WATER MANAGEMENT PLAN FOR LEAVENWORTH NATIONAL FISH HATCHERY

DECEMBER 2004

PREPARED FOR:
JACOBS CIVIL INC.
BY:

MONTGOMERY
WATER GROUP, INC.

MONTGOMERY
WATER GROUP, INC.

Water Resources Engineering

December 20, 2004

Rolf Wielick, P.E.
Jacobs Civil, Inc.
600-108th Ave NE, Suite 700
Bellevue, WA 98007

RE: U.S. Fish and Wildlife Service - W.O. No. 11 - Leavenworth NFH Water Management Plan

Dear Rolf:

Enclosed is the completed Water Management Plan for the USFWS Leavenworth National Fish Hatchery. Three copies have also been sent to the LNFH for their use.

Please call if we can address further comments or requests for information.

Very truly yours,
MONTGOMERY WATER GROUP, INC.

Bob Montgomery

Robert A. Montgomery, P.E.
Principal Engineer

Enc.

803 Kirkland Ave, Suite 100
P.O. Box 2517
Kirkland, WA 98083-2517

PHONE **(425) 827-3243**
FAX **(425) 827-3509**
www.mwater.com

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1.0 Introduction

The purpose of this technical report is to present a water management plan for operation of the Leavenworth National Fish Hatchery (LNFH) diversion on Icicle Creek, Snow Lakes, groundwater wells and pumpback system. An objective is to optimize the use of water available to the LNFH and to plan for potential shortfalls in late summer. The report is divided into sections describing Icicle Creek hydrology, patterns of Icicle Creek water use, estimates of flow downstream of the LNFH diversion and a spreadsheet water balance model that can estimate the volume of water available and needed for pumping from the hatchery to the diversion under different instream flow scenarios. A discussion of the yield of the Snow Lakes water sources is provided as well as recommendations for further analysis of Snow Lakes.

2.0 Hydrology

The primary source of water for the LNFH is from Icicle Creek. Icicle Creek originates on the south side of Stevens Pass in the Wenatchee National Forest in Chelan County. Icicle Creek flows southwest towards the City of Leavenworth and has a drainage basin area of approximately 193 square miles above the USGS stream gage at river mile (RM) 5.8 and 211 square miles at its confluence with the Wenatchee River. Flow in Icicle Creek is predominately snowmelt derived and peaks in late spring. Flows recede in summer and fall with lowest flows typically occurring in September and October. The mean annual runoff measured at the USGS gage above Snow Creek is 43.7 inches, or 621 cfs. The major diversions present on Icicle Creek are the Icicle and Peshastin Irrigation District (IPID) at RM 5.7, the City of Leavenworth at RM 5.5, and LNFH combined with Cascade Orchards Irrigation Company at RM 4.5. Flow in Icicle Creek is supplemented with discharge from high alpine lakes operated by IPID and LNFH.

2.1 Streamflow Data Available

Table 2-1 presents a summary of streamflow data available for Icicle Creek and water diversions from Icicle Creek. Figure 1 shows the locations of the gages and diversions listed in Table 2-1. Some of the data for the sites listed in Table 2-1 is in the form of spot measurements. For example, the USGS measured flow in September and October 1991 at the sites listed in Table 2-1 except for the location of the DOE gage (USGS, 1992).

Table 2-1
Availability of Flow Record

Streamflow Data Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
USGS Gage #12458000 (Daily, also 1936-1971)													
Icicle/Peshastin Irrigation District (Monthly Average)													
City of Leavenworth Diversion													
USFWS Snow Creek Gage (Daily)													
LNFH Diversion Spot Measurements													
DOE Gage #45B050 (Daily)													

Although most of the records are not coincidental, there is some overlap between streamflow records that allow a comparison of water use to streamflow data available, particularly in 1994-1995 and 1998-1999. Figures 2-1 and 2-2 graphically present the streamflow data available in those two time periods. The following sections describe in more detail the data available and characterize the different flow records.

Figure 2-1
Flow Data Available from 1994-1995

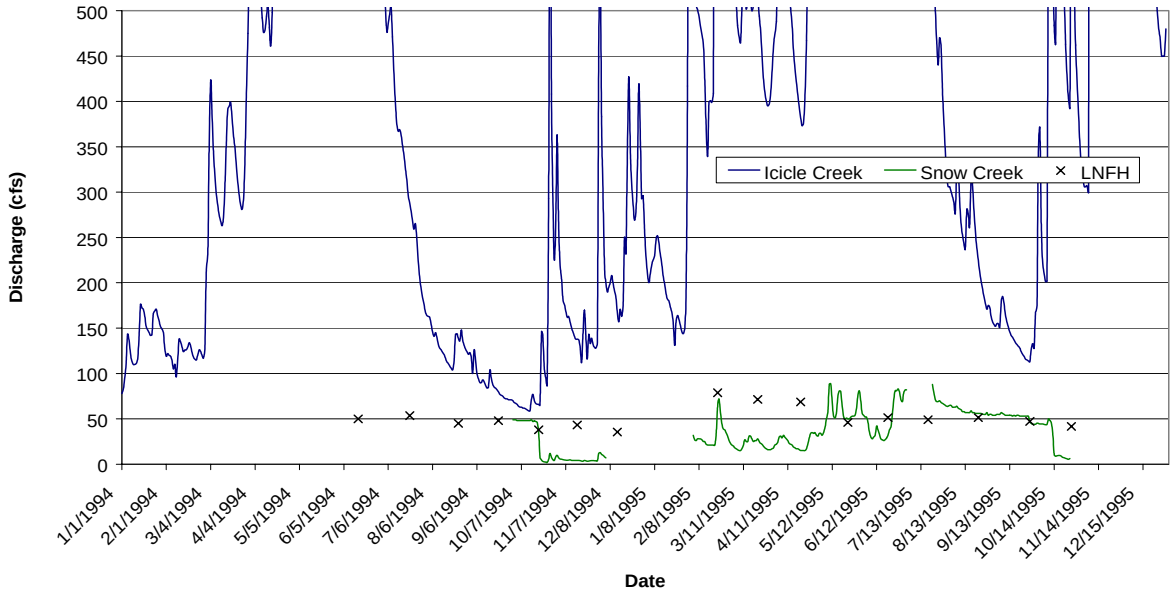
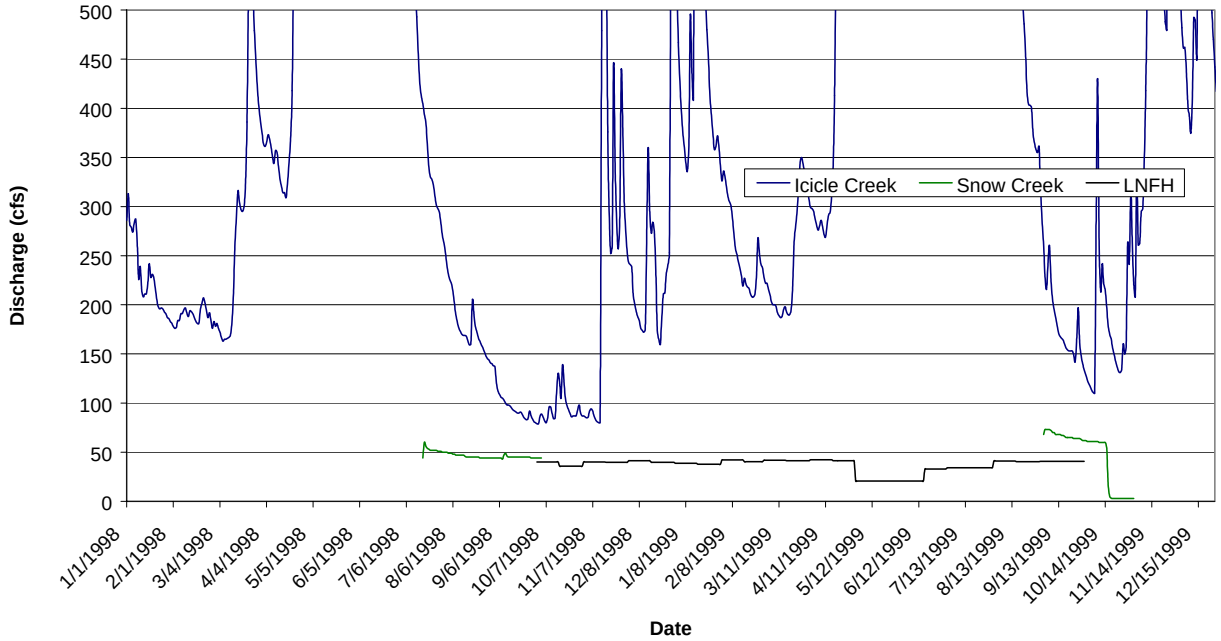


Figure 2-2
Flow Data Available from 1998-1999



2.2 Analysis of Streamflow Data from USGS Gage

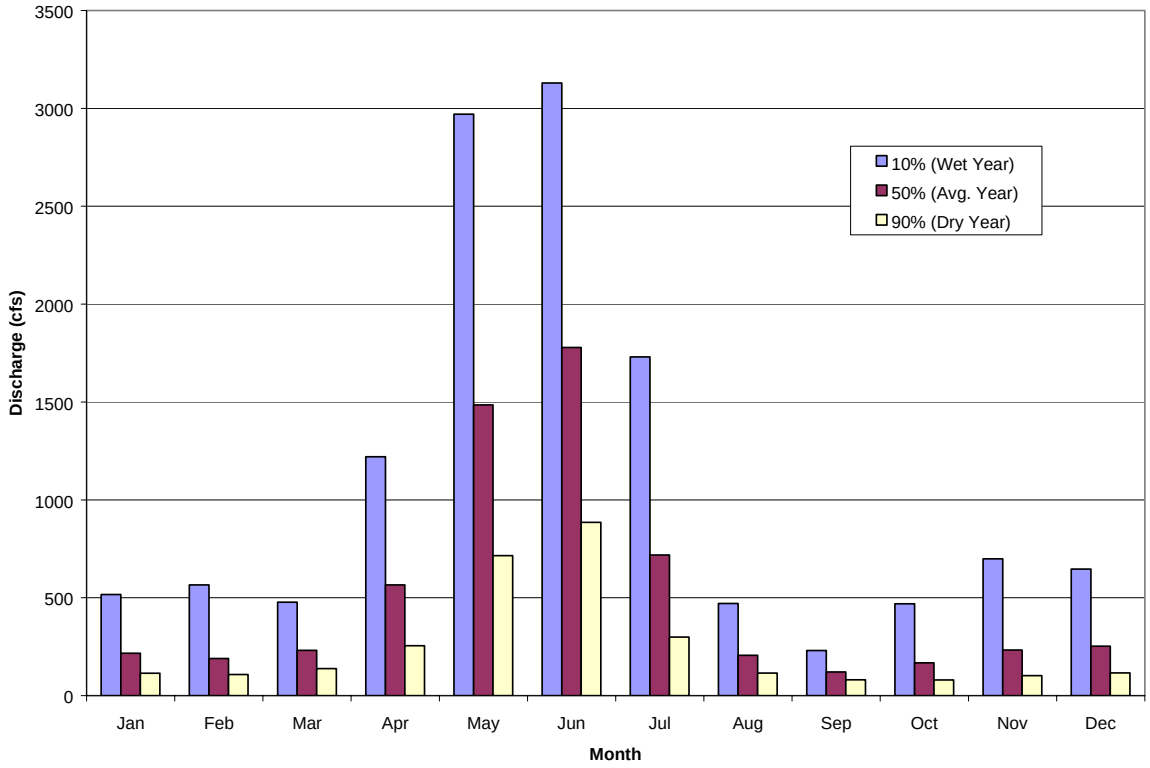
The USGS gage data was compiled to estimate the flow regime in Icicle Creek. Table 2-2 presents the results of the analysis of Icicle Creek at the USGS gage, with flows presented monthly. The flows are presented as 10%, 50% and 90% exceedance flows. Those flows typically represent a high flow or wet year, median flow or average year and low flow or dry year, respectively. Note that the flow record at the USGS gage is affected by supplementation from high alpine lakes operated by the Icicle and Peshastin Irrigation Districts. The rate of supplementation is not available, but is believed to be about 15 cfs. The gage record was not corrected for the supplementation as it represents the way the water supply has been managed over a very long time period, and without precise knowledge of the rate and timing of supplementation, a good correction to the gage record would not be possible. Figure 2-3 presents the USGS data in a graphical format.

Table 2-2
Estimated Flows Icicle Creek above Snow Creek
USGS Gage 12458000

Month	Icicle Creek Flow Statistics (cfs)		
	10% (high flow)	50% (mean flow)	90% (low flow)
Jan	516	217	114
Feb	565	190	108
Mar	477	232	138
Apr	1220	565	255
May	2,970	1,485	715
Jun	3,130	1,778	885
Jul	1,730	718	299
Aug	485	221	130
Sep	245	136	96
Oct	469	168	80
Nov	699	233	102
Dec	646	253	116

Note: Flow in Icicle Creek is augmented in August and September by Icicle and Peshastin Irrigation District.

Figure 2-3
Icicle Creek above Snow Creek Streamflow Regime
USGS Gage # 12458000



2.3 Diversions from Icicle Creek

The Icicle and Peshastin Irrigation diversion is located on the right bank about 500 ft downstream from the USGS gage. Table 2-3 shows the diversions from Icicle Creek for the Icicle and Peshastin Irrigation District. The diversions are reported in a Water Conservation Plan (Klohn Leonoff, 1992) for the Icicle Irrigation District. More recent data has not been found, but it was reported in the *Wenatchee River Basin Watershed Assessment* (MWG, 2003) that data is still representative of their diversions.

Table 2-3
Icicle and Peshastin Irrigation District Diversions

Month	Icicle and Peshastin Irrigation District Diversion (cfs)		
	1990	1991	Average
Jan	0.0	0.0	0.0
Feb	0.0	0.0	0.0
Mar	0.0	0.0	0.0
Apr	77.8	59.3	68.6
May	97.7	78.7	88.2
Jun	100.6	91.6	96.1
Jul	102.9	95.6	99.3
Aug	102.9	93.6	98.3
Sep	78.8	78.1	78.5
Oct	0.0	0.0	0.0
Nov	0.0	0.0	0.0
Dec	0.0	0.0	0.0

The other larger diversions from Icicle Creek downstream of the USGS gage are for the City of Leavenworth, which is estimated to be 2 cfs all year, and for Cascade Orchards, which is estimated to be 7 cfs in May through September. The City of Leavenworth diversion is about 1,500 ft downstream from the USGS gage, and is on the left bank of the creek opposite the Icicle and Peshastin Irrigation District Diversion. The diversion for Cascade Orchards is shared with the Leavenworth National Fish Hatchery and is located about 6,500 feet downstream from the USGS gage. Table 2-4 shows the data available for the LNFH and Cascade Orchards diversion from Icicle Creek. This data was compiled from various sources. Other smaller diversions exist but do not amount to much water use.

Table 2-4
LNFH & Cascade Orchards Diversions

Month	LNFH & Cascade Orchards Diversion (cfs)											
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Avg.
Jan	-	-	-	-	-	-	-	-	38.2	-	-	38.2
Feb	-	-	-	-	48.0	-	-	-	41.1	-	-	44.6
Mar	-	-	-	-	50.4	-	-	-	41.6	-	-	46.0
Apr	-	-	-	-	38.4	-	-	-	41.8	-	-	40.1
May	-	-	-	-	29.2	-	-	-	27.6	-	-	28.4
Jun	-	-	-	50.0	43.4	-	-	-	33.8	-	-	42.4
Jul	-	-	-	53.6	49.0	49.2	-	-	41.1	-	-	48.2
Aug	-	-	-	45.0	51.4	-	-	-	47.6	-	44.8	47.2
Sep	49.7	-	-	48.0	47.2	-	-	-	47.6	-	27.7	44.0
Oct	43.7	-	44.4	38.0	41.7	-	-	37.8	-	-	-	41.1
Nov	-	-	-	43.3	-	-	-	39.9	-	-	-	41.6
Dec	-	-	-	35.6	-	-	-	40.4	-	-	-	38.0

Note: (-) indicates no data.

The LNFH uses water diverted from Icicle Creek and well water obtained from on-site wells. Table 2-5 presents a three-year average estimate of the water supplied from the different sources. There are seven production wells located at the Leavenworth National Fish Hatchery. The groundwater is used as a supplemental source of water to the Icicle Creek water when quantities are limited or when temperatures are inappropriate. The wells have a limited capacity and their use is carefully managed. The well supply is measured with flow meters.

Table 2-5
LNFH Water Supply

Month	LNFH Water Supply (cfs)	
	Icicle Creek	Wells
Jan	33.4	6.4
Feb	36.7	8.8
Mar	37.3	8.8
Apr	27.4	10.3
May	20.3	5.1
Jun	28.9	1.4
Jul	35.4	4.3
Aug	35.5	5.3
Sep	29.8	6.5
Oct	38.8	3.5
Nov	38.0	3.3
Dec	38.9	4.8

Note: Table is an average of three years (1999, 2002, and 2003) based on Hatchery Records, per conversation with Dan Davies (LNFH).

2.4 Snow Lakes Contribution to Icicle Creek

The headwaters for Snow and Nada Lakes is in Enchantment Basin west of Icicle Creek and east of the Cascade Range. The LNFH owns water rights for storage and use of water from the lakes and manages the lakes to augment streamflow in Icicle Creek in late summer and fall. Water released from the lakes flows through Snow Creek into Icicle Creek approximately 2,100 ft downstream from the USGS gage. LNFH personnel have recorded flow in Snow Creek for several years out of the past ten. That data is compiled and provided in Table 2-6. The flow records shown in Table 2-6 include partial month records so the monthly average shown may not be for an entire month. The total flow shown is for the available flow records and is less than the total flow out of the basin on an annual as many months of records were not available.

The data includes periods when water is not being released from the Snow Lakes. Flow is released primarily in the August – October time period. The average flow during that time period is 38 cfs. An estimate of the flow released from Snow Lakes was made using the available flow data. A summary is provided in Table 2-7. The releases varied from an estimated 1,700 acre-feet in 1994 to 7,560 acre-feet in 1995 with an average of 4,140 acre-feet.

Table 2-6
Snow Lakes Flow at USFWS Gage

Month	Snow Lakes Average Flow (cfs)									
	1994	1995	1996	1997	1998	1999	2000	2001	2002	Average
Jan	-	-	-	-	-	-	-	-	-	-
Feb	-	32.3	-	-	-	-	-	-	-	32.3
Mar	-	21.6	-	-	-	-	-	-	-	21.6
Apr	-	23.7	-	-	-	-	-	-	-	23.7
May	-	56.0	-	-	-	-	-	-	-	56.0
Jun	-	47.9	-	-	-	-	-	11.3	-	29.6
Jul	-	72.8	-	-	52.0	-	-	5.6	-	43.5
Aug	-	58.5	-	-	46.1	-	-	21.7	19.9	36.6
Sep	-	52.8	-	-	44.8	67.0	-	34.4	17.5	43.3
Oct	31.1	26.9	-	-	44.0	31.2	-	34.1	-	33.5
Nov	4.7	-	-	-	-	3.0	-	-	-	3.9
Dec	9.0	-	-	-	-	-	-	-	-	9.0
Total (Ac-ft)	2,290	20,727	-	-	7,394	5,651	-	3,996	2,224	20,627

Note: (-) indicates no data. Flow records include partial month records. Total is sum of available records and is less than the total flow out of the basin because of incomplete records.

Table 2-7
Estimated Releases from Snow Lakes
August - October

Year	Estimated Flow Release (ac-ft)
1994	1,700
1995	7,560
1996	-
1997	-
1998	6,910
1999	3,580
2000	-
2001	3,130
2002	1,920
Average	4,140

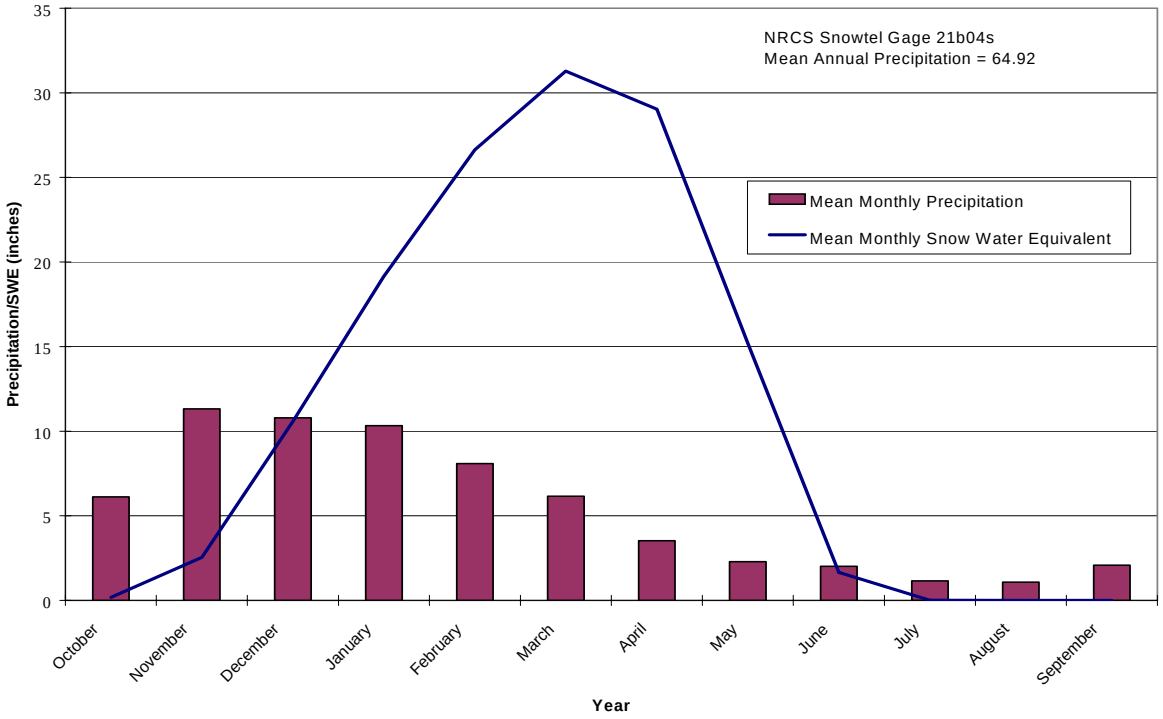
Note: (-) indicates no data. Baseflow of 5 ac-ft/day from remainder of Snow Creek basin assumed.

2.4.1 Potential Yield of Snow Lakes

The Snow Lakes are located at a high elevation; the upper Snow Lake has a water surface elevation of 5,420 ft. The lower Snow Lake water surface elevation is 5,415 ft. and Nada Lake is at 4,920 ft. The contributing area to Snow Lakes is approximately 3,213 acres and 985 acres for Nada Lake (see Map 2). Recharge for Snow and Nada Lakes is provided from snowmelt, precipitation, and melt from Snow Creek Glacier and ice fields. An estimate of the potential yield of the Snow Lakes was made using precipitation data from a nearby precipitation and snow gage, along with estimates of annual precipitation obtained from Oregon State University's Spatial Climate Analysis Service.

The Fish Lake SnoTel Data Station is located west of Snow Lakes and just west of the Cascade Divide at an elevation of 3,371 ft. The median annual precipitation for the Fish Lake station is 63 inches and ranges from 49 inches in dry years to 89 inches in wet years. The rate and timing of precipitation, snow accumulation and snow depletion for that station is shown in Figure 2-4. In Figure 2-4, the y-axis units are in inches of water, either expressed as precipitation (rain and snow) or snow-water equivalent (the volume of water in the snowpack).

Figure 2-4
Precipitation, Snow Accumulation and Snowmelt
Fish Lake SnoTel Station



The Snow Lakes basin is located east of the Fish Lake Station and receives slightly less precipitation. From precipitation mapping performed by Oregon State University (OSU, 2003) the average annual precipitation for the Snow Lakes basin is estimated to be 50 inches, which is approximately 77% of the annual average precipitation at Fish Lake.

Recharge or runoff to Snow Lakes was estimated using 77% of the precipitation values for Fish Lake, multiplying it by the contributing area and subtracting the estimated evapotranspiration, evaporation from lakes and ablation from snowpack. No measurements or studies of evapotranspiration and other losses are available for the basin and those losses were estimated based upon experience to be 18 inches annually. Those losses will vary from year to year and are primarily related to air temperature. The losses were assumed to be the same for dry, average and wet years as there is not a correlation between precipitation (most of which falls in the wintertime) and temperature during summer months when most of the losses occur.

The estimated annual water yield from the Snow Lakes is provided in Table 2-8. The estimated yield ranges from 6,930 ac-ft in dry years (driest year in ten-year period) to 17,900 ac-ft in wet years (wettest year in ten-year period), with an estimated median of approximately 10,700 ac-ft per year. That yield corresponds to a runoff of 30.6 inches per year in average water years, much

less than the average yield from the entire Icicle Creek basin measured at the USGS gage (44 inches per year). That may indicate our yield calculations are conservative. Note in Table 2-8 that the total of the monthly precipitation values for each exceedance probability do not add up to the annual precipitation total for each exceedance value. That is because the exceedance values for each month do not correspond to the same year of data. The annual values of precipitation were used to calculate the yield of the Snow Lakes basin.

Table 2-6 presented measurements of flow in Snow Creek that reflected both natural runoff from the remainder of the Snow Creek basin (3,357 acre drainage area) and releases from Snow Lakes. The measurements do not cover the entire year so the total volume of runoff is not known. The year with the most complete flow record is 1995; the measured flow equaled 20,700 ac-ft for a 9-month period, which equals a yield of 33 inches measured over the entire Snow Creek basin. The precipitation for that year was above average (72.6 inches at Fish Lake compared to the median of 63 inches). The yield for that year (33 inches in 9 months) compared to our estimated average yield for the Snow Lakes basin (30.6 inches in an average year) indicates our calculations are reasonable.

The relative contribution from Snow Lakes and other parts of the Snow Creek basin is not known however most all of the flow in August through October in Snow Creek is released from the Snow Lakes. Table 2-7 presented an estimate of that volume, which ranged from 1,700 to 6,900 acre-feet during the period of gaging.

Table 2-8
Snow Lakes Recharge/Yield

Month	Fish Lake SnowTel Precip. (in) Exceedance Probability			Snow Lakes Recharge (ac-ft)		
	10%	50%	90%	10%	50%	90%
Jan	10.8	5.4	2.2	2,909	1,455	593
Feb	15.9	10.7	5.6	4,283	2,882	1,508
Mar	15.8	10.7	5.5	4,256	2,882	1,482
Apr	13.5	10.5	7.2	3,636	2,828	1,939
May	14.5	6.8	4.0	3,906	1,832	1,077
Jun	8.3	5.7	3.3	2,236	1,535	889
Jul	6.4	3.0	1.5	1,724	808	404
Aug	3.3	2.1	1.3	889	566	350
Sep	3.7	1.7	0.6	997	458	162
Oct	1.8	0.8	0.1	485	215	27
Nov	2.1	0.8	0.0	566	215	0
Dec	4.0	1.9	0.1	1,077	512	27
Annual Precip.	89.8	63.0	49.1	24,189	16,970	13,226
Annual Evap.				6,297	6,297	6,297
Recharge/Yield				17,892	10,673	6,929

The estimated yield of the Snow Lakes basin was made assuming a prolonged dry period. The precipitation records for the Fish Lake Station were examined and the lowest annual, two-year duration and three-year duration volume of precipitation was used to estimate the cumulative recharge into the Snow Lakes. A graph of those annual volumes is shown in Figure 2-5. The

values of lowest annual to lowest three-year precipitation and yield from the Snow Lakes basin are provided in Table 2-9.

Figure 2-5
Precipitation Record
Fish Lake SnoTel Station

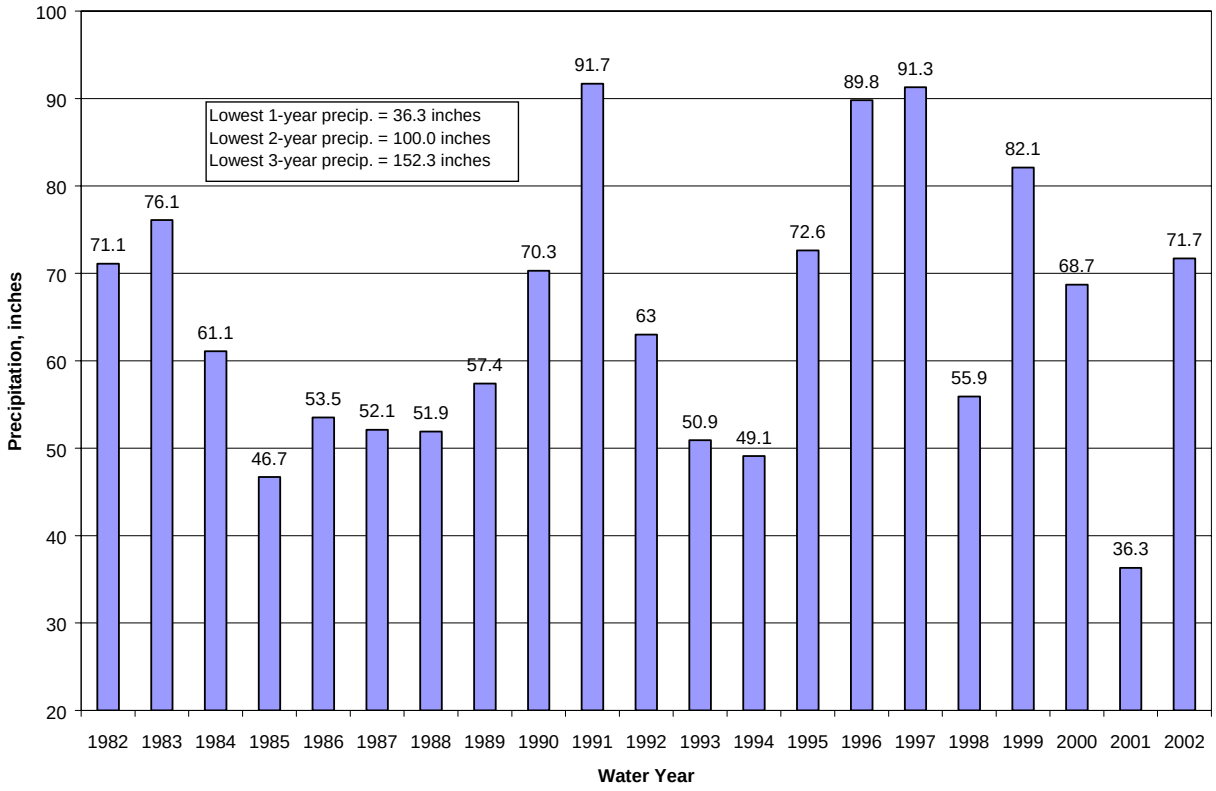


Table 2-9
Lowest One to Three-year Precipitation and Snow Lake Recharge Volumes

Duration	Year	Precipitation at Fish Lake (inches)	Estimated Recharge to Snow Lakes (Cumulative volume in ac-ft)	Equivalent Flow over Aug-Oct period (cfs)
One Year	2001	36.3	3,481	19
Two Years	1993-1994	100.0	14,343	39
Three Years	1985-1987	152.3	22,134	40

The estimated recharge for the worst year on record (2001) is 3,481 acre-feet. The estimated discharge from Snow Lakes in August – October for that year is 3,130 acre-feet (Table 2-7). For the worst two years of record, the total recharge is estimated to be just over 14,000 acre-feet while for the worst three-year period of record the total recharge is estimated to be just over 22,000 acre-feet. Although one year may be short of water, it appears that even during 2-year and 3-year droughts the lakes should still provide about 40 cfs for three months provided

sufficient storage in the lakes exist. That supply should be adequate for meeting water supply needs.

2.4.2 Discussion of Potential Effect on Water Supply from Climate Change

A review of the potential effect on Snow Lakes basin yield from climate change was made. Climate models are predicting an increase in temperature in the Pacific Northwest (PNW) an average of 2.8 degrees C by 2050. An increase in precipitation would also result, with a prediction of 10% in the November-May time period (Mote et al 2001). A change in dry season precipitation is not expected. The warmer temperatures would cause more precipitation to fall as rain than snow during the winter time and cause spring melt to occur more quickly depleting streamflow sooner during the summer. Projections are that spring melt in the PNW could occur 1-2 months earlier than it does now, with fall streamflow returning to normal levels 1-2 months later (Hamlet, no date). The maximum flows in late spring and early summer could decrease by 17% below average historic levels by 2020, and as much as 27% by 2050. In late summer and fall months, modeled flows decrease by an average of 25% in 2020 and 2050 (Hamlet, no date).

Two factors may mitigate the effect of climate warming on the water yield from Snow Lakes basin. The first is the elevation of the basin. Snow Lake and Nada Lake are at elevations 5415 ft and 4920 ft, respectively. The largest changes in annual snow accumulation and melt will likely occur at elevations between 3000 ft and 4000 ft. The second is the storage in the lakes, which would refill from either precipitation falling as rain or melting as snow. The overall effect on Snow Lakes from climate change may not be significant, but should be a consideration in future planning for water use from that basin. Additional monitoring of water levels and discharge in the Snow Lakes is warranted to track the potential for changes in water supply.

3.0 Estimates of Flow in Icicle Creek Downstream of LNFH Diversion

Water balance calculations were made to estimate Icicle Creek flow downstream of the LNFH diversion after all diversions and supplementations are made. The water balance analysis was performed by subtracting from the USGS gage record the Icicle and Peshastin Irrigation District diversion, the City of Leavenworth diversion, the Cascade Orchards diversion, and the LNFH water supply from Icicle Creek (Table 2-5) and adding contributions from Snow Lakes. The analysis was performed on a monthly basis. Limited data is available for the Icicle and Peshastin Irrigation District diversion and an average of 1990-1991 diversion data was used. Limited data is also available for the Snow Lakes contributions so available data was averaged. No data was available for the month of January for Snow Creek therefore the value for December was used for January. Where actual data for Snow Creek for the year analyzed was available, it was used instead of the average.

Flow data for years that are representative of average, dry and wet conditions were used. For an average year, data from 1998 was used. For a dry year, data from 2001 was used and for a wet year, data from 1997 was used. Table 3-1 presents an analysis of estimated flows in Icicle Creek downstream of the LNFH diversion for an average flow year. Tables 3-2 and 3-3 present an analysis of estimated flows in Icicle Creek downstream of the LNFH diversion for a wet and dry year, respectively.

The analysis shows that flows below the LNFH diversion are low in August and September until the Icicle and Peshastin Irrigation District stop diverting for the season. For average years in late September, flows could be less than 5 cfs even with supplementation from Snow Lakes. In dry

years, those low flows could be extended to the end of October. The flow released from Snow Lakes comprises a significant part of the LNFH diversions in average to dry years.

An agreement is under negotiation with other federal agencies to determine the requirement for flow downstream of the LNFH diversion. Assuming the instream flow need downstream of the diversion is approximately 20 cfs, we estimate an additional 1,500 ac-ft would be required during dry years to meet that flow target. The water yield of the Snow Creek basin appears to have the capacity to supply that flow. Additional monitoring should be performed of lake water levels and discharge to confirm its capacity. In addition, the LNFH would like to divert their full water right of 42 cfs throughout the entire year for optimal fish production operation. This could entail additional discharge from Snow Lakes of approximately 6 cfs in an average September to maintain the target instream flow without using the pump-back facilities (that pumps water from below the hatchery to the diversion dam to maintain instream flow).

Table 3-1
Results of Hydrologic Analyses – Average Flow Year - 1998

Month	Inflow and Outflow(cfs)						Instream Flow downstream of LNFH diversion (cfs) (=)
	Icicle Creek at USGS gage	IPID (-)	City (-)	Snow Creek (+)	CO (-)	LNFH (-)	
Jan	227.6		2	*9.0*		33.4	201.2
Feb	188.8		2	32.3		36.7	182.4
Mar	296.9		2	21.6		37.3	279.2
Apr	571.9	68.6	2	23.7		27.4	497.7
May	1,929.7	88.2	2	56.0	7.0	20.3	1,868.2
Jun	1,331.8	96.1	2	29.6	7.0	28.9	1,227.4
Jul	486.5	99.3	2	52.0	7.0	35.4	394.8
Aug	180.1	98.3	2	46.1	7.0	35.5	83.4
Sep	98.5	78.5	2	44.8	7.0	29.8	26.0
Oct	94.8		2	44.0		38.8	98.0
Nov	259.6		2	3.9		38.0	223.5
Dec	291.8		2	9.0		38.9	259.9

Note: Highlighted cells represent actual data for Snow Creek for that year, the other values are averages for the data record from 1991-2002. LNFH values are a three year average (1999, 2002 and 2003) from Hatchery records as provided by Dan Davies. Cascade Orchards diversion estimated based on information provided by Jacobs.

Table 3-2
Results of Hydrologic Analyses – Wet Flow Year -1997

Month	Inflow and Outflow(cfs)						Instream Flow downstream of LNFH diversion (cfs) (=)
	Icicle Creek at USGS gage	IPID (-)	City (-)	Snow Creek (+)	CO (-)	LNFH (-)	
Jan	313.1		2	*9.0*		33.4	286.7
Feb	369.2		2	32.3		36.7	362.8
Mar	668.6		2	21.6		37.3	650.9
Apr	834.3	68.6	2	23.7		27.4	760.1
May	2401.2	88.2	2	56.0	7.0	20.3	2339.7
Jun	2409.3	96.1	2	29.6	7.0	28.9	2304.9
Jul	1179.4	99.3	2	43.5	7.0	35.4	1079.1
Aug	341	98.3	2	36.6	7.0	35.5	234.8
Sep	239.8	78.5	2	43.3	7.0	29.8	165.8
Oct	576.5		2	33.5		38.8	569.2
Nov	510.9		2	3.9		38.0	474.8
Dec	244.5		2	9.0		38.9	212.6

Note: LNFH values are a three year average (1999, 2002 and 2003) from Hatchery records as provided by Dan Davies. Cascade Orchards diversion estimated based on information provided by Jacobs.

Table 3-3
Results of Hydrologic Analyses – Dry Flow Year - 2001

Month	Inflow and Outflow(cfs)						Instream Flow downstream of LNFH diversion (cfs) (=)
	Icicle Creek at USGS gage	IPID (-)	City (-)	Snow Creek (+)	CO (-)	LNFH (-)	
Jan	100.9		2	*9.0*		33.4	74.5
Feb	81		2	32.3		36.7	74.6
Mar	149.1		2	21.6		37.3	131.4
Apr	349.8	68.6	2	23.7		27.4	275.6
May	1154.4	88.2	2	56.0	7.0	20.3	1092.9
Jun	735.9	96.1	2	11.3	7.0	28.9	613.2
Jul	324	99.3	2	5.6	7.0	35.4	185.9
Aug	150.2	98.3	2	21.7	7.0	35.5	29.1
Sep	86.3	78.5	2	34.4	7.0	29.8	3.4
Oct	151.7		2	34.1		38.8	145.0
Nov	515.6		2	3.9		38.0	479.5
Dec	311		2	9.0		38.9	279.1

Note: Highlighted cells represent actual data for Snow Creek for that year; the other values are averages for the data record from 1994-2002. LNFH values are a three year average (1999, 2002 and 2003) from Hatchery records as provided by Dan Davies. Cascade Orchards diversion estimated based on information provided by Jacobs.

4.0 Flow Management Plan for Icicle Creek Below the LNFH Diversion

The purpose of this section is to provide a tool for LNFH to use in evaluating flow management options for various times of year. The constraints on managing flow are:

- Water Supply provided by Icicle Creek
- Diversions by others (Icicle and Peshastin Irrigation District, Cascade Orchards, City of Leavenworth)
- Water Supply available from Snow Lakes
- Hatchery Water Supply Needs, both flow and temperature
- Target flow needs below diversion and in historic channel
- Flow need in hatchery channel upstream of spillway to recharge groundwater and to spill water over spillway.

A spreadsheet model that uses the same water balance as described in Section 3 was set up to review various "what-if" scenarios of water supply available, diversions by others and hatchery water supply from Icicle Creek. The model is setup on a monthly basis and the input is:

- Monthly time period
- Flow in Icicle Creek at USGS gage
- Desired diversion by LNFH
- Desired flow in Icicle Creek downstream of LNFH

The spreadsheet model uses historic information on Icicle and Peshastin Irrigation District diversions, as well as City of Leavenworth and Cascade Orchards diversions for the time period used in the model. The model calculates the volume of water needed to pumpback from the hatchery to the diversion to supplement instream flow.

An example output from the spreadsheet model is provided in Table 4-1. For this example, the September time period was selected; the flow in Icicle Creek at the USGS gage was input as 105 cfs, the desired LNFH diversion is 30 cfs and the desired flow released downstream of the LNFH diversion is 20 cfs. The pumpback required is zero under those conditions.

The purpose of the model is not to provide a "real-time" operational model of Icicle Creek but to allow review of flow scenarios and historic operating conditions and review what volume of water that needs to be pumped back to the diversion from the hatchery under different flow conditions. The model was provided to LNFH for their use.

Table 4-1
Leavenworth National Fish Hatchery Water Management Plan Flow Table

Icicle Creek Flow and Time Period	Source of Information	Flow, cfs
Flow in Icicle Creek at USGS Gage (cfs)	Enter Flow	105
Time Period	Enter Time Period (month)	9
Diversions by Others		
Icicle/Peshastin Irrigation Diversion (cfs)	From Lookup table, average of data available	78
City of Leavenworth Diversion (cfs)	From Lookup table, average of data available	2
Snow Creek Discharge (cfs)	From Lookup table, average of data available	43
Cascade Orchards Diversion (cfs)	From Lookup table, average of data available	7
Water Remaining in Icicle Creek		
Water Available for Leavenworth National Fish Hatchery Diversion (cfs)	Calculated from Water Balance	61
Desired Diversions and Instream Flow		
Desired National Fish Hatchery Diversion (cfs)	Enter Desired Flow, currently average from lookup table	30
Target Flow (cfs)	Enter Desired Flow, currently average from lookup table	20
Estimates of Available Instream Flow and Pumpback Needed		
Estimated Icicle Creek Flow After LNFH Diversion (cfs)	Calculated from Water Balance	31
Pumpback Necessary to Meet Recommended Instream Flow (cfs)	Calculated from Water Balance	none

5.0 Summary and Conclusions

This report characterizes hydrologic conditions within the Icicle Creek and Snow Creek basins and presents estimates of the potential yield of the Snow Lakes basin, which currently supplements irrigation and LNFH water supplies. The estimated yield from the Snow Lakes basin (runoff into the lakes) is 10,670 acre-feet for a year with average precipitation. The current use of Snow Lakes was analyzed using data collected by USFWS. The releases from the lakes in the August – October time period varied from an estimated 1,700 acre-feet in 1994 to 7,560 acre-feet in 1995 with an average of 4,140 acre-feet.

It appears the water supply available from the Snow Lakes is not fully used and additional flow could be discharged from the lakes to increase water supply at LNFH or increase instream flow in Icicle Creek below the LNFH diversion. However the volume of the lakes needs to be confirmed prior to their additional use. A review of the potential yield from consecutive dry years was made and it was determined enough water could be captured to supply flow to the LNFH in the second and third year of a dry period.

Based on the information provided in this report and discussions with the Leavenworth National Fish Hatchery staff, the pumpback system being installed for the hatchery will most likely not have to be used except in dry years. In dry years, the flow in Icicle Creek is expected to drop below recommended instream flows in September and Icicle Creek flow may need to be augmented.

We recommend that additional monitoring of the Snow Lakes be performed to track water levels in the lakes throughout the year and flow in Snow Creek. In addition, the volume of the lakes should be measured through a survey to determine the available storage volume.

Respectfully submitted,
MONTGOMERY WATER GROUP, INC.

Bob Montgomery

Robert A. Montgomery, P.E.
Principal Engineer

6.0 References

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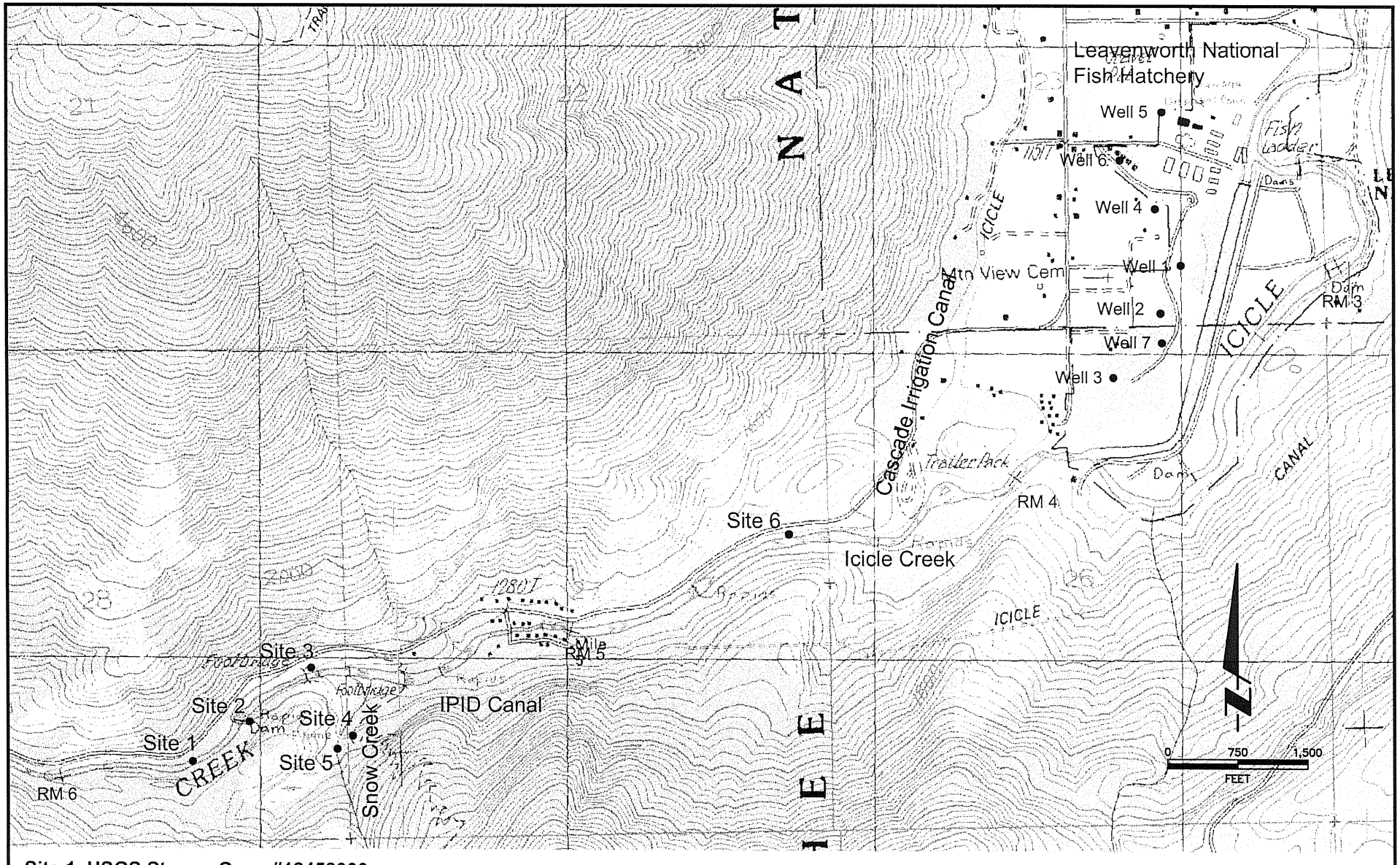

Site 1 USGS Stream Gage #12458000
Site 2 Icicle and Peshastin Irrigation District Diversion
Site 3 City of Leavenworth Diversion
Site 4 IPID Canal Flume Gage
Site 5 USFWS Snow Creek Stream Gage
Site 6 Leavenworth National Fish Hatchery and Cascade Orchards Diversion

Map 1
Location Map
Water Management Plan

Leavenworth National Fish Hatchery

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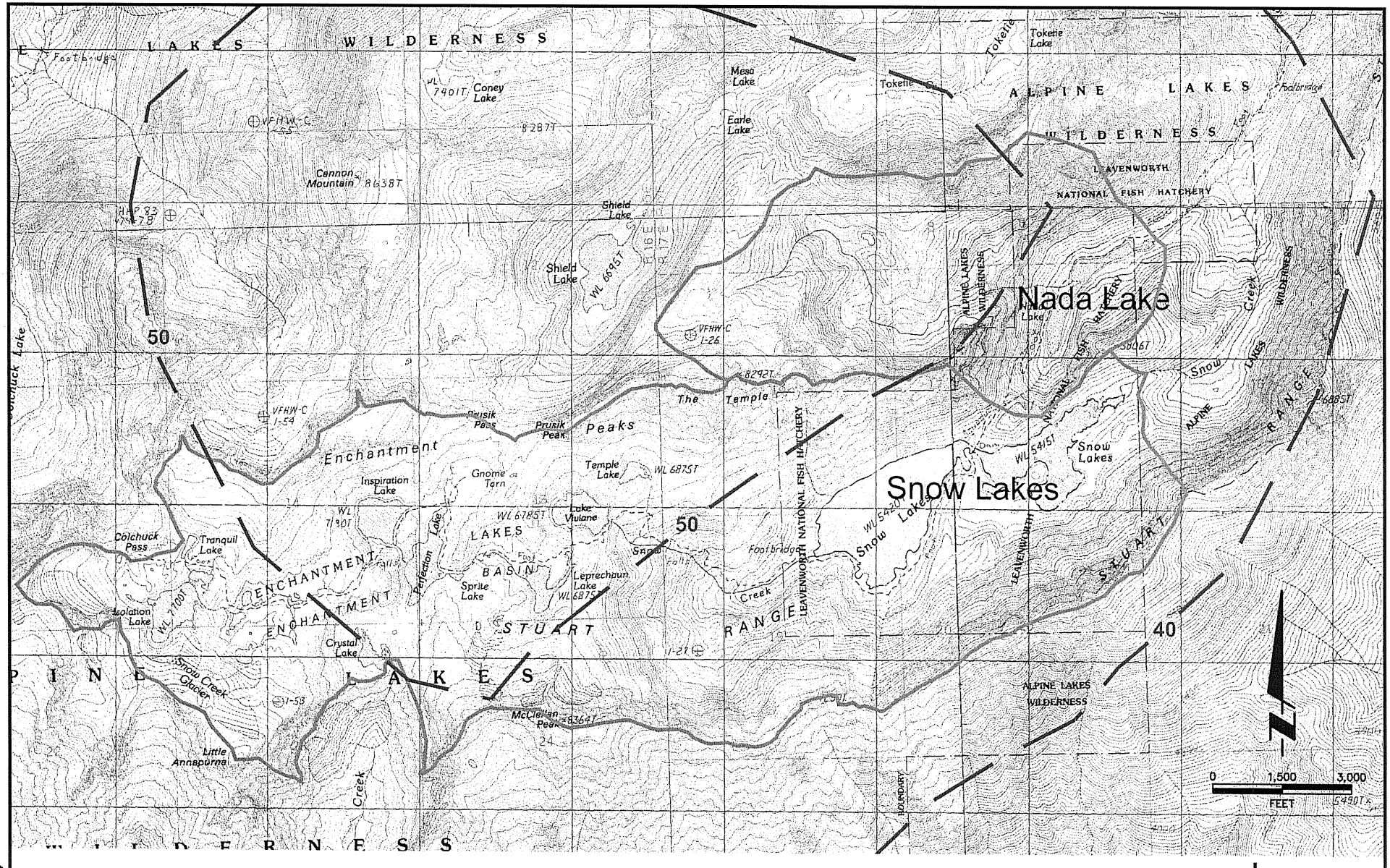

50 Annual Average Precipitation

Drainage Area Boundary

Map 2
Snow Lakes Recharge Area Water Management Plan

Leavenworth National Fish Hatchery

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