Analysis of Icicle Creek Instream Flow Benefits Of Three "Base Projects" During Low-Flow Months

Mark Hersh
Wild Fish Conservancy

and

Dick Rieman
Icicle Creek Watershed Council

July 2013

Executive Summary

Harriet Bullitt, the Icicle Creek Watershed Council, and Wild Fish Conservancy are stakeholders in the Chelan County-led effort to improve instream flows in Icicle Creek. A number of "base projects" were proposed at the May 17, 2013, meeting in Leavenworth. The projects either increase flow by releases from storage in the basin, or preclude the need to divert Icicle Creek water through improvements/efficiencies to irrigation system or by diverting water from the Wenatchee River.

At the May 17, 2013 meeting of the Icicle Working Group, Chelan County proposed an initial "Integrated Project List" that included nine base projects. Three of those nine base projects are analyzed in this paper: 1) a "pump exchange" with the Icicle-Peshastin Irrigation Districts(IPID), 2) improvement efficiencies in the IPID and Cascade Orchards Irrigation Company (COIC) systems, and 3) savings in water diverted by the Leavenworth National Fish Hatchery (collectively the "three base projects"). While the group expressed general support for the overall goal of these three projects—increasing flows in Icicle Creek—there was not consensus that these three projects would be the most effective means of achieving that goal. Moreover, a number of stakeholders expressed concern about two other base projects involving some of the Alpine Lakes, as well as the project to amend the Icicle instream flow rule.

This report assesses the benefits of the three base projects against low stream flows in September, October, and December. The three base projects will not result in enough "saved" water (not diverted from Icicle Creek) to result in sufficient instream flow. Definite predictions on habitat cannot be made until the results of the IFIM study for the historical channel (RM 3.8 to 2.8) are available, but this examination of low-flow months indicates that even after the three base projects are implemented, periods of very low instream flows would occur.

One reason why this is the case is that two of the three base projects affect only seasonal diverters – the IPID and COIC. Even though up to 40 cfs may no longer need to be diverted from Icicle Creek after implementing a pump exchange program with IPID and realizing improvements and efficiencies to both irrigation systems, those savings will not apply once those entities stop diverting on September 30 of the year. Any improvements after that date must come from either smaller diversions by the Leavenworth National Fish Hatchery, or from instream flow augmentation from storage, which may be problematic in autumn and winter.

The following chart summarizes the analysis. For many days in September, December, and especially October, Icicle Creek would continue to experience insufficient benchmark flows between RM 4.5 to RM 2.8, even after the three base projects were implemented.

Month / Flow	**Days below 50 cfs**	**Days below 40 cfs**	**Days below 30 cfs**
September	18	10	0
October	31	28	9
December	8	3	1

These data indicate that as much or more attention must be paid to instream flow in October and December as in September.

Introduction

The purpose of this report is to assess the benefits of three "base projects" presented at the May 17, 2013 meeting of the Icicle Subbasin stakeholders. Those projects include: 1) a "pump exchange" with the Icicle-Peshastin Irrigation Districts (IPID) that results in 30 cfs not diverted from Icicle Creek, 2) improvement efficiencies in the IPID and Cascade Orchards Irrigation Company (COIC) systems resulting in another 10 cfs not diverted, and 3) savings in water diverted by the Leavenworth National Fish Hatchery resulting in a savings of 20 cfs. A number of stakeholders, however, expressed concern about other base projects, 1) Alpine Lakes optimization, modernization, and automation (14.57 cfs over 75 days); 2) Eight-Mile Lake restoration, involving some of the Alpine Lakes; and 3) amending the instream flow rule. Those projects will not be assessed, although this report can serve as a basic template to evaluate the benefits of implementing other projects.

The presentation on May 17 used the mean flow of the month of September for Icicle Creek as a basis for comparison, i.e., how the implementation of the base projects will improve habitat over that provided by the mean (average) monthly flow for September. It is not clear why the mean flow was used. Mean flows are skewed by high runoff events and can therefore give a false sense of security. A flow that reflects a frequency -- *how often* a flow occurs -- is more to the point than the average monthly flow for comparison purposes. For instance, if one chose the median flow, one would then be sure that the chosen baseline flow occurred at least 50% of the days of the time period in question. Another way to express the median flow is the "50% exceedence flow."

Assembling a set of projects for the purpose of augmenting stream flow to protect aquatic life and aesthetics, however, should use a more stringent flow than the median flow. The 95% exceedence flow, those flows that are equaled or exceeded 95% of the time, is a reasonable flow to use for this purpose. First, if the effort to improve aquatic life is to succeed, it needs to ensure that adequate flow will be realized almost every year. Adequate flow for one-half or even three-quarters of the years will not suffice. Second, recovery of steelhead and bull trout will be greatly enhanced by more normative flows. Besides habitat, adequate flow is needed so that these fish can negotiate fish passage impediments. These impediments can become blockages if flow is inadequate.

Low flows in Icicle Creek occur in late summer and early fall. September is therefore a proper month to consider. But low flows can also occur later in autumn or in winter. While the seasonal aspect of the IPID diversion assures that the largest diverter is no longer a factor by September 30, the same cannot be said about the second-largest diverter, the LNFH, which diverts surface water year-round. For that reason, this exercise constructed low-flow hydrographs for the months of September, October, and December[1], and compared the existing conditions to those that would result if the three base projects described above were implemented. This was done in order to ensure that the stakeholder effort does not go to great lengths to augment stream flow for aquatic life in September -- only to find the habitat is quickly lost in October or December.

---

1 A cursory examination indicated flows in December were generally lower than those occurring in November, January, February, or March.

This exercise does not attempt to look ahead to the changes that are happening to climate and Icicle Creek hydrology, not because they are not important, but due to a lack of time. This exercise did construct the low-flow monthly hydrographs using the flow data from water years 1994 through 2012, rather than use the entire period of record. That is contrary to what hydrology texts recommend, that is, using as long as a record as possible. Because evidence of a changing climate is already apparent from an examination of the record, however, we concluded that the years since 1994 would be more predictive of future conditions. In any event, we believe that the working group must assess any package of projects through the expected changes to the yield of the Icicle Creek watershed over the next thirty to fifty years.

Methods

Flow Record

As stated above, this report uses the USGS Icicle Creek gage station (12458000) at RM 5.8, from the years 1994-2012. The 2004 Water Management Plan states that the flow record is augmented in summer months by a 15 cfs release from the Alpine Lakes by IPID. The 95% exceedence flows were derived from the daily flow record for the months of September, October, and December using Excel. Those flows were then put into tabular form along with the diversion and additions of Icicle Creek in descending order (RM 5.8 to RM 2.8).

Base Projects

The evaluated projects include three projects ("base projects") presented by Chelan County at the May 17, 2013, stakeholder meeting in Leavenworth (Table 1).

Table 1. Base projects evaluated in this report.

Project Name	Description	Instream flow benefit
Icicle-Peshastin Irrigation District (IPID) Pump Exchange	Pump exchange at Dryden or Leavenworth	30 cfs (May 1 to Sep 30); for this exercise, September only
IPID and Cascade Orchard Irrigation Company Efficiencies	Management plan and infrastructure improvements	9.9 cfs (5 cfs from IID, 3.3 cfs from PID, 1.6 cfs from COIC; May 1 to Sep 30); for this exercise, September only
Leavenworth National Fish Hatchery conservation	Combination of on-site reuse, effluent pump-back (for aquifer recharge), or wellfield enhancements	20 cfs (presumably year-round; this exercise assumes that the project was something that obviated the need for the aquifer recharge diversion)

The "base project" for the LNFH was a "performance standard" of 20 cfs water saved, and in this analysis it is assumed to have been attained through a cessation of the diversion for aquifer recharge (RM 3.8). If the LNFH "performance standard" was met, for instance, through a 20 cfs reduction in the surface water diversion at RM 4.5, any instream flow benefits would accrue in a longer reach (RM 4.5 to RM 2.8 *vs*. RM 3.8 to 2.8).

Diversions and Additions

The 2009 LNFH Proposed Flow Management Operations document and the 2004 LNFH Water Management Plan (by the Montgomery Water Group) give estimates for various amounts of water diverted or added to Icicle Creek by the various water right holders (Table 2). The amounts assigned to diverters in Table 2, are less than the recorded water rights, with the exception of the City of Leavenworth, as the amount assigned is equal to the recorded water right.

Table 2. Diversions and additions to Icicle Creek in descending river mile (RM) order.

	RM	**Type**	**Duration**	**Amount used in this analysis (cfs)**
City of Leavenworth intake	5.7	diversion	Year-round	2 (all months)
Icicle-Peshastin Irrigation District intake	5.7	diversion	May 1 to Sep 30	78 (Sep only)
Snow Creek confluence	5.5	addition	Base flow of stream is year round; LNFH adds water from Snow/Nada lakes in August and September	50 (Sep, the contribution from Snow Creek plus Snow/Nada lakes); 4 (Oct and Dec, representing base flow in Snow Creek)
Leavenworth National Fish Hatchery surface water intake	4.5	diversion	Year-round	40, 41, and 35 for Sep, Oct, and Dec, respectively
Cascade Orchard Irrigation Company intake	4.5	diversion	May 1 to Sep 30	6 (September only)
Leavenworth National Fish Hatchery headgate (used to divert water for aquifer recharge)	3.8	diversion	As needed in the period August through March when stream flows are less than 300 cfs[*]	Assumed to be 20 cfs, or stream flow when stream flow less than 20 cfs [**]
Leavenworth National Fish Hatchery fish ladder/outfall plus any flow over spillway dam	2.8	addition	Year-round	Sum of surface water intake + ground water used (Sep: 40 + 7; Oct 41+ 4; Dec 35 + 5)[***]

[*]The 2011Biological Assessment (prepared for the ESA consultation for bull trout) states " [w]hen stream flow in Icicle Creek is approximately below 300 cfs, LNFH may need to lower one or more radial gates of structure 2 for fifteen or more days at a time to ensure that enough water is in the hatchery channel for aquifer recharge." There are no ESA constraints on the LNFH's operation of Dam 2 for aquifer recharge in September, October, or December.

[**]A figure of 20 cfs was chosen to equal the 20 cfs "performance standard" assigned to the LNFH in the stakeholder process; an assumption that a diversion of only 20 cfs occurs when stream flow is greater than 20 cfs gives the benefit of the doubt to the LNFH. In any case, for this analysis, 20 cfs was considered sufficient to recharge the aquifer, although this calculation is not intended to be an accurate model of the groundwater use or recharge characteristics of this reach, but instead a simplification constructed for this analysis.

[***] Before the projects are implemented. This projection assumes that ground water use equals pump-back in a steady-state; therefore, after the three base projects were implemented, the addition at RM 2.8 consists solely of the surface water diversion amount.

Results

Existing Conditions: September

September low flows are critical in that diversions continue to take place as stream flow decreases to nearly base flow (Table 3). Flows at the USGS gage (RM 5.8) fall below 100 cfs. The 95% exceedence flow for many days in September is insufficient for the IPID and City of Leavenworth diversions.

Currently, the LNFH releases ~ 50 cfs from Snow and Nada lakes (plus the base flow from Snow Creek) that enters Icicle Creek at RM 5.5. That water supplies the LNFH's diversion plus enough to operate the fish ladder at the diversion dam at RM 4.5. Many days in a low-flow September, the reach from RM 4.5 to RM 3.8 is wetted only by a few cfs of water that is not diverted by LNFH and COIC. But any remaining water can be diverted (and during low-flow periods, is very likely to be diverted) by LNFH at the headgate at RM 3.8 into the hatchery canal to recharge the aquifer.

The existing conditions scenario indicates that the LNFH essentially releases the water it needs for its surface water diversion from Snow/Nada lakes, as Icicle Creek flow is not sufficient for all users. Below the IPID/City intakes, the stream flow is essentially zero. The Snow/Nada lakes addition wets the channel between RM 5.5 and 4.5, but downstream of the LNFH/COIC intakes, the stream is again reduced to near zero. Any remaining water is liable for diversion by LNFH for aquifer recharge at RM 3.8.

Table 3. Instream flow in Icicle Creek during existing conditions in a low-flow September (95% exceedence flow).

		Flow-affecting event (diversion or addition)				
	RM 5.8: Icicle Creek 95% exceedence flow @ USGS gage	RM 5.7: Minus 80 cfs (IPID 78 cfs net; City 2 cfs)	RM 5.5: Plus 50 cfs (Snow/Nada Lakes + Snow Creek base flow)	RM 4.5: Minus 46 cfs (LNFH 40 cfs ; COIC 6 cfs)	RM 3.8: Minus 20 cfs or stream flow if less than 20 (LNFH aquifer recharge diversion)	RM 2.8: Plus 47 cfs (LNFH surface water diversion plus ground water use)
	RM 5.8 to 5.7	RM 5.7 to 5.5	RM 5.5 to 4.5	RM 4.5 to 3.8	RM 3.8 to 2.8	RM 2.8 to mouth (discounting accretion)
1-Sep	117	37	87	41	25	72
2-Sep	109	29	79	33	13	60
3-Sep	100	20	70	24	4	51
4-Sep	101	21	71	25	5	52
5-Sep	99	19	69	23	3	50
6-Sep	96	16	66	20	0	47
7-Sep	93	13	63	17	0	47
8-Sep	90	10	60	14	0	47
9-Sep	88	8	58	12	0	47
10-Sep	91	11	61	15	0	47
11-Sep	90	10	60	14	0	47
12-Sep	87	7	57	11	0	47
13-Sep	84	4	54	8	0	47
14-Sep	85	5	55	9	0	47
15-Sep	81	1	51	5	0	47
16-Sep	81	1	51	5	0	47
17-Sep	81	1	51	5	0	47
18-Sep	78	0	50	4	0	47
19-Sep	78	0	50	4	0	47
20-Sep	76	0	50	4	0	47
21-Sep	75	0	50	4	0	47
22-Sep	74	0	50	4	0	47
23-Sep	74	0	50	4	0	47
24-Sep	73	0	50	4	0	47
25-Sep	72	0	50	4	0	47
26-Sep	71	0	50	4	0	47
27-Sep	71	0	50	4	0	47
28-Sep	70	0	50	4	0	47
29-Sep	70	0	50	4	0	47
30-Sep	74	0	50	4	0	47

With Base Projects Implemented: September

With implementation of the three base projects (assuming that the IPID pump exchange is 30 cfs, not 15 cfs as originally proposed), stream flow generally improves. However in a low-flow year, the three base projects are insufficient. Assuming a 30 cfs input into Icicle Creek from the pump-exchange project plus an additional 10 cfs realized from improvement/efficiencies from IPID and COIC, the reach from RM 4.5 to 2.8 nonetheless falls below 50 cfs for almost 2/3 of the days in a low-flow September, and that is even when Snow/Nada lakes water is released (Table 4).

In addition to returning water to the Icicle Creek from the three base projects, assurances, via binding agreements, must be made to ensure that any newly returned water stays in the Creek. Specifically 1) IPID must agree to continue to augment Icicle Creek flow with at least 15 cfs from Alpine Lakes during low-flow years; and 2) LNFH must agree to continue to release Snow/Nada lakes water, and not capture the saved water from the IPID pump exchange/efficiency projects. Also, we suggest that if the IPID intake is rebuilt and properly screened as part of this package of projects, that the intake be sized to the water right minus the project savings.

Table 4. Instream flows during a low-flow September after three base projects implemented.

		Flow-affecting event (diversion or addition)			
	RM 5.8 Hickle Creek 95% exceedence flow @ USGS gage	RM 5.7: Minus 42 cfs (IPID 40 cfs; City 2 cfs)	RM 5.5: Plus 50 cfs (Snow/Nicada Lakes + Snow Creek base flow)	RM 4.5: Minus 46 cfs (LNFH 40 cfs ; CCRC 6 cfs)	RM 2.8: Plus 40 cfs (LNFH surface water diversion plus ground water use)
	RM 5.8 to 5.7	RM 5.7 to 5.5	RM 5.5 to 4.5	RM 4.5 to 2.8	RM 2.8 to mouth (discounting accretion)
1-Sep	117	75	125	81	121
2-Sep	109	67	117	73	113
3-Sep	100	58	108	64	104
4-Sep	101	59	109	65	105
5-Sep	99	57	107	63	103
6-Sep	96	54	104	60	100
7-Sep	93	51	101	57	97
8-Sep	90	48	98	54	94
9-Sep	88	46	96	52	92
10-Sep	91	49	99	56	95
11-Sep	90	48	98	54	94
12-Sep	87	45	95	51	91
13-Sep	84	42	92	48	88
14-Sep	85	43	93	49	89
15-Sep	81	39	89	45	85
16-Sep	81	39	89	45	85
17-Sep	81	39	89	45	85
18-Sep	78	36	86	42	82
19-Sep	78	36	86	42	82
20-Sep	76	34	84	40	80
21-Sep	75	33	83	39	79
22-Sep	74	32	82	38	78
23-Sep	74	32	82	38	78
24-Sep	73	31	81	37	77
25-Sep	72	30	80	36	76
26-Sep	71	29	79	35	75
27-Sep	71	29	79	35	75
28-Sep	70	28	78	34	74
29-Sep	70	28	78	34	74
30-Sep	74	32	82	38	78

Existing Conditions: October

By October 1, Icicle Creek is no longer augmented by releases from the Alpine Lakes by IPID (reflected in the gage record). In addition, LNFH has stopped its releases from Snow/Nada lakes and the contribution from the Snow Creek watershed consists only of base flow. According to its Proposed Flow Management Operations plan, LNFH continues its surface water diversion (41 cfs) and could divert water into the canal for aquifer recharge (again, assumed as a 20 cfs diversion). In a low-flow year, the LNFH would almost certainly divert water in October for aquifer recharge purposes.

These factors result in little water in in Icicle Creek in October (Table 5). Instream flow in the historical channel is less than 20 cfs during all but three days in October.

Table 5. Instream flow in Icicle Creek during existing conditions in a low-flow October (95% exceedence flow).

		Flow-affecting event (diversion or addition)				
	RM 5.8: Icicle Creek 95% exceedence flow @ USGS gage	RM 5.7: Minus 2 cfs (City)	RM 5.5: Plus 4 cfs (Snow Creek base flow)	RM 4.5 Minus 41 cfs (LNFH surface water diversion)	RM 3.8: Minus 20 cfs (LNFH aquifer recharge diversion)	RM 2.8: Plus 45 cfs (LNFH surface water diversion plus ground water use)
	RM 5.8 to 5.7	RM 5.7 to 5.5	RM 5.5 to 4.5	RM 4.5 to 3.8	RM 3.8 to 2.8	RM 2.8 to mouth (discounting accretion)
1-Oct	70	68	72	31	11	56
2-Oct	68	66	70	29	9	54
3-Oct	67	65	69	28	8	53
4-Oct	66	64	68	27	7	52
5-Oct	65	63	67	26	6	51
6-Oct	65	63	67	26	6	51
7-Oct	65	63	67	26	6	51
8-Oct	65	63	67	26	6	51
9-Oct	69	67	71	30	10	55
10-Oct	68	66	70	29	9	54
11-Oct	67	65	69	28	8	53
12-Oct	69	67	71	30	10	55
13-Oct	75	73	77	36	16	61
14-Oct	76	74	78	37	17	62
15-Oct	77	75	79	38	18	63
16-Oct	74	72	76	35	15	60
17-Oct	73	71	75	34	14	59
18-Oct	71	69	73	32	12	57
19-Oct	70	68	72	31	11	56
20-Oct	70	68	72	31	11	56
21-Oct	74	72	76	35	15	60
22-Oct	73	71	75	34	14	59
23-Oct	77	75	79	38	18	63
24-Oct	79	77	81	40	20	65
25-Oct	86	84	88	47	27	72
26-Oct	82	80	84	43	23	68
27-Oct	78	76	80	39	19	64
28-Oct	76	74	78	37	17	62
29-Oct	77	75	79	38	18	63
30-Oct	75	73	77	36	16	61
31-Oct	73	71	75	34	14	59

With Base Projects Implemented: October

Because by October, neither IPID nor COIC are diverting, the two base projects that depend on their diversions are inapplicable in October (Table 6). Only the LNFH base project is operable in October--but its impact is nominal. Assuming the LNFH ceases the aquifer recharge diversion at RM 3.8, the historical channel has very low instream flows of below 40 cfs for all but three days in October. Without the results of the IFIM study, however, we cannot postulate what the impacts these month-long low flows would have on habitat.

To increase Icicle Creek's instream flow in October, further consideration must be given to potential projects that would reduce the LNFH's diversions and/or augment instream flow through releases from Snow/Nada lakes or any other controlled lakes in the Icicle Creek watershed. This released water must be specifically designated for augmenting instream flow.

Table 6. Instream flows during a low-flow October after three base projects implemented.

		Flow-affecting event (diversion or addition)			
	RM 5.8: Icicle Creek 95% exceedence flow @ USGS gage	RM 5.7: Minus 2 cfs (City)	RM 5.5: Plus 4 cfs (Snow Creek base flow)	RM 4.5 Minus 41 cfs (LNFH surface water diversion)	RM 2.8: Plus 41 cfs (LNFH surface water diversion)
	RM 5.8 to 5.7	RM 5.7 to 5.5	RM 5.5 to 4.5	RM 4.5 to 2.8	RM 2.8 to mouth (discounting accretion)
1-Oct	70	68	72	31	72
2-Oct	68	66	70	29	70
3-Oct	67	65	69	28	69
4-Oct	66	64	68	27	68
5-Oct	65	63	67	26	67
6-Oct	65	63	67	26	67
7-Oct	65	63	67	26	67
8-Oct	65	63	67	26	67
9-Oct	69	67	71	30	71
10-Oct	68	66	70	29	70
11-Oct	67	65	69	28	69
12-Oct	69	67	71	30	71
13-Oct	75	73	77	36	77
14-Oct	76	74	78	37	78
15-Oct	77	75	79	38	79
16-Oct	74	72	76	35	76
17-Oct	73	71	75	34	75
18-Oct	71	69	73	32	73
19-Oct	70	68	72	31	72
20-Oct	70	68	72	31	72
21-Oct	74	72	76	35	76
22-Oct	73	71	75	34	75
23-Oct	77	75	79	38	79
24-Oct	79	77	81	40	81
25-Oct	86	84	88	47	88
26-Oct	82	80	84	43	84
27-Oct	78	76	80	39	80
28-Oct	76	74	78	37	78
29-Oct	77	75	79	38	79
30-Oct	75	73	77	36	77
31-Oct	73	71	75	34	75

Existing Conditions: December

As December's diversions are practically identical to October's, the question is whether there are some periods of sustained low flows that approach the very low flows of October. Due to increased precipitation, low ambient stream flows in Icicle Creek occur less frequently than in October, but the LNFH diversions in December are comparable to those in October. A constructed hydrograph for December reveals that there are eighteen days under 40 cfs, eight days under 30 cfs, and three under 20 cfs in the reach RM 3.8 to 2.8 (historical channel) (Table 5).

Table 7. Instream flow in Icicle Creek during existing conditions in a low-flow December (95% exceedence flow).

		Flow-affecting event (diversion or addition)				
	RM 5.8: Icicle Creek 95% exceedence flow @ USGS gage	RM 5.7: Minus 2 cfs (City)	RM 5.5: Plus 4 cfs (Snow Creek base flow)	RM 4.5 Minus 35 cfs (LNFH surface water diversion)	RM 3.8: Minus 20 cfs (LNFH aquifer recharge diversion)	RM 2.8: Plus 40 cfs (LNFH surface water diversion plus ground water use)
	RM 5.8 to 5.7	RM 5.7 to 5.5	RM 5.5 to 4.5	RM 4.5 to 3.8	RM 3.8 to 2.8	RM 2.8 to mouth (discounting accretion)
1-Dec	106	104	108	73	53	93
2-Dec	105	103	107	72	52	92
3-Dec	105	103	107	72	52	92
4-Dec	105	103	107	72	52	92
5-Dec	102	100	104	69	49	89
6-Dec	101	99	103	68	48	88
7-Dec	99	97	101	66	46	86
8-Dec	97	95	99	64	44	84
9-Dec	88	86	90	55	35	75
10-Dec	84	82	86	51	31	71
11-Dec	82	80	84	49	29	69
12-Dec	64	62	66	31	11	51
13-Dec	62	60	64	29	9	49
14-Dec	66	64	68	33	13	53
15-Dec	77	75	79	44	24	64
16-Dec	77	75	79	44	24	64
17-Dec	81	79	83	48	28	68
18-Dec	82	80	84	49	29	69
19-Dec	84	82	86	51	31	71
20-Dec	83	81	85	50	30	70
21-Dec	90	88	92	57	37	77
22-Dec	89	87	91	56	36	76
23-Dec	89	87	91	56	36	76
24-Dec	88	86	90	55	35	75
25-Dec	87	85	89	54	34	74
26-Dec	87	85	89	54	34	74
27-Dec	94	92	96	61	41	81
28-Dec	97	95	99	64	44	84
29-Dec	97	95	99	64	44	84
30-Dec	96	94	98	63	43	83
31-Dec	93	91	95	60	40	80

With Base Projects Implemented: December

In the historical channel (RM 3.8 to 2.8), the average in December over the period studied was eight days below 50 cfs, three below 40 cfs, and one below 30 cfs.

Any additional projects that the stakeholder group considers to increase instream flow in October should be separately analyzed for December or later in winter.

Table 8. Instream flows during a low-flow October after three base projects implemented.

		Flow-affecting event (diversion or addition)			
	RM 5.8: Icicle Creek 95% exceedence flow @ USGS gage	RM 5.7: Minus 2 cfs (City)	RM 5.5: Plus 4 cfs (Snow Creek base flow)	RM 4.5 Minus 35 cfs (LNFH surface water diversion)	RM 2.8: Plus 35 cfs (LNFH surface water diversion)
	RM 5.8 to 5.7	RM 5.7 to 5.5	RM 5.5 to 4.5	RM 4.5 to 2.8	RM 2.8 to mouth (discounting accretion)
1-Dec	106	104	108	73	108
2-Dec	105	103	107	72	107
3-Dec	105	103	107	72	107
4-Dec	105	103	107	72	107
5-Dec	102	100	104	69	104
6-Dec	101	99	103	68	103
7-Dec	99	97	101	66	101
8-Dec	97	95	99	64	99
9-Dec	88	86	90	55	90
10-Dec	84	82	86	51	86
11-Dec	82	80	84	49	84
12-Dec	64	62	66	31	66
13-Dec	62	60	64	29	64
14-Dec	66	64	68	33	68
15-Dec	77	75	79	44	79
16-Dec	77	75	79	44	79
17-Dec	81	79	83	48	83
18-Dec	82	80	84	49	84
19-Dec	84	82	86	51	86
20-Dec	83	81	85	50	85
21-Dec	90	88	92	57	92
22-Dec	89	87	91	56	91
23-Dec	89	87	91	56	91
24-Dec	88	86	90	55	90
25-Dec	87	85	89	54	89
26-Dec	87	85	89	54	89
27-Dec	94	92	96	61	96
28-Dec	97	95	99	64	99
29-Dec	97	95	99	64	99
30-Dec	96	94	98	63	98
31-Dec	93	91	95	60	95

Discussion

The LNFH "base project" is a combination of on-site reuse, effluent pump-back and/or wellfield enhancements. This analysis only considers the effluent pump-back option because it removes LNFH's need to divert for aquifer recharge at RM 3.8. The water re-circulation or re-use option would allow the hatchery to divert 20 cfs less water at RM 4.5 and would result in greater instream flow benefits beginning at that point on the river. But those benefits might be wiped out at RM 3.8 if aquifer recharge diversion continues. The radial gates at Dam 2 are not precision instruments, and an assumption that the LNFH diverts only 20 cfs at RM 3.8 during low flow years may in fact be an underestimate. More precise data are required to evaluate the benefit of that option.

In any event, the three options listed under the LNFH base project, if implemented, would not collectively result in enough "saved" water to provide sufficient instream flow to Icicle Creek in low flow months (Table 9). In September, of course, the IPID and COIC projects would be helping instream flow, to the point where October is a much more critical low-flow month than September.

Table 9. Number of days below benchmark flows in RM 4.5 to RM 2.8 in low-flow months after base projects implemented.

Month / Flow	Days below 50 cfs	Days below 40 cfs	Days below 30 cfs
September	18	10	0
October	31	28	9
December	8	3	1

Even with implementation of the three base projects, this chart underscores that low flows continue to be a problem in September, October, and December. The benefits of the IPID- and COIC-related projects, moreover, cease on September 30th when the districts stop diverting. After that date, smaller diversions from LNFN or augmentation from storage (if feasible) are the only possible means to increase instream flows. Definite predictions for habitat cannot be made until the results of the IFIM study for the historical channel (RM 3.8 to 2.8) are available.