to describe data sets, using Microsoft XCEL and Golden Software GRAPHER. Data sets were plotted, using GRAPHER.

The following variables are used in this report:

P = *daily precipitation at Sitka Japonski Airport*
Q_d = *diversion* (the diversion lies between Q_l and Q_u)
$\hat{Q}_d$ = *predicted diversion*
Q_l = *discharge at lower gage*
Q_{rf} = *return flow discharge*

Q_u = *discharge at the upper gage*
Q_x = *gains (+) to or losses (-) from the river between upper gage and lower gage, excluding the diversion*
$\hat{Q}_x$ = *predicted gains to or losses from the river between upper gage and lower gage, excluding the diversion*

The discharge at the lower gage is represented by Equation 1:

$$(1) \quad Q_l = Q_u + Q_x - Q_d$$

The gains and losses (Q_x) are important to consider in formulating a mass balance. The processes causing the gains or losses have not been measured and include overland flow, subsurface flow, infiltration, evaporation, plant interception, and transpiration.

Forms of Equation 1 can be used to predict diversions for periods of record where there are no measured diversions. The development of Equation 1 into a predictive equation is described below in the subsection titled "Model."

Flow duration curves were constructed for selected data sets. A flow-duration curve is a cumulative frequency curve that shows the percent of values that specified discharges were equaled or less than (percentile), or the percent of values that specified discharges were equaled or exceeded (percent exceedance). Percent exceedance is 100 minus the percentile. Example: the 75th percent exceedance (the value that 75 percent of the flows are equal to or greater than) is the 25th percentile (the value that 25 percent of the flows are equal to or less than). While the flow-duration curve does not show the chronological sequence of flows, it is an important means of representing flow characteristics of a stream throughout the range of flow on a single curve (U.S. Geological Survey, 2010c).

RESULTS

In the common period of record for the upper gage and precipitation (August 1980 to September 2009), the annual mean precipitation was 92.0 in and the annual median 91.5 in (Table 4). The annual mean discharge at the upper gage for the same period was 102 ft^3/s and the annual median 101 ft^3/s (Table 5).

The driest period of the year for precipitation is April through July, and the wettest September through November (see Table 4 and Figure 3). The months with the smallest discharge at the upper gage are March and April. The months with the largest discharge are September and October (Table 5 and Figure 3).

Daily precipitation was plotted with daily mean discharge of the lower gage and upper gage for the early period (October 1998 through September 2003, Figure 4) and later period (June 2007 through September 2009, Figure 5). Figure 6 shows a hydrograph for daily mean discharge at the upper and lower gages along with daily precipitation for calendar year 2008. This year was selected to show fluctuations in discharge and precipitation more clearly over a one-year period.

The principal flow source of Indian River is precipitation runoff. Discharge generally coincides with precipitation. Discharge in the Indian River Basin responds quickly to rainfall events because of steep topography and shallow soils. Flood-peak durations are usually measured in hours rather than days. The greatest discharges occur during the fall months in response to regional storms. However, rain-on-snow floods occur during the winter months in many southeast Alaska streams (Neal and others, 2004, pp. 16-17).

Discharges generally are greatest (September and October), when storms are most frequent, and exhibit a gradual decline through winter and early spring. Discharge typically increases in May and June in response to snowmelt in the higher elevations of the drainage (Neal and others, 2004, p. 17).

For the early period of record (October 1998 through September 2003), the discharge at the upper gage was less than SSSC's proposed diversion about nearly zero percent of the time; for the later period of record (June 2007 through September 2009), zero percent, and for calendar year 2008, zero percent. For the early period of record, the discharge at the lower gage was less than SSSC's proposed diversion about one percent of the time; for the later period of record, about one percent, and for calendar year 2008, zero percent. See Figures 4, 5, and 6.

Also represented on figures 4, 5, and 6 are the Alaska Department of Fish and Game's (ADFG) flow reservations for the Indian River from the mouth upstream to river mile 2.5. The annual mean discharge of ADFG's flow reservation is about 49 ft^3/s. For the early period of record, the discharge at the upper gage was less than ADFG's flow reservation about 28 percent of the time; for the later period of record, about 24 percent, and for calendar year 2008, about 11 percent. Frequently, there is insufficient water in the stream at the upper gage to entirely meet ADFG's water-right requirements. For the early period of record, the discharge at the lower gage was less than ADFG's flow reservation about 45 percent of the time; for the later period of record, about 30 percent, and for calendar year 2008, about 19 percent. See Figures 4, 5, and 6. ADFG's water-right requirements frequently are not met at the lower gage, which is located within SITK.

Correlation

Coefficients of correlation and determination were calculated for selected data sets and periods of record.

Item No.	*Correlated data sets (and period of record)*	r	r^2
1	Q_u with P (later period)	0.58	0.34
2	Q_l with P (later period)	0.61	0.38
3	Q_l with Q_u (later period)	0.95	0.91
4	Q_l-Q_u with P (later period)	0.53	0.28
5	Q_d with P (measured diversion period)	0.31	0.10
6	Q_d with Q_l-Q_u (measured diversion	0.05	0.00

Item No.	*Correlated data sets (and period of record)*	*r*	r^2
	period)		
7	Q_d with Q_u (measured diversion period)	0.37	0.14
8	Q_d with Q_l (measured diversion period)	0.28	0.08

All but one of the correlations are weak. As expected, the daily mean discharge of the lower gage correlates strongly with that of the upper gage, because the lower gage is located about a mile and a half downstream from the upper gage. Weak correlations occur between streamflow and precipitation, because of several unknowns (Q_x) that control the timing and rate of discharge between the upper and lower gages. The measured diversions have weak or no correlations with stream discharge and precipitation.

It was hypothesized that a mathematical or statistical relationship between Q_l-Q_u and Q_d could be used to predict diversions. However, as noted above, the coefficient of correlation (r) of Q_d with Q_l-Q_u is 0.05. The coefficient of determination (r^2) is 0.00. Thus, the quantity Q_l-Q_u should not be used to predict diversions. Q_x is not included in this correlation.

Measured Diversions and Return Flows

The measured diversions and return flows (October 1998 through September 2000) provide the best information regarding water use proposed by SSSC, provided SSSC uses the same amount of water as SJC. Statistics were calculated for the upper and lower gages, diversion, return flow, and gains to or losses from river (excluding diversion) during the measured diversion period of record.

Statistic	*Daily mean discharge, ft^3/s*					
	Upper gage (Q_u)	*Diversion (Q_d)*	*Lower gage (Q_l)*	*Return flow (Q_{rf})*	*Diversion less return flow (Q_d-Q_{rf} water use)*	*Gains (+) to and losses (-) from river, excluding diversion (Q_x or Q_l-Q_u+Q_d)*
Number	731	726	731	673	668	726
Maximum	1560	47	2390	51	14	859
Minimum	17	0.0	14	0.0	-5.0	-11
Mean	100	21	99	14	5.6	20
Median	71	22	57	12	8.0	8.0
Mode	50	34	37	24	9.0	7.0
Standard deviation	124	11	179	9.5	4.2	62

When SJC diverted water from the Indian River during the measured diversion period of record (October 1998 through September 2000), the daily mean discharge for Q_d was 21 ft^3/s and the

median 22 ft^3/s. (See Figure 7). Q_{rf} had a daily mean discharge of 14 ft^3/s and a median of 12 ft^3/s. Q_d-Q_{rf} (water use) averaged about 6 ft^3/s with a median of 8 ft^3/s. It appears that about 6 ft^3/s to 8 ft^3/s was large enough to meet the needs of the SJC hatchery during the measured diversion period, compared to the proposed annual mean discharge of 11 ft^3/s for SSSC's diversions. Q_x has a mean of 20 ft^3/s and a median of 8 ft^3/s. Thus it can be a substantial part of the water budget and shouldn't be ignored.

Water use (Q_d-Q_{rf}) never exceeded 14 ft^3/s, which indicates that diversions larger than 14 ft^3/s were not needed, provided there were no losses during conveyance from the diversion point to Chapel Dam. Generally more water was diverted by SJC than the rate requested by SSSC.

The gains to or losses from the river, excluding diversion, (Q_x or Q_l-Q_u+Q_d) was 20 ft^3/s, five percent less than daily mean Q_d of 21 ft^3/s. On average, over long periods of time, it appears that Q_d captured most, if not all, of Q_x.

Flow duration curves of Q_d, Q_{rf}, and Q_d-Q_{rf} for the measured diversion period of record were constructed (Figure 8). The following table shows the percent of time or less when discharges were equaled or larger.

Variable	*10 percent or less of time*	*25 percent or less of time*	*50 percent or less of time*	*75 percent or less of time*	*90 percent or less of time*
	Daily mean discharge, ft^3/s, or larger				
Q_d	37	29	20	7.6	4.6
Q_{rf}	27	22	12	5.5	3.3
Q_d-Q_{rf}	10	9.0	8.0	1.0	0.2

About 50 percent or less of the time, 20 or more ft^3/s of water was diverted (Q_d) during the measured period of record, and 8 or more ft^3/s of water was used (Q_d-Q_{rf}).

It is unknown whether SJC adjusted diversion headgates during the measured diversion period of record. It appears, however, that the openings of the headgates were not adjusted, except for maintenance perhaps in November 1998 (Figure 9). The peaks and troughs of the diversion (Q_d) appear to mimic that of the discharge of the lower gage (Q_l), but with smaller amplitudes.

Model

There was no satisfactory correlation of measured diversions with stream discharge, which might be used to predict diversions during periods of record with no measured diversions. A predictive method was devised to do so. Q_d, Q_l, and Q_u are knowns for the measured diversion period of record (October 1998 through September 2000). Hence, Q_x can be calculated for the same period of record using Equation 2, which is derived from Equation 1.

$$(2) \quad Q_x = Q_l - Q_u + Q_d$$

This equation was used to calculate Q_x the values of which are shown in the table above. For the measured diversion period of record (excluding the values for 09/07/2000 through 09/11/2000), the following mean and median values were calculated:

Parameter	*Mean*	*Median*
	Discharge, ft³/s	
Q_u	99	71
Q_l	99	56
Q_d	21	22
Q_x	20	8
$Q_u+Q_x-Q_d$	98	57

For the means, $Q_u+Q_x-Q_d$ differs from that of Q_l by one percent, whereas, for the medians, the difference is 24 percent. The calculated average gains to or losses from the Indian River excluding diversions (Q_x) is about 21 percent of the average discharge at the upper gage. The drainage area of the lower gage is 19 percent larger than that of the upper gage.

For all other periods of record, Q_l and Q_u are known, and Q_d and Q_x are unknown. Predicted Q_x ($\hat{Q}_x$) can be calculated for another period of record using Equation 3 and the equation from a linear regression solution of Q_u plotted against Q_x for the measured diversion period of record (October 1998 through September 2000).

$$(3) \quad \hat{Q}_x = f(Q_u)$$

The coefficient of correlation for Q_u with Q_x is 0.91. The plot of Q_x values as y against Q_u as x and the resulting linear fit and statistics are shown in Figure 9. Predicted Q_x ($\hat{Q}_x$) is calculated using Equation 4.

$$(4) \quad \hat{Q}_x = 0.445Q_u - 25.1$$

$\hat{Q}_d$ can then be calculated using Equation 5.

$$(5) \quad \hat{Q}_d = 0.455Q_u - 25.1 - Q_l + Q_u$$

The mean predicted diversion ($\hat{Q}_d$) for the entire later period of record (June 2007 through September 2009) is 16 ft³/s, approximately SSSC's maximum diversion rate. Monthly averages of the predicted diversions were calculated for the later period of record (June 2007 through September 2009) and are compared below with the average proposed monthly diversion rates of SSSC.

Month 2007	Mean $\widehat{Q}_d$, ft^3/s	Mean SSSC Proposed Diversion, ft^3/s (rounded)	Month 2008	Mean $\widehat{Q}_d$, ft^3/s	Mean SSSC Proposed Diversion, ft^3/s (rounded)	Month 2009	Mean $\widehat{Q}_d$, ft^3/s	Mean SSSC Proposed Diversion, ft^3/s (rounded)
Jan	—	6	Jan	-13	6	Jan	20	17
Feb	—	6	Feb	-7	6	Feb	3	6
Mar	—	7	Mar	-4	7	Mar	-4	7
Apr	—	7	Apr	1	7	Apr	9	7
May	—	7	May	29	7	May	32	7
Jun	—	10	Jun	44	10	Jun	26	10
Jul	34	16	Jul	57	16	Jul	13	16
Aug	-30[7]	16	Aug	37	16	Aug	8	16
Sep	21	16	Sep	51	16	Sep	29	16
Oct	-17	16	Oct	50	16	Oct	—	16
Nov	-7	16	Nov	38	16	Nov	—	16
Dec	-13	6	Dec	16	6	Dec	—	6

By month, the average predicted diversion has a weak correlation with the mean proposed diversion of SSSC ($r = 0.34$). This suggests that the model will not work for monthly or daily periods. During the later period of record (June 2007 through September 2009), predicted diversions generally are smaller in the winter and larger in the summer. The model should not be used to predict daily mean diversions and should only be used for long periods of record, longer than one month.

Statistics and Flow-Duration Curves

Statistics were calculated and flow duration curves are presented for two periods of record: the combined period of record (October 1998 through September 2003, and June 2007 through September 2009), and the combined summer period of record (July through September, 1999 through 2003, and 2007 through 2009).

The following table shows statistics for the combined period of record (October 1998 through September 2003, and June 2007 through September 2009).

Statistics	*Upper Gage*	*Lower Gage*
	Daily mean discharge, ft^3/s	
Count	2665	2665
Maximum	1560	2390
Minimum	12	9.2
Mean	94	93
Median	69	56
Mode	31	23
Standard	103	149

[7] The negative sign denotes discharge entering the stream from the diversion.

Statistics	*Upper Gage*	*Lower Gage*
	Daily mean discharge, ft³/s	
deviation		

For the combined period of record, the minimum discharge at the lower gage was about 9 ft^3/s and 12 ft^3/s at the upper gage. The means of the two gages differ by one percent. The medians of the two gages differ by 23 percent.

The discharge of the lower gage is larger than that of the upper gage about 12 percent or less of the time (Figure 11). The two curves cross at a daily mean discharge of about 150 ft^3/s. The following table shows the percent of time or less when discharges were equaled or larger.

Variable	*10 percent or less of time*	*25 percent or less of time*	*50 percent or less of time*	*75 percent or less of time*	*90 percent or less of time*	*95 percent or less of time*
	Daily mean discharge, ft³/s, or larger					
Q_u	163	107	69	42	29	25
Q_l	168	96	56	33	20	16

The following table shows statistics for the combined summer period of record (July through September, 1999 through 2003, and 2007 through 2009).

Statistics	*Upper Gage*	*Lower Gage*
	Daily mean discharge, ft³/s	
Count	736	736
Maximum	1150	2016
Minimum	12	14
Mean	100	97
Median	73	55
Mode	56	44
Standard deviation	102	150

For the combined summer period of record, the minimum discharge at the lower gage was 12 ft^3/s and 14 ft^3/s at the upper gage. The means of the two gages differ by three percent. The medians of the upper gage and lower gages differed by 33 percent.

The discharge of the lower gage appears to be larger than that of the upper gage about 14 percent or less of the time (Figure 12). The two curves cross at a daily mean discharge of about 160 ft^3/s. The following table shows the percent of time or when discharges were equaled or larger.

Variable	*10 percent or less of time*	*25 percent or less of time*	*50 percent or less of time*	*75 percent or less of time*	*90 percent or less of time*	*95 percent or less of time*
	Daily mean discharge, ft^3/s or larger					
Q_u	184	113	73	49	31	25
Q_l	190	97	55	34	24	22

CONCLUSIONS

In August and October 2009, the Alaska Department of Natural Resources measured discharge four times in the water delivery system of SSSC. Results indicate that SSSC uses about 6.5 to 7.7 ft^3/s of water diverted from the Indian River, about half of the proposed diversion. Proposed diversions as large as 15.4 to 16.3 ft^3/s may not be warranted.

SSSC's application for a salmon hatchery permit shows a maximum monthly water use of 4.2 (4.367-0.212, rounded) ft^3/s in August. If the raceway diversion were added, the maximum diversion rate is 9.2 ft^3/s.

Frequently (about 11 to 28 percent of the time), there is insufficient water in the Indian River at the upper gage to entirely meet ADFG's water-right requirements. About 19 to 45 percent of the time, ADFG's water-right requirements are not met at the lower gage, which is located just upstream of SITK.

For the measured diversion period of record (October 1998 through September 2000), all but one of the coefficients of correlation between two different datasets are weak. The daily mean discharge of the lower gage correlates strongly with that of the upper gage. Daily precipitation has weak coefficients of correlation with all discharge data sets. The measured diversions have weak correlations with discharge at the upper gage and lower gage.

The measured diversions provide the best information about the diversions proposed by SSSC, provided SSSC diverts and uses the same amount of water as SJC did. For the measured diversion period of record, it appears that on average about 6 ft^3/s (Q_d-Q_{rf}) was used to meet the needs of the hatchery. This takes into account lower and higher water-use rates over the period of record. Water use was 10 ft^3/s or less for 93 percent of time, 9 ft^3/s or less 75 percent of the time, and 8 ft^3/s or less 50 percent of the time. The water use never exceeded 14 ft^3/s during the measured diversion period of record, which indicates that proposed diversions as large as 15.4 to 16.3 ft^3/s may not be not warranted.

It was hypothesized that a mathematical or statistical relationship might exist between discharge at the lower gage less that upper gage and the measured diversions during the measured diversions period of record, and that this relationship could be used to predict diversions in other periods of record. The coefficient of determination (r^2) between the two sets of data is 0.00, however. Thus, the discharge at the lower gage less that upper gage cannot be used to predict diversions in other periods of record.

The mean gain to or loss from the river between the upper gage and lower gage excluding diversion (Q_x) is a substantial part of the water budget and thus cannot be ignored. For the measured diversion period of record, the mean gain to or loss from river between the upper gage and lower gage, excluding diversion, was 20 ft^3/s, only five percent less than the mean diversion of 21 ft^3/s. Over long periods of time, it appears that diversions capture most of Q_x.

For the measured diversion period of record, it appears that SJC did not actively manage the headgate, except for maintenance, perhaps in November 1998.

A model was constructed to predict diversions for periods of record not having measured diversions. The results of the model only work well for long periods of time, when predicted diversions are averaged. The mean predicted diversion for the later period of record (June 2007 through September 2009) is 16 ft^3/s, approximately SSSC's maximum proposed daily mean diversion rate. However, the coefficient of correlation ($r = 0.34$) and the coefficient of determination ($r^2 = 0.10$) between the predicted diversions and SSSC proposed diversions over the later period of record are very weak.

The discharge of the lower gage appears to be larger than that of the upper gage about 12 to 14 percent of the time, thus reducing instream flows available for salmonids at SITK.

For the combined period of record (October 1998 through September 2003, and June 2007 through September 2009), the minimum daily mean discharge at the lower gage was about 9 ft^3/s. For the combined summer period of record (July through September, 1999 through 2003, and 2007 through 2009), the minimum daily mean discharge at the lower gage was 14 ft^3/s.

For the combined period of record (October 1998 through September 2003, and June 2007 through September 2009), the daily mean discharge at the lower gage was 16 ft^3/s or larger for 95 percent of the time. For the combined summer period of record (July through September, 1999 through 2003, and 2007 through 2009), the daily mean discharge at the lower gage was 22 ft^3/s or larger for 95 percent of the time.

In sum, there is no evidence to conclude that hatchery facilities have used 15.4 to 16.3 ft^3/s from June 16 to November 30. It appears that, on the average 6 to 8 ft^3/s of water has been sufficient to meet the needs of the facilities. This range does not take into account any transmission losses that might occur from the diversion dam to the facilities.

RECOMMENDATIONS

Proposed raceway discharges of 5 ft^3/s, incubation, rearing, and adult/holding fish ladder water use are not questioned. These diversions range from a total of 5.4 to 9.2 ft^3/s. It is not understood, however, why SSSC requires water use greater than 9.2 ft^3/s. SSSC proposed diversions and NPS recommended diversions are shown in the table below.

Month	*SSSC proposed diversions, ft^3/s*	*NPS recommended diversions, ft^3/s*
Jan	6.4	6.4
Feb	6.4	6.4
Mar	6.7	6.4
Apr	6.8	6.4
May	6.8	6.6
Jun	10.4	5.4
Jul	15.5	7.1
Aug	15.8	8.9
Sep	16.2	9.2
Oct	16.2	7.7
Nov	16.3	6.4
Dec	6.4	6.4

The SSSC proposed diversions in the table above was calculated from values in Table 1. The NPS recommended diversions are calculated by adding Columns 1, 2, and 3 in Table 3 with the value 5 ft^3/s.

It is recommended that SSSC measure its diversions. In lieu of measuring its diversions, SSSC could establish and operate another gaging station just upstream from the main dam on the Indian River. If a gaging station is operated just upstream of the main dam, the upper gage could be discontinued, provided a suitable site exists. It is also recommended that SSSC report quarterly data collected to interested parties.

It is recommended that SSSC participate in the funding and/or operation of the lower gage along with the NPS, ADFG, and CBS.

The return flows to the river do not appear necessary. It is recommended that SSSC only divert the water necessary to support hatchery operations. The return-flow ditch may be used, when maintenance is necessary.

The diversion control structures need to be properly adjusted, as flows change, to pass SSSC's approved diversion rates, thereby reducing effects on instream flows and salmonids.

It is recommended that the ADNR issue a conditional or temporary right, until beneficial use is documented and proven through actual measurements.

It is recommended that stakeholders work together to reduce diversions during low-flow periods, which harm salmon in the Indian River.

REFERENCES CITED

Alaska Department of Fish and Game (2010a), "ADFG Wildlife Notebook Series, Fish," accessed December 16, 2010, at http://www.adfg.state.ak.us/pubs/notebook/notehome.php.

Alaska Department of Fish and Game (2010b), "Application, Private Nonprofit Salmon Hatchery Permit, Sitka Sound Science Center," received September 28 2010, and accessed December 23, 2010, at http://www.cf.adfg.state.ak.us/geninfo/enhance/hatchery/11-1_sssc_sjh_hatchery_application.pdf.

Alaska Department of Natural Resources, Alaska Hydrologic Survey MLW, 2010, Memorandum from Terry Schwartz to Gary Prokosch, dated May 12, 2010, subject Sheldon Jackson Hatchery water use, ADL 43671, pages unnumbered.

Desert Research Institute (2010), "Western Regional Climate Center, Historical Climate Information," accessed September 29, 2010 at http://www.wrcc.dri.edu/CLIMATEDATA.html.

Eckert, G., Hood, E., Talus, C., and Nagorski, S., 2006, Assessment of coastal water resources and watershed conditions at Sitka National Historical Park: National Park Service, Natural Resources Program Center, Water Resources Division, Technical Report NPS/NRWRD/NRTR-2006/347, 81 p.

Neal, .E.G., Brabets, T.P., and Frenzel, S.A., 2004, Water quality and streamflow of the Indian River, Sitka, Alaska, 2001-2: US Geological Survey Scientific investigation Report 04-5023, 33 p.

National Oceanic and Atmospheric Administration (2010), "NOAA Satellite and Information Service, National Climatic Data Center, Locate Weather Observation Station Record," requested records accessed August 20, 2010 at http://www.ncdc.noaa.gov/oa/climate/stationlocator.html.

Smith, G., 2010, Indian River stream gauge monitoring, *in* Alaska Park Science, Volume 9, Issue 1, June 2010, 1 p., accessed November 8, 2010 at http://www.nps.gov/akso/AKParkScience/2010Vol9-1/Indian-River-Stream-Gauge-Smith.pdf .

U.S. Geological Survey, 2010a, "National Water Information System, USGS Surface-Water Data for the Nation," accessed several times in August and September 2010 at http://waterdata.usgs.gov/nwis/sw.

U.S. Geological Survey, 2010b, "Explanation of the Records," accessed November 1, 2010 at http://il.water.usgs.gov/annual_report/misc/cdextion.htm.

U.S. Geological Survey, 2010c, "Flow-Duration Plot Description," accessed November 1, 2010 at http://va.water.usgs.gov/duration_plots/fdp_description.htm.

FIGURES

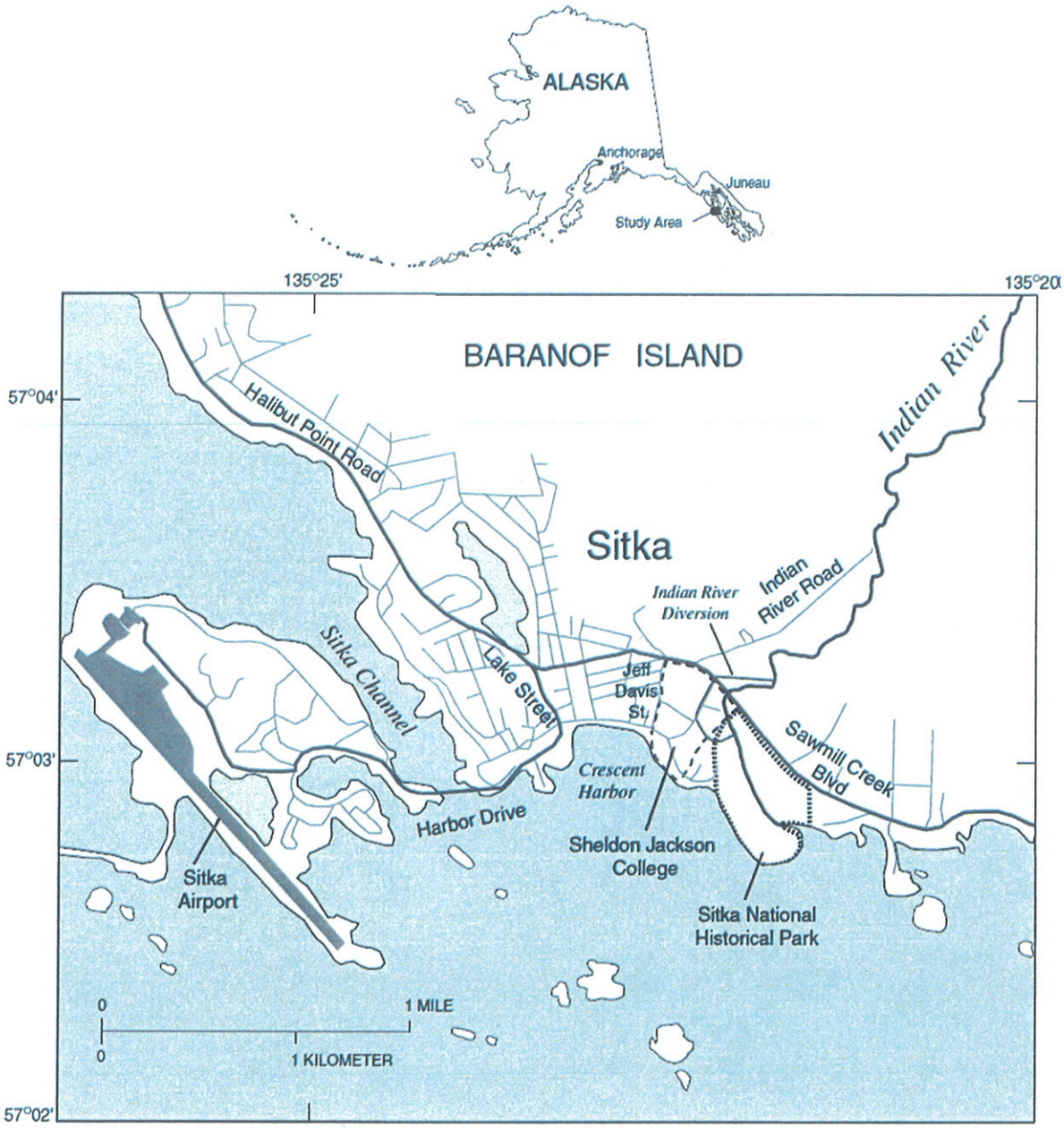


Figure 1. Location of Sitka and the Indian River

From Neal and others, 2004, p. 2.

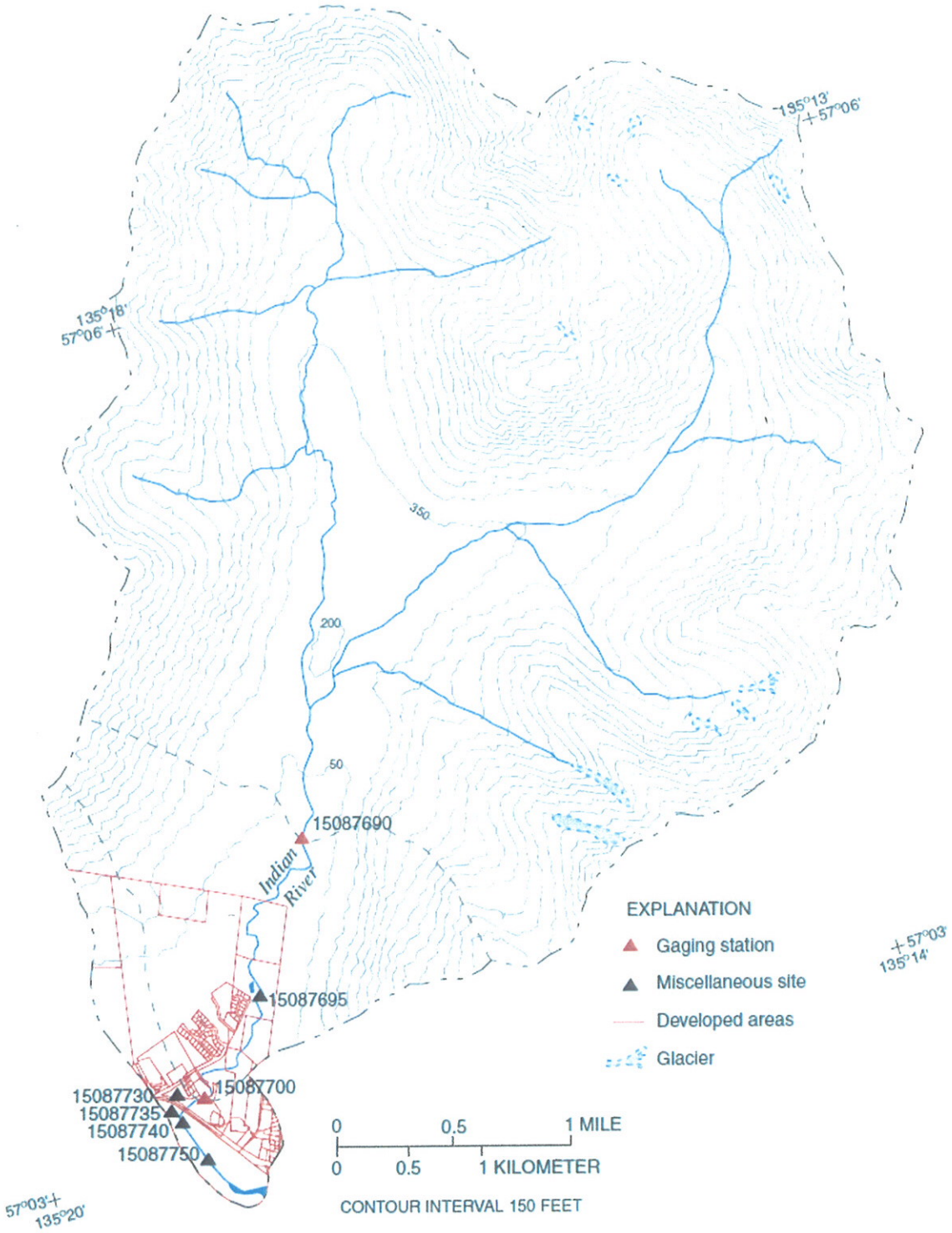
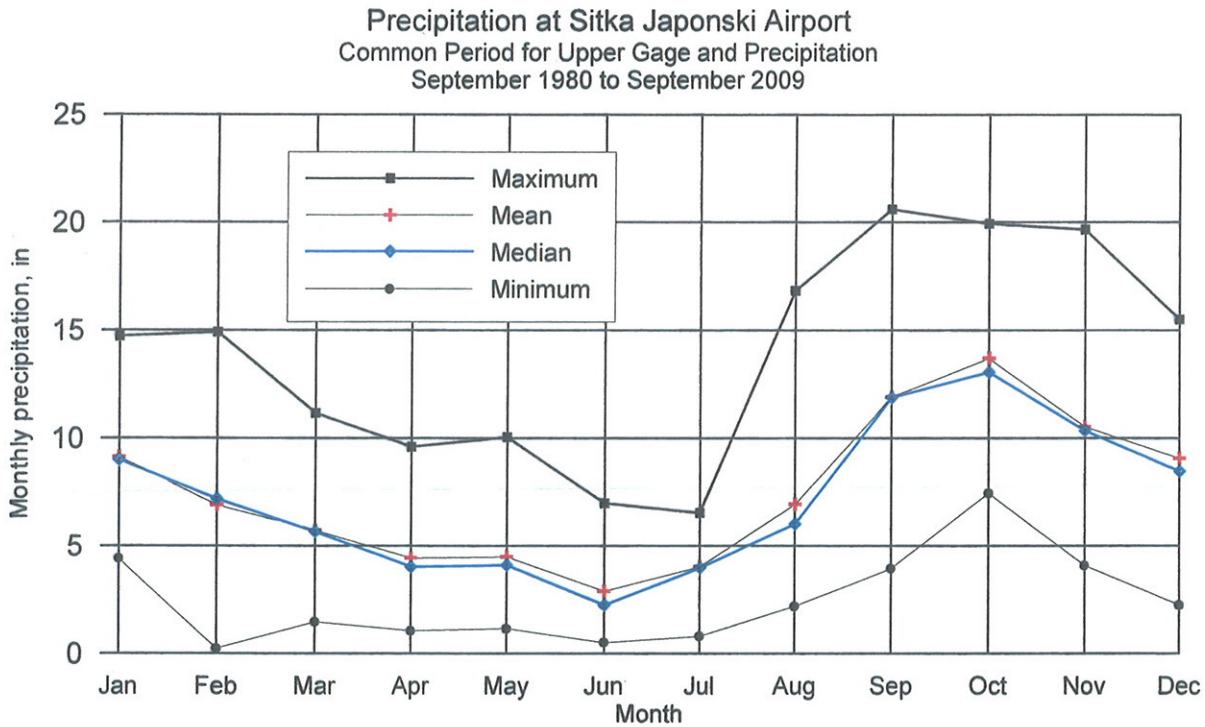


Figure 2. Indian River watershed, Alaska

From Neal and others, 2004, p. 3


Precipitation at Sitka Japonski Airport
Common Period for Upper Gage and Precipitation
September 1980 to September 2009
Maximum
Mean
Median
Minimum
Monthly precipitation, in
25
20
15
10
5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

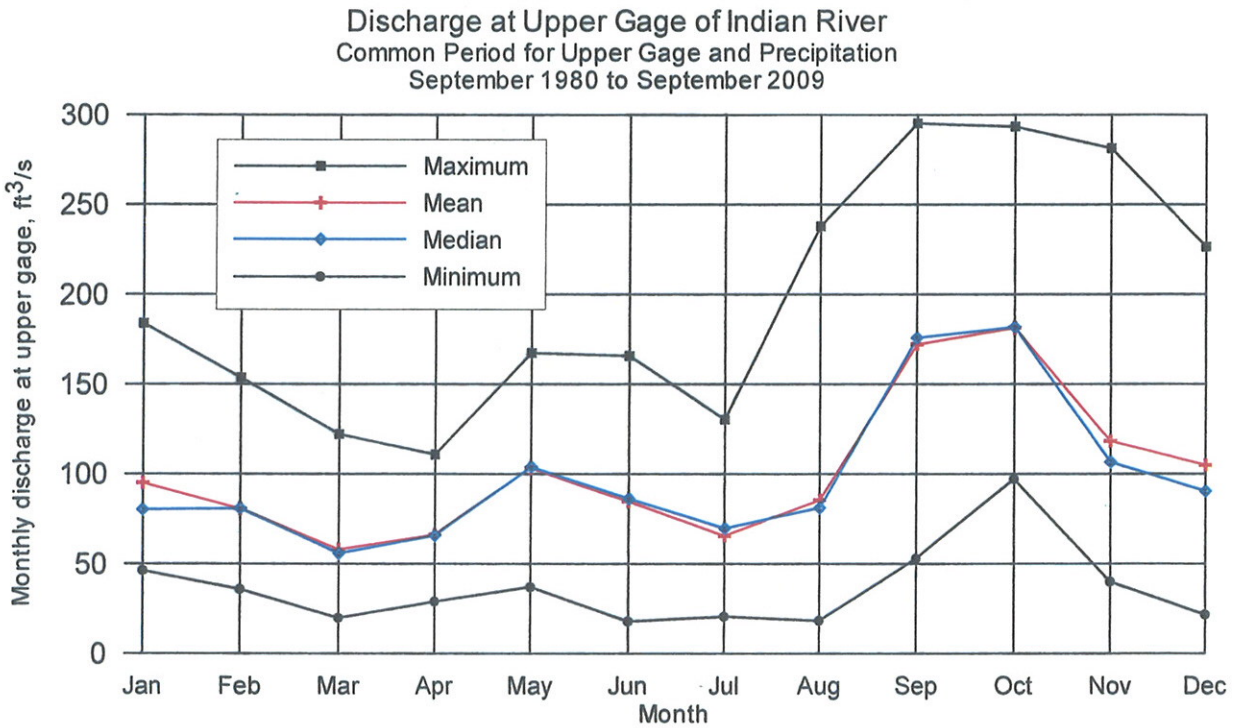

Discharge at Upper Gage of Indian River
Common Period for Upper Gage and Precipitation
September 1980 to September 2009
Maximum
Mean
Median
Minimum
Monthly discharge at upper gage, ft3/s
300
250
200
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

Figure 3

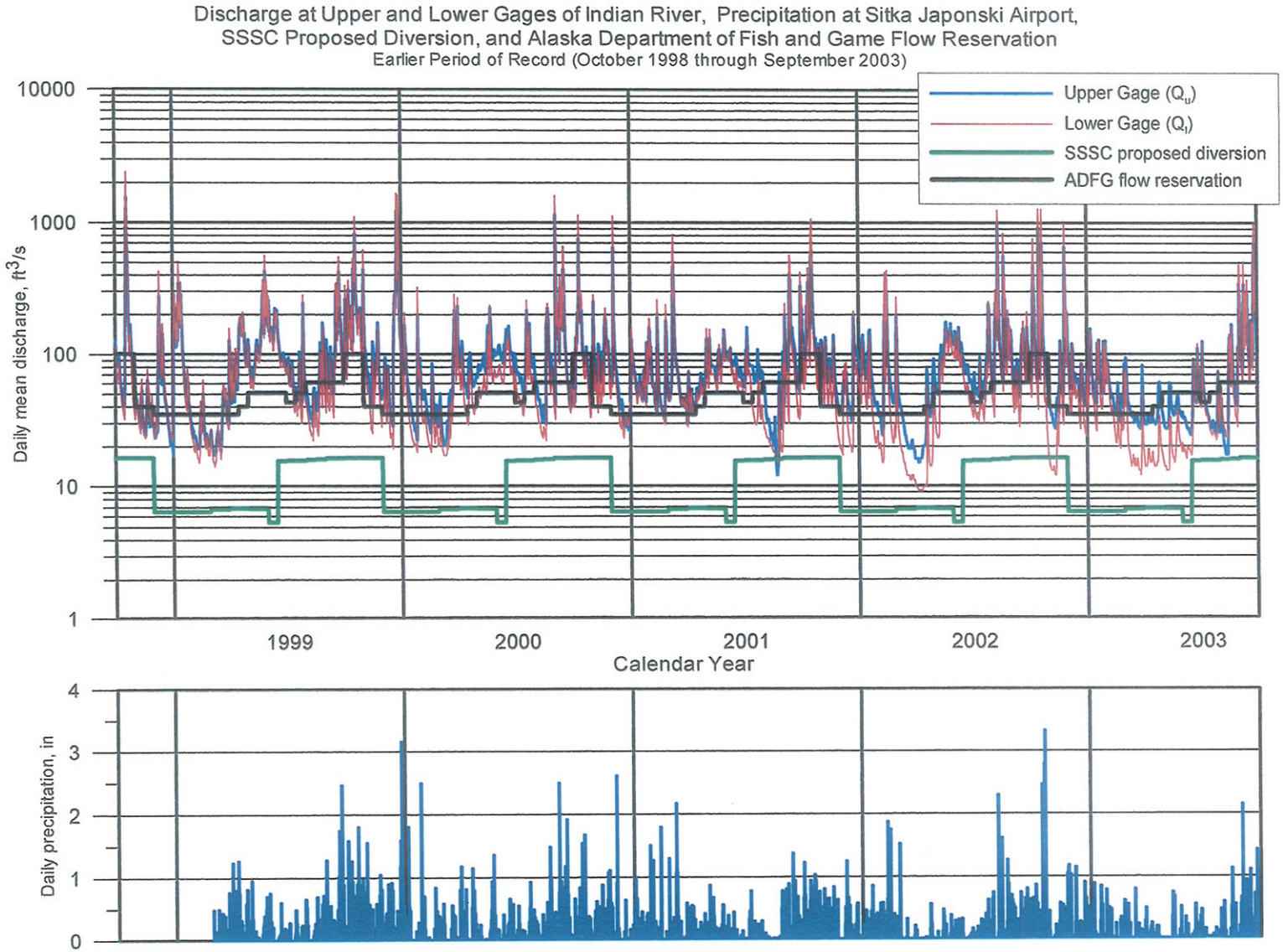

Discharge at Upper and Lower Gages of Indian River, Precipitation at Sitka Japonski Airport,
SSSC Proposed Diversion, and Alaska Department of Fish and Game Flow Reservation
Earlier Period of Record (October 1998 through September 2003)
Upper Gage (Q_u)
Lower Gage (Q_l)
SSSC proposed diversion
ADFG flow reservation
Daily mean discharge, ft^3/s
10000
1000
100
10
1
1999
2000
2001
2002
2003
Calendar Year
Daily precipitation, in
4
3
2
1
0

Figure 4

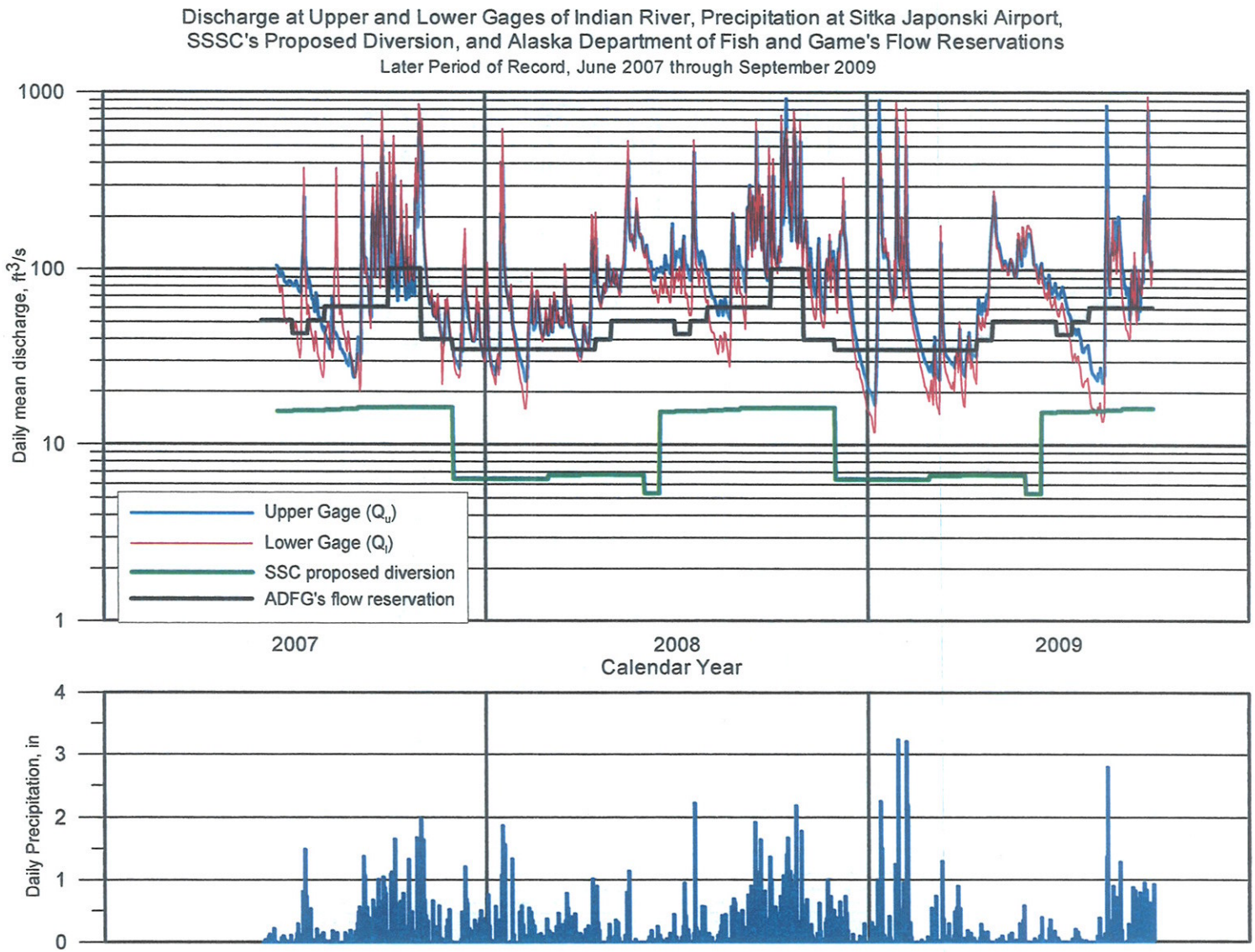

Discharge at Upper and Lower Gages of Indian River, Precipitation at Sitka Japonski Airport,
SSSC's Proposed Diversion, and Alaska Department of Fish and Game's Flow Reservations
Later Period of Record, June 2007 through September 2009
Daily mean discharge, ft3/s
1000
100
10
1
Upper Gage (Qu)
Lower Gage (Ql)
SSC proposed diversion
ADFG's flow reservation
2007
2008
2009
Calendar Year
Daily Precipitation, in
4
3
2
1
0

Figure 5.

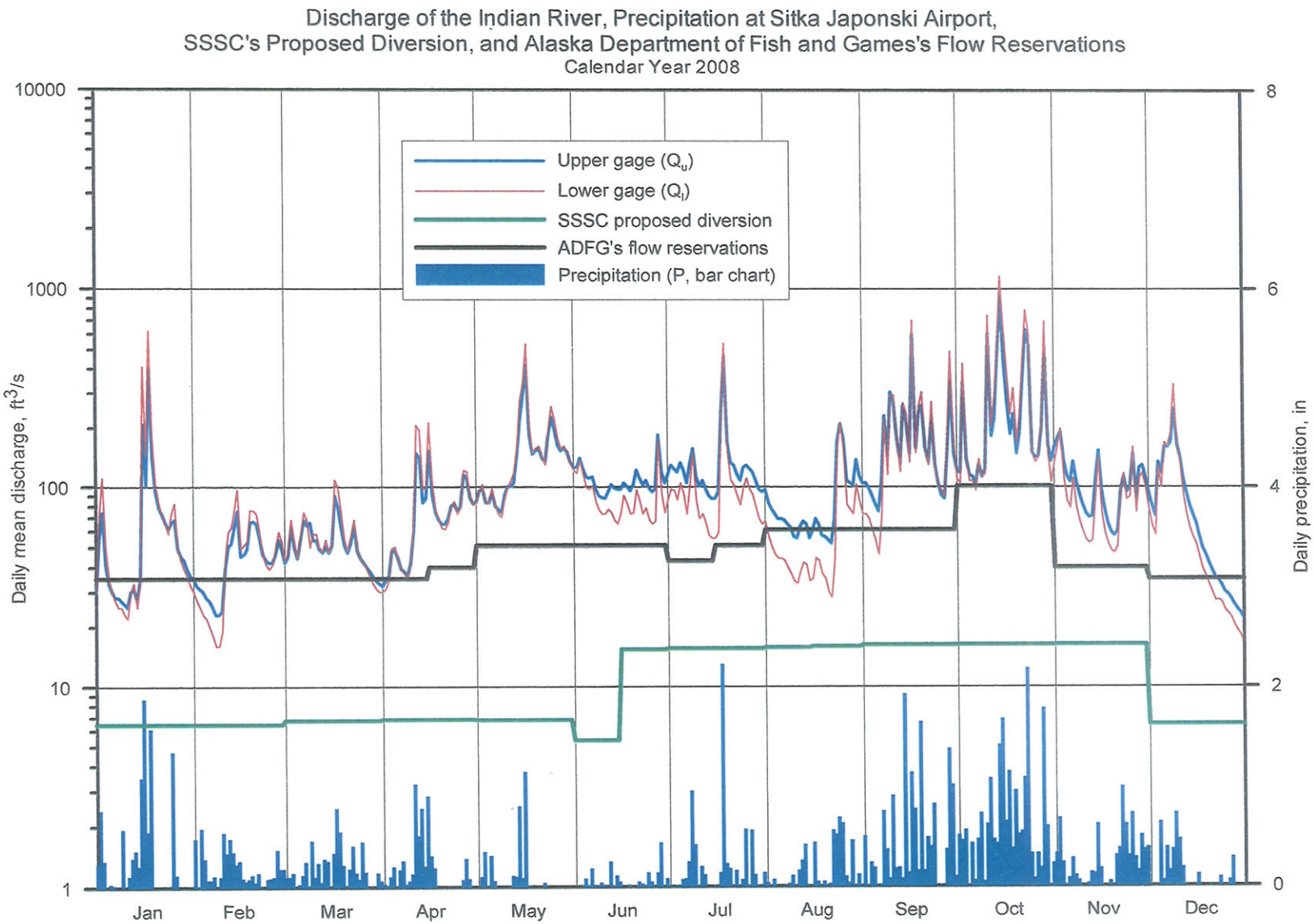

Discharge of the Indian River, Precipitation at Sitka Japonski Airport,
SSSC's Proposed Diversion, and Alaska Department of Fish and Games's Flow Reservations
Calendar Year 2008
Upper gage (Q_u)
Lower gage (Q_l)
SSSC proposed diversion
ADFG's flow reservations
Precipitation (P, bar chart)
Daily mean discharge, ft^3/s
Daily precipitation, in
10000
1000
100
10
1
8
6
4
2
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Figure 6

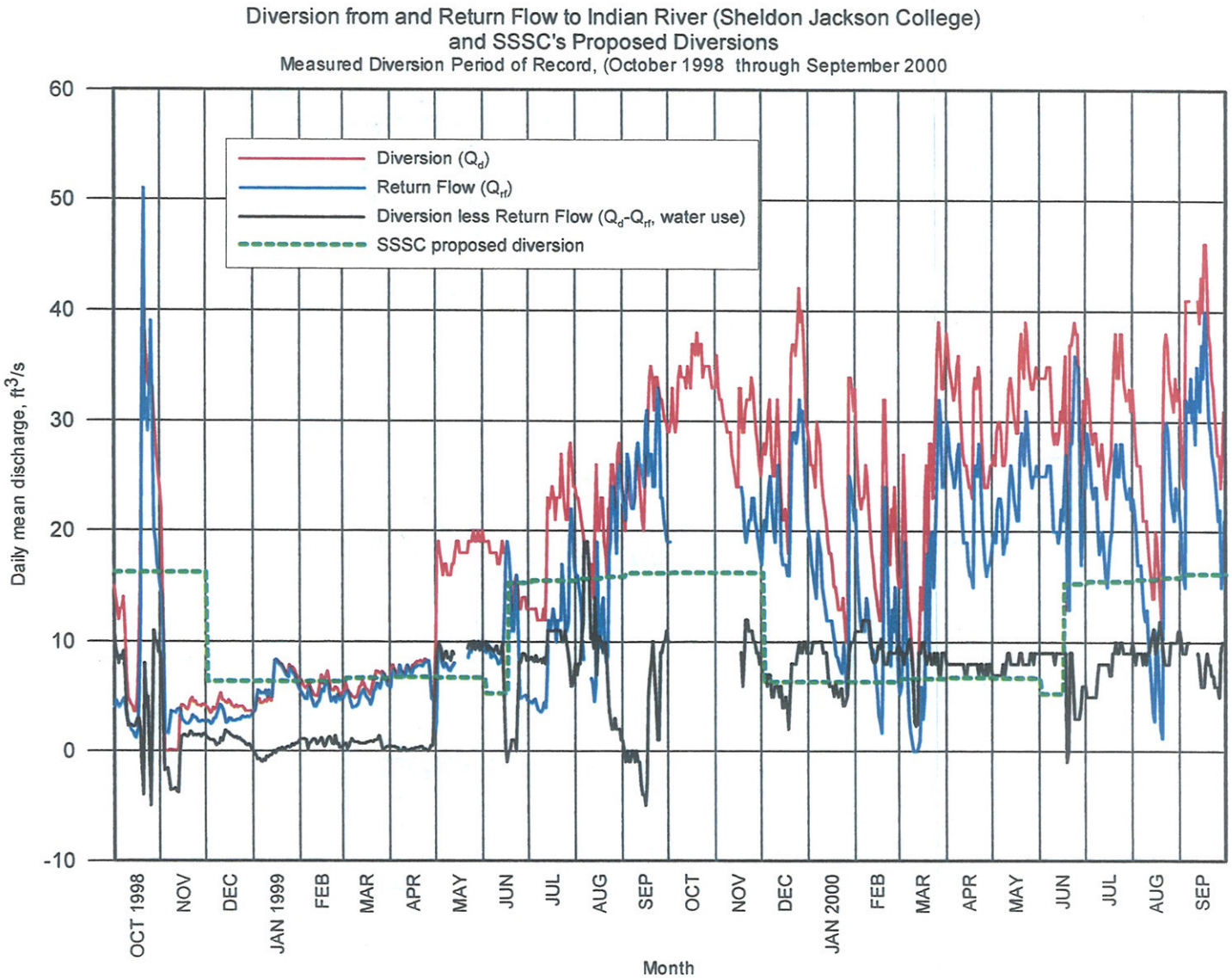

Diversion from and Return Flow to Indian River (Sheldon Jackson College)
and SSSC's Proposed Diversions
Measured Diversion Period of Record, (October 1998 through September 2000
Diversion (Q_d)
Return Flow (Q_{rf})
Diversion less Return Flow (Q_d-Q_{rf}, water use)
SSSC proposed diversion
Daily mean discharge, ft^3/s
60
50
40
30
20
10
0
-10
OCT 1998
NOV
DEC
JAN 1999
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN 2000
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
Month

Figure 7

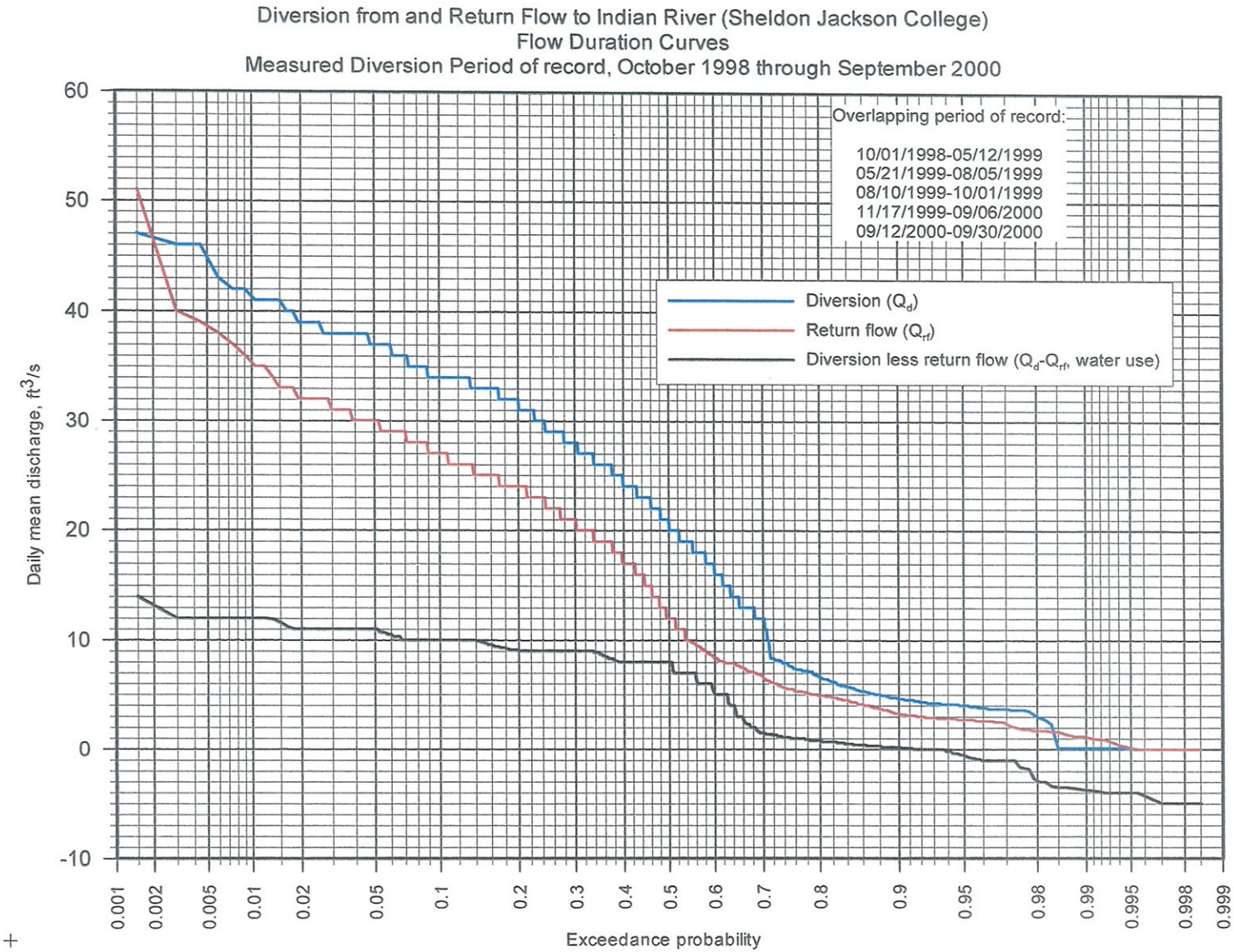

Diversion from and Return Flow to Indian River (Sheldon Jackson College)
Flow Duration Curves
Measured Diversion Period of record, October 1998 through September 2000
Overlapping period of record:
10/01/1998-05/12/1999
05/21/1999-08/05/1999
08/10/1999-10/01/1999
11/17/1999-09/06/2000
09/12/2000-09/30/2000
Diversion (Q_d)
Return flow (Q_{rf})
Diversion less return flow (Q_d-Q_{rf}, water use)
Daily mean discharge, ft^3/s
60
50
40
30
20
10
0
-10
0.001
0.002
0.005
0.01
0.02
0.05
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0.95
0.98
0.99
0.995
0.998
0.999
Exceedance probability

Figure 8

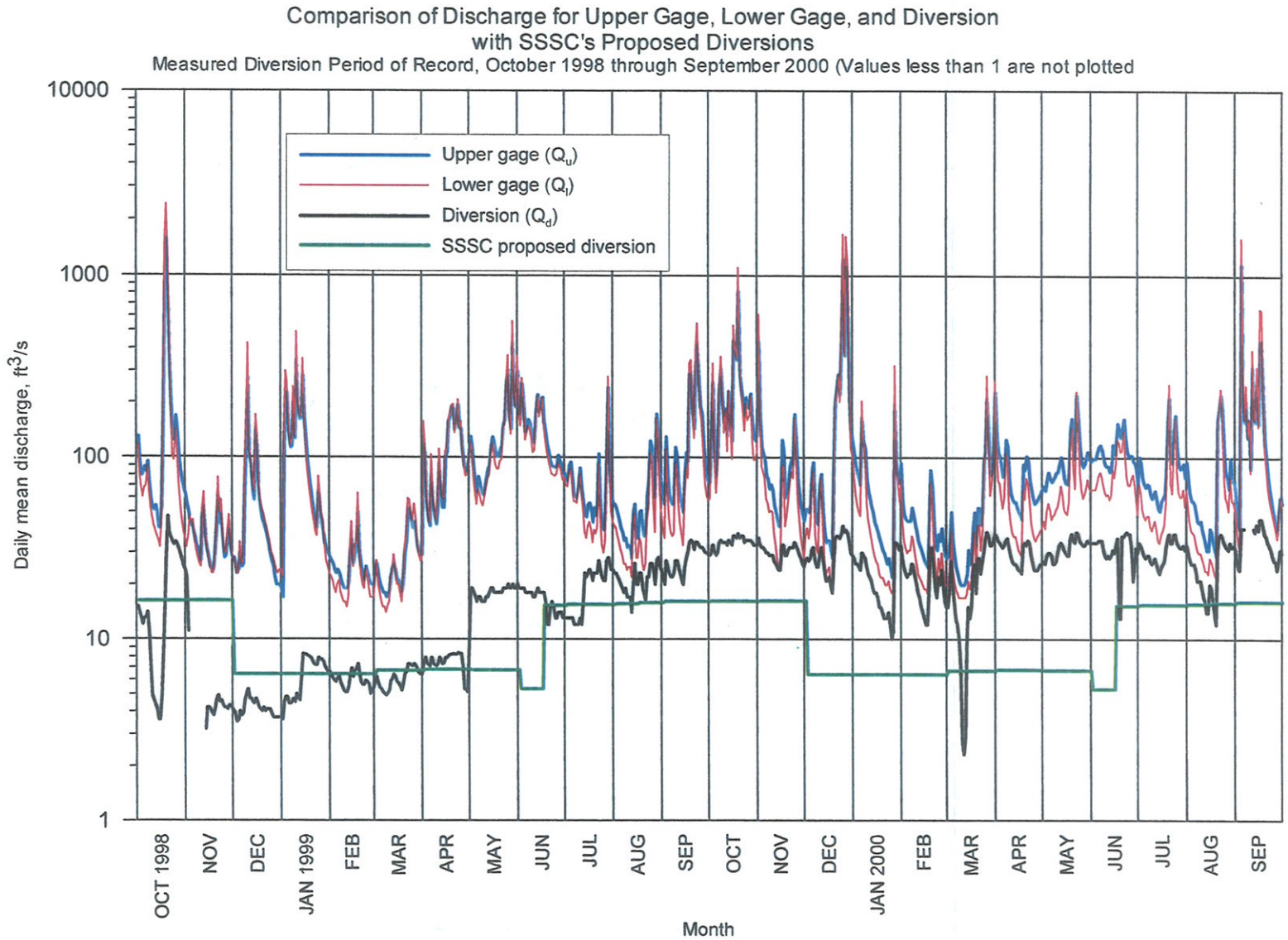

Comparison of Discharge for Upper Gage, Lower Gage, and Diversion
with SSSC's Proposed Diversions
Measured Diversion Period of Record, October 1998 through September 2000 (Values less than 1 are not plotted
Upper gage (Q_u)
Lower gage (Q_l)
Diversion (Q_d)
SSSC proposed diversion
Daily mean discharge, ft^3/s
10000
1000
100
10
1
OCT 1998
NOV
DEC
JAN 1999
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN 2000
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
Month

Figure 9

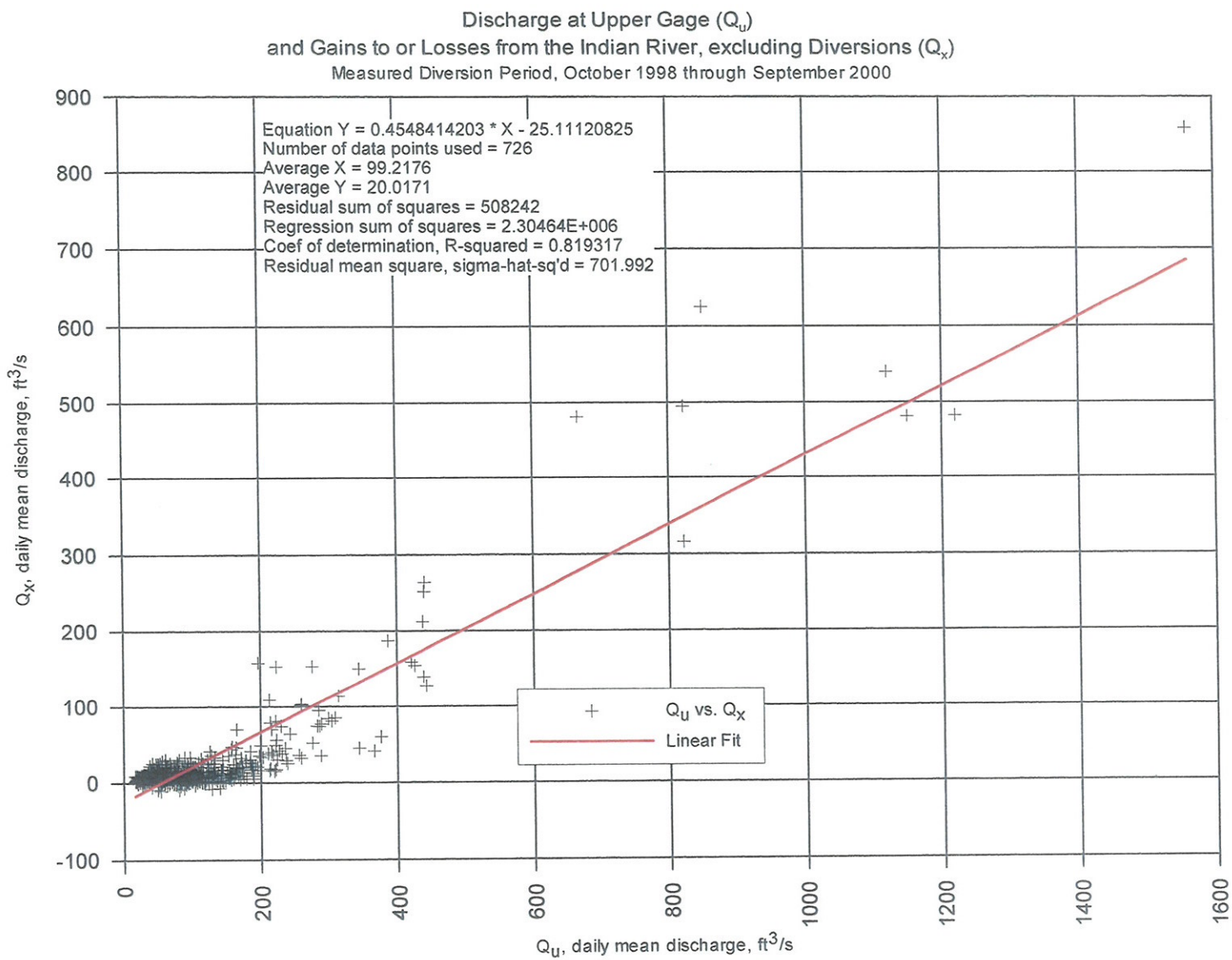

Discharge at Upper Gage (Q_u)
and Gains to or Losses from the Indian River, excluding Diversions (Q_x)
Measured Diversion Period, October 1998 through September 2000
Equation Y = 0.4548414203 * X - 25.11120825
Number of data points used = 726
Average X = 99.2176
Average Y = 20.0171
Residual sum of squares = 508242
Regression sum of squares = 2.30464E+006
Coef of determination, R-squared = 0.819317
Residual mean square, sigma-hat-sq'd = 701.992
Q_u vs. Q_x
Linear Fit
Q_x, daily mean discharge, ft^3/s
Q_u, daily mean discharge, ft^3/s
900
800
700
600
500
400
300
200
100
0
-100
0
200
400
600
800
1000
1200
1400
1600

Figure 10

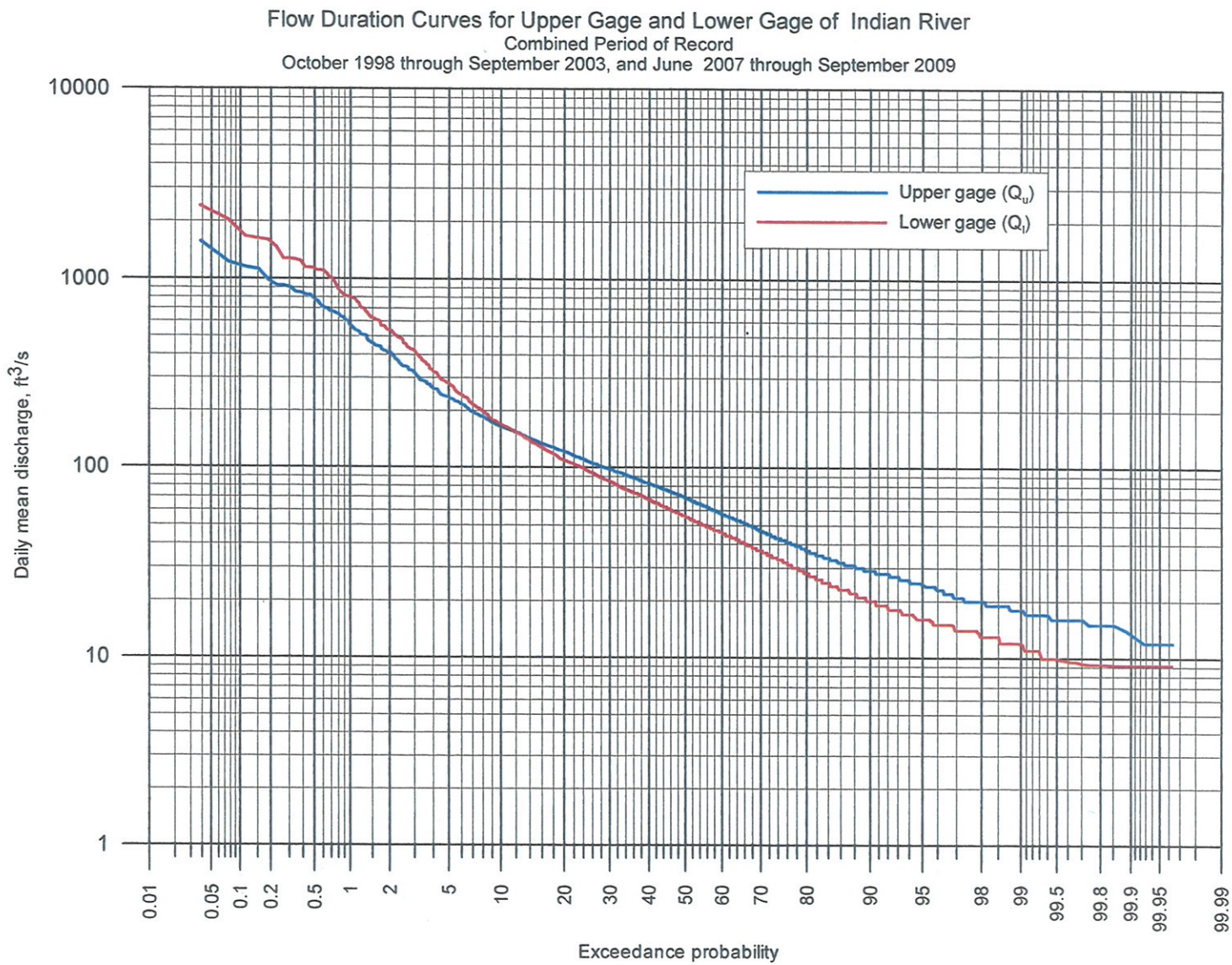

Flow Duration Curves for Upper Gage and Lower Gage of Indian River
Combined Period of Record
October 1998 through September 2003, and June 2007 through September 2009
Upper gage (Q_u)
Lower gage (Q_l)
Daily mean discharge, ft^3/s
10000
1000
100
10
1
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.5
99.8
99.9
99.95
99.99
Exceedance probability

Figure 11.

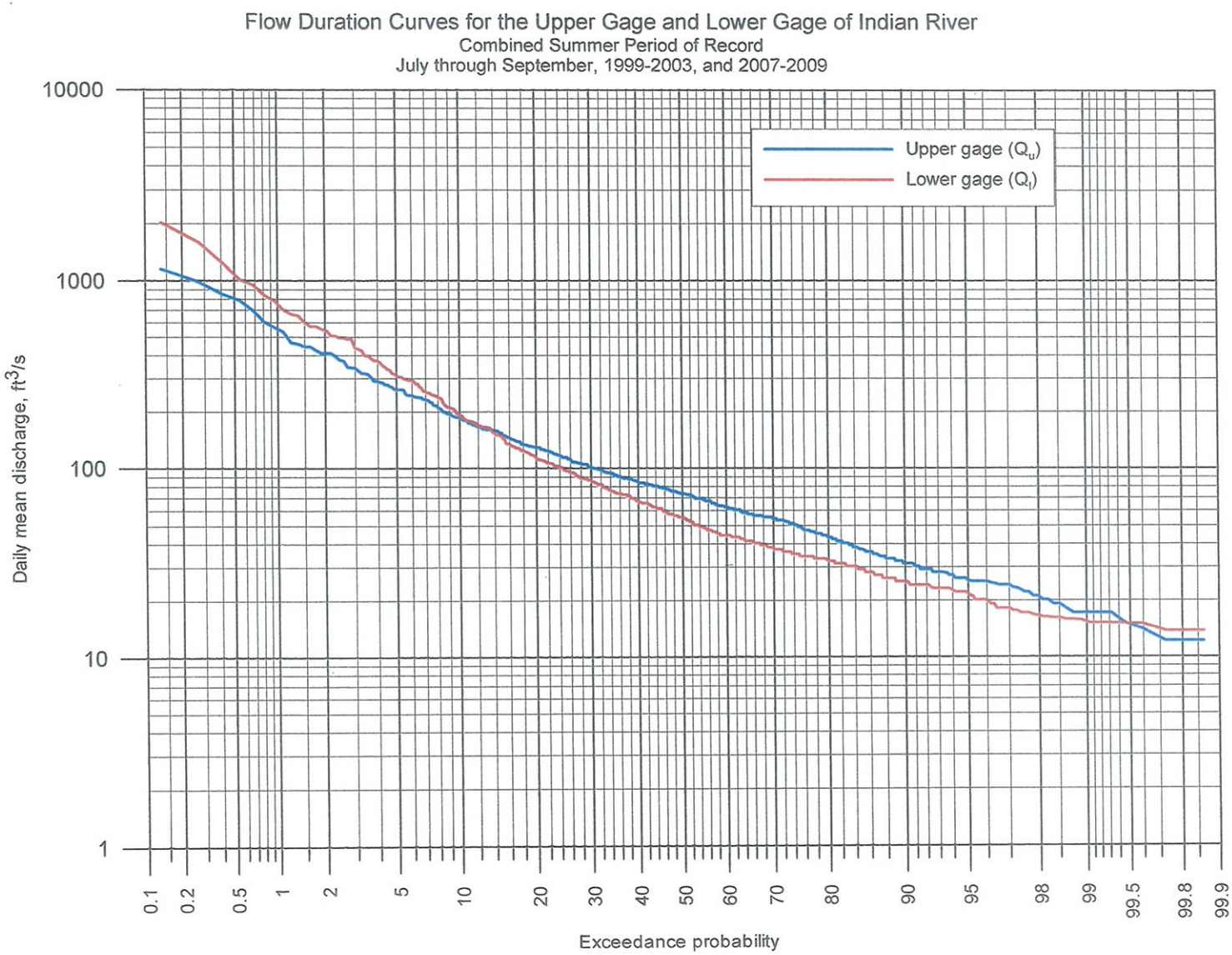

Flow Duration Curves for the Upper Gage and Lower Gage of Indian River
Combined Summer Period of Record
July through September, 1999-2003, and 2007-2009
Upper gage (Q_u)
Lower gage (Q_l)
Daily mean discharge, ft^3/s
10000
1000
100
10
1
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.5
99.8
99.9
Exceedance probability

Figure 12

TABLES

TABLE 1.
PROPOSED DIVERSION SCHEDULE OF SSSC
(from Alaska Department of Natural Resources, 2010)

DATE	RACEWAY (cfs)	INCUBATION (cfs)	REARING (cfs)	TOTAL (cfs)
January 1-15	5	0.178	1.248	6.426
January 16-31	5	0.178	1.248	6.426
February 1-15	5	0.178	1.248	6.426
February 16-28	5	0.178	1.248	6.426
March 1-15	5	0.134	1.604	6.738
March 16-31	5	0.134	1.604	6.738
April 1-15	5	0.045	1.782	6.827
April 16-30	5	0.045	1.782	6.827
May 1-15	5	0	1.782	6.782
May 16-30	5	0	1.782	6.782
June 1-15	5	0	0.356	5.356
June 16-30	15	0	0.356	15.356
July 1-15	15	0	0.535	15.535
July 16-31	15	0	0.535	15.535
August 1-15	15	0.011	0.713	15.724
August 16-31	15	0.178	0.713	15.891
September 1-15	15	0.312	0.891	16.203
September 16-30	15	0.312	0.891	16.203
October 1-15	15	0.356	0.891	16.247
October 16-31	15	0.356	0.891	16.247
November 1-15	15	0.178	1.096	16.274
November 16-30	15	0.178	1.096	16.274
December 1-15	5	0.178	1.248	6.426
December 16-31	5	0.178	1.248	6.426

Figure 9 (Proposed flow schedule for the SSSC hatchery. Raceway flow from the 47" wooden pipe and incubation and rearing flow from the 12" HDPE pipe)

TABLE 2. WATER USE NOTED IN SSSC'S PPLICATION FOR SALMON HATCHERY PERMIT (ADFG, 2010b, Appendix H)

9/23/2010
Sheldon Jackson Hatchery Water Useage Table
All water flow values are in liters per minute

Month	Incubation pink	Incubation chum	Incubation coho	Incubation Total	Freshwater Rearing	Adult Holding/fish ladder	Total Monthly Water Useage
January	270	90	80	440	1900	0	2780
February	270	90	80	440	1900	0	2780
March	270	90	80	440	1900	0	2780
April	0	0	80	80	2240	0	2400
May	0	0	0	0	2800	0	2800
June	0	0	0	0	700	0	700
July	0	0	0	0	1100	2400	3500
August	240	120	0	360	1500	4800	7020
September	240	120	0	360	1900	4800	7420
October	240	120	0	360	1900	2400	5020
November	270	90	80	440	1900	0	2780
December	270	90	80	440	1900	0	2780

January	2,780
February	2,780
March	2,780
April	2,400
May	2,800
June	700
July	3,500
August	7,020
September	7,420
October	5,020
November	2,780
December	2,780

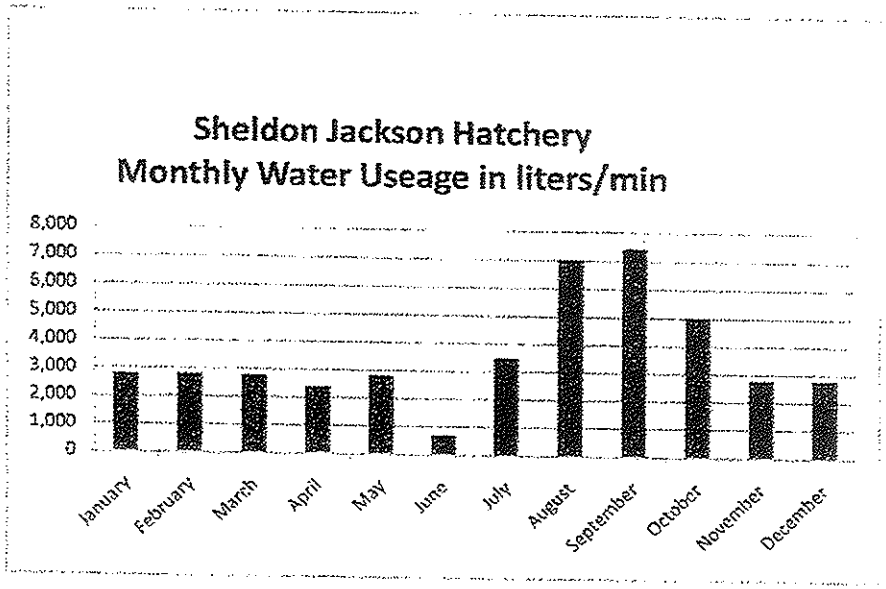


TABLE 3. COMPARISON OF SSSC'S PROPOSED DIVERSIONS AND WATER USE

(from ADWR 2010, Figure 9) Proposed diversion of SSSC All values ft^3/s					(from ADFG, 2010a, Appendix H) SSSC water use All values ft^3/s				
Raceway	Incubation	Rearing	Total	Dates	Total	Adult holding/fish ladder (Column1)	Freshwater rearing (Column 2)	Incubation (Column 3)	Other (not listed in water use table)
5	0.178	1.248	6.426	Jan 1-15	1.636	0.000	1.118	0.259	0.259
5	0.178	1.248	6.426	Jan 16-31	1.636	0.000	1.118	0.259	0.259
5	0.178	1.248	6.426	Feb 1-15	1.636	0.000	1.118	0.259	0.259
5	0.178	1.248	6.426	Feb 16-28	1.636	0.000	1.118	0.259	0.259
5	0.134	1.604	6.738	Mar 1-15	1.636	0.000	1.118	0.259	0.259
5	0.134	1.604	6.738	Mar 16-31	1.636	0.000	1.118	0.259	0.259
5	0.045	1.782	6.827	Apr 1-15	1.413	0.000	1.318	0.047	0.047
5	0.045	1.782	6.827	Apr 16-30	1.413	0.000	1.318	0.047	0.047
5	0.000	1.782	6.782	May 1-15	1.648	0.000	1.648	0.000	0.000
5	0.000	1.782	6.782	May 16-31	1.648	0.000	1.648	0.000	0.000
5	0.000	0.356	5.356	Jun 1-15	0.412	0.000	0.412	0.000	0.000
15	0.000	0.356	15.356	Jun 16-30	0.412	0.000	0.412	0.000	0.000
15	0.000	0.535	15.535	Jul 1-15	2.060	1.413	0.647	0.000	0.000
15	0.000	0.535	15.535	Jul 16-31	2.060	1.413	0.647	0.000	0.000
15	0.011	0.713	15.724	Aug 1-15	4.132	2.825	0.883	0.212	0.212
15	0.178	0.713	15.891	Aug 16-31	4.132	2.825	0.883	0.212	0.212
15	0.312	0.891	16.203	Sep 1-15	4.367	2.825	1.118	0.212	0.212
15	0.312	0.891	16.203	Sep 16-30	4.367	2.825	1.118	0.212	0.212
15	0.356	0.891	16.247	Oct 1-15	2.955	1.413	1.118	0.212	0.212
15	0.356	0.891	16.247	Oct 16-31	2.955	1.413	1.118	0.212	0.212
15	0.178	1.096	16.274	Nov 1-15	1.636	0.000	1.118	0.259	0.259

(from ADWR 2010, Figure 9) Proposed diversion of SSSC All values ft^3/s					(from ADFG, 2010a, Appendix H) SSSC water use All values ft^3/s				
Raceway	Incubation	Rearing	Total	Dates	Total	Adult holding/fish ladder (Column1)	Freshwater rearing (Column 2)	Incubation (Column 3)	Other (not listed in water use table)
15	0.178	1.096	16.274	Nov 16-30	1.636	0.000	1.118	0.259	0.259
5	0.178	1.248	6.426	Dec 1-15	1.636	0.000	1.118	0.259	0.259
5	0.178	1.248	6.426	Dec 16-31	1.636	0.000	1.118	0.259	0.259

Table 4. Monthly and Annual Precipitation at Sitka Japonski Airport for the common period between the upper gage and precipitation. (Months are not included where more than five days of daily precipitation are missing. and where no mean monthly discharge is available in the table below. Annuals are not calculated where one or more months are missing.)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1980									11.48	18.91	14.25	7.65	
1981	8.21	7.11	5.07	4.33	2.05	4.05	5.18	8.32	16.60	12.74	12.95	4.32	90.93
1982	7.37	3.07	5.97	5.78	10.04	0.89	2.54	5.66	8.70	15.09	5.62	4.84	75.57
1983	9.43	4.88	2.80	9.60	9.52	2.19	2.56	16.82	12.86	15.00	4.08	2.25	91.99
1984	14.71	10.42	7.51	2.75	3.19	5.59	4.39	10.29	6.15	8.19	7.76	11.96	92.91
1985	12.69	14.91	8.91	7.58	5.42	5.71	3.41	5.75	8.91	12.11	5.02	13.15	103.57
1986	9.16	5.72	11.16	6.23	3.89	5.16	3.32	8.33	3.94	19.21	13.87	12.95	102.94
1987	9.97	7.19	5.07	6.86	5.36	6.98	4.32	4.75	20.59	17.80	12.07	13.70	114.66
1988	5.98	12.21	9.35	3.91	5.80	1.48	4.88	5.81	10.61	16.62	12.42	8.36	97.43
1989	11.37	0.23	1.92	1.14	4.26	2.12	2.43	2.43	11.91	9.16	13.46	11.50	71.93
1990	7.23	7.43	5.91	2.27	1.22	3.00	3.29	7.67	16.03	12.75	7.08	11.94	85.82
1991	4.42	8.37	5.73	5.22	4.86	2.08	5.69	11.45	18.68	12.99	14.88	12.08	106.45
1992	12.77	8.09	7.92	3.81	9.01	3.35	5.11	6.79	12.61	8.69	10.95	8.11	97.21
1993	12.36	8.67	5.60	3.10	2.33	1.18	2.68	2.79	8.71				
1999			4.71	8.47	6.75	2.39	3.47	6.71		18.70	9.01	14.56	
2000	8.75	3.60	5.31	5.83	4.56	4.11	5.45	5.92	13.35	13.08	9.68	5.58	85.22
2001	9.67	5.14	8.26	3.93	6.09	1.50	3.94	2.50	10.78	11.89	6.08	6.30	76.08
2002	5.80	10.59	2.67	1.05	2.82	1.80	4.81	11.57	8.14	13.15	8.62	6.22	77.24
2003	5.60	2.84	3.67	1.27	3.05	3.75	1.67	5.99	11.78	7.44	12.91	8.53	68.50
2004	7.70	7.84		4.05	2.34	0.51	3.91	2.92		10.64	19.67	15.50	
2005	7.37	6.55	4.71	3.62	1.15	2.25	6.46	9.86	14.26	10.40	16.81	10.18	93.62
2006	6.79	3.86	1.47										
2007							5.70	2.19	12.02	16.74	6.27	6.23	
2008	9.39	5.45	5.66	5.35	3.11	1.78	6.54	4.79	14.00	19.93	8.00	3.58	87.58
2009	13.75	7.59	6.35	1.45	1.94	1.75	0.80	9.73	9.43				

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
count	22	22	22	22	22	22	23	23	22	22	22	22	18
maximum	14.71	14.91	11.16	9.60	10.04	6.98	6.54	16.82	20.59	19.93	19.67	15.50	114.66
minimum	4.42	0.23	1.47	1.05	1.15	0.51	0.80	2.19	3.94	7.44	4.08	2.25	68.50
mean	9.11	6.90	5.72	4.44	4.49	2.89	4.02	6.91	11.89	13.69	10.52	9.07	89.98
median	8.96	7.15	5.63	3.99	4.08	2.22	3.94	5.99	11.85	13.04	10.32	8.45	91.46
st dev	2.84	3.33	2.45	2.39	2.58	1.74	1.51	3.59	3.92	3.80	4.14	3.87	12.40

Table 5. Mean Monthly and Annual Discharge at the Upper Gage during the common period

Months are not included where mean monthly discharge is not calculated
and where monthly precipitation does not occur in table above.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1980									130.8	245.4	106.8	60.7	
1981	138.9	81	48.4	39.1	53.3	53.8	84.6	94.7	195.2	121.8	135.7	50.7	91.4
1982	67.6	35.9	33.6	48.6	154.4	101.5	57.5	57.7	142.9	212.2	62.1	36.4	84.5
1983	72.6	36.2	35	110.6	167.3	69	49.4	237.9	192	157.4	42.8	21.7	99.8
1984	184	128.9	99	51.4	61.3	76.3	57.9	126.8	58.3	103.7	61.7	103.3	92.9
1985	182.1	147.2	59.7	63.1	145.5	165.8	111.5	76.2	146.1	170.7	40.1	147.5	121.3
1986	76.8	66.7	122	67.2	75.2	108.7	69.1	92.6	52.8	217.8	106.6	161.6	101.9
1987	130.3	82.5	73.8	95.8	118.1	124.7	43	53.5	262.1	293.4	139.6	129.1	128.9
1988	46.3	150.9	88.9	70.2	138.8	73.9	64.4	96.3	168.2	182.9	149.7	94.7	110.2
1989	87.5	36.5	19.9	59.8	94.7	57.6	22.4	30	195.7	134.2	218.3	206.7	97.0
1990	70.7	42.5	80.3	79.9	75.9	69.9	36.4	80.7	264.5	192.3	74.2	151.2	101.8
1991	86.5	118.7	41	76.6	114.8	102.3	84.3	109.7	295.2	236.4	129.1	85.7	123.1
1992	127.6	84.8	66.9	49	133.8	84.9	87.5	117.1	208.5	228.6	153.3	78	118.5
1993	98.7	153.7	82.5	71.9	72.2	28.8	20.6	42.6	218.7				
1999			27.5	102.2	137.7	138.6	69.8	59.6		217.1	93.7	201.8	
2000	66.8	40.9	58.7	76.2	98.6	108.6	88.6	72.6	172.1	128.6	100.1	72.5	90.4
2001	69.7	70.9	89.9	49.3	88.1	86.6	78.2	31.9	126	180.1	79	63.3	84.5
2002	80	80.2	38.2	29	108.3	100.1	76.7	173.5	90.9	189.6	88.9	67.1	93.8
2003	79.8	47.8	42.9	34.9	37.1	43.3	40	55.3	188.1	97.1	128.5	94.6	74.1
2004	78.1	93.2		84.7	76.2	35.5	25.9	18.3		110.1	220.2	226.4	
2005	79.7	97	58.9	62.5	41.1	17.9	73.8	99.6	229.5	132.9	281.4	129.5	108.3
2006	47.2	48.8	19.2										
2007							80.1	36.0	150.3	168.9	84.6	44.5	
2008	67.2	45.4	51.8	73.7	145.1	107.7	130.3	84.6	178.7	267.1	105.9	79.8	111.7
2009	150.6	80.6	36.6	56.5	130.7	105.7	52.7	118.0	119.1				

Statistics below by NPS

Count	22	22	22	22	22	22	23	23	22	22	22	22	18
Maximum	184	154	122	111	167	166	130	238	295	293	281	226	129
Minimum	46	36	20	29	37	18	21	18	53	97	40	22	74
Mean	95	80	58	66	103	85	65	85	172	181	118	105	102
Median	80	80	55	65	103	86	69	81	175	182	106	90	101
Standard Deviation	40	39	27	21	38	37	27	50	63	55	60	57	15