Shuswap Project Water Use Plan

Flow Disruptions at Wilsey Dam

Implementation Year 1

Reference: SHUWORKS-1

Final Report on Findings

Study Period: April 2009 – Mar 2011

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December 29, 2012

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Michael McArthur
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Submitted digitally to: Michael.McArthur2@bchydro.com

Re: MIDDLE SHUSWAP RIVER WATER LEVEL AND COMPLIANCE MONITORING REPORT (SHUWORKS#1)

Dear Mr. McArthur:

Summit Environmental Consultants Inc. (Summit) is pleased to provide you with this technical assessment on the effects of flow disruptions on fisheries populations in the Middle Shuswap River.

BC Hydro recently completed a three year field study on flow disruptions in the Middle Shuswap River caused by sudden outages at the Shuswap River Generation Station (SRGS). The purpose of this study was to assess the effectiveness of upgrades to the bypass valve (BPV) in reducing the frequency and magnitude of flow disruptions and the resulting impacts on fisheries populations downstream of Wilsey Dam. Summit was recently retained by BC Hydro to complete a technical assessment of these data. The primary objectives of this assessment were to:

- Summarize the magnitude, duration and rate of water level changes during SRGS outages;
- Assess the potential impacts on fisheries populations in the Middle Shuswap River due to water level reductions;
- Determine the effectiveness of the BPV upgrades according to performance measures outlined in the WUP;
- Identify information gaps critical to the above tasks; and
- Provide recommendations, as necessary.

Summit completed a preliminary assessment on the effectiveness of the BPV upgrades which was submitted to BC Hydro on May 24, 2012 . The following letter provides a technical assessment of flow disruptions and the potential impacts on fish and fish habitat downstream of Wilsey Dam. This letter also elaborates on the effectiveness of the BPV upgrades from an operational and fisheries perspective. A gap assessment identifies additional data and information to refine this assessment and is presented below along with recommendations on the next steps.

1 PROJECT OVERVIEW

The Shuswap River Generation Station (SRGS) is a 6 MW hydroelectric facility located on the Middle Shuswap River, near Lumby B.C. (Figure 1). This facility consists of an intake, two penstocks and generation units (Units 1 and 2), a bypass flow valve (on Unit 2) and two dams. Wilsey Dam is located adjacent to the SRGS and provides constant head pressure and sufficient water level required for operations. The Sugar Lake Dam is located about 35 km upstream of the SRGS and provides flow regulation and storage.

Reducing the frequency and magnitude of flow disruptions and the resulting impacts on fisheries populations in the Middle Shuswap River was identified as a high priority in the Shuswap River Water Use Plan[1] (WUP). Flow disruptions occur downstream of Wilsey Dam when a generation unit trips causing a sudden reduction in flow proportional to the volume no longer flowing through the penstocks (up to 31.6 m^3/s). The bypass valve (BPV) is operated during both Unit 1 and Unit 1 and 2 outages to minimize downstream flow disruptions until flows can be routed through the spillway. The total capacity of the BPV is 19.3 m^3/s. Historically, there were some issues with the operation of the BPV. If the BPV fails to operate correctly, there is a time delay (up to 90 minutes) between the unit outage and flow restoration downstream of the Dam, which can cause stranding of fish, dewatering of eggs/alevins, and temporary reductions in fish habitat suitability and availability.

A BC Hydro commitment made during the Shuswap River WUP was to investigate options for reducing malfunctions of the BPV so as to minimize downstream flow disruptions[2]. The primary findings and recommendations from this investigation and report focused on improving the reliability of the BPV and operational control logic[3]. The in-service date for the BPV upgrades was November 27, 2008, a detailed description of these upgrades is provided in the project completion report[4]. In addition, BC Hydro now operates the headpond water level in a manner which reduces the flow restoration lag during outages (i.e. water levels are maintained at the spillway sill).

As part of the Water License Requirement study commitment made under the WUP, BC Hydro monitored water levels at several locations along the Middle Shuswap River between April 2009 and March 2011 to assess the effectiveness of the BPV upgrades. The following report analyzes these data and makes some general comparisons to historic events.

[1] BC Hydro. 2007. Consultative Committee Report: Shuswap River Water Use Plan.
[2] Comptroller of Water Rights. 2006. Shuswap Water License Order (SHUSWAP#1).
[3] BC Hydro. 2006. Shuswap River Water License Requirements: Flow Disruptions at Wilsey Dam Report on Findings.
[4] BC Hydro. 2008. Project Completion Report: Shuswap Unit 2 Bypass Valve Control and Reliability Enhancement.

2 METHODS

As previously mentioned, a continuous water level monitoring program was completed by RE, on behalf of BC Hydro, between 2009 and 2011. Five water level monitoring stations, which were previously established by BC Hydro in 2000, and an existing Water Survey Canada (WSC) Hydrometric Station formed the basis for this monitoring program. The 6 monitoring sites included: Hatchery, WSC, Wilsey 1X, Deep Pool, Wilsey 2X and Wilsey 3X (Figure 2). Monitoring locations were selected based on the presence of critical spawning habitats, which were generally located near the monitoring sites[5].

All monitoring stations consisted of secured water level sensors and data loggers. Water level loggers were installed in relatively deeper areas of the stream to ensure they remained wetted throughout the monitoring period. The water level measurements recorded at these sites referenced to local benchmarks, not absolute elevations. The BC Hydro monitoring stations recorded continuous data at 5 minute intervals, while the WSC station recorded both 15 minute (2009 and 2010) and 5 minute (2011) data. BC Hydro provided Summit with all available water level data for the 5 Wilsey sites. Water level and flow data was retrieved directly from the WSC site[6].

The date, time and duration of outages at the SRGS were determined by reviewing Unit 2 flow records, which were also provided by BC Hydro. The onset (start) of an outage was identified when Unit 2 flow began to rapidly recede from a steady level eventually reaching zero. The date, time and duration of changes in water level were determined for each outage and at each site according to the same criteria, recognizing the lag in response between the dam and sites. Plots showing a 24 hr water level record at all sites were developed for each outage event. The following metrics were also calculated for each outage and site:

- Range in water level change;
- Maximum change in water level; and
- Average and maximum 5 min, 15 min and hourly rates of water level change;

Flow data from the WSC monitoring station was also plotted with instream flow requirements (IFR) for the SRGS to identify any potential exceedances.

Available background reports were reviewed to identify fisheries resource values, critical habitats and limiting factors. All of the above information was used to assess the effectiveness of the BPV upgrades and potential impacts of flow disruptions on fisheries populations.

[5] Personal communication with Remote Environmental (Kirk), May 29, 2012.
[6] Environment Canada. 2012. Water Survey of Canada: Archived Hydrometric Data. Rretrieved online May 22, 2012.

3 RESULTS

3.1 FLOW DISRUPTIONS

A total of 8 outages occurred at the SRGS between 2009 and 2011, 6 of which occurred in 2009 and 2 in 2011. The duration of these outages ranged from 1 to more than 17 hrs. The BPV appeared to trigger during all events. Further discussion on the effectiveness of the BPV is provided in Section 3.3. A summary of the outage dates and durations is provided in Table 1, with an indication of the available data. Water level data from the Wilsey monitoring sites was not available for one event in 2009 and both 2011 events.

The instream flow requirements (IFR) for the Middle Shuswap River, downstream of Wilsey Dam, include: 13 m^3/s (Jan 1 to Aug 14) and 16 m^3/s (Aug 15 to Dec 31). A review of the 2009 and 2011 flow data from the WSC site confirms that these criteria were met during each outage period, and over the course of each year. Annual hydrographs for the WSC site are presented in Figures 3 and 4 for 2009 and 2011, respectively, and include a depiction of the above IFRs.

The average maximum change in flow at the WSC site during the 2009 and 2011 outages was 1.4 m^3/s (range 0.2 to 1.9 m^3/s), with unaffected (pre-outage) flows between 18.2 and 63.3 m^3/s (Table 2). This corresponds to an average maximum reduction in flow of about 6% (range to 9%). Given the respective Unit 2 flows (~5 to 9 m^3/s) and maximum changes noted above, the upper sections of the Middle Shuswap River, between Wilsey Dam and the WSC site, appear to mitigate the risk of stranding during outages (i.e. water in these areas continues draining after inflow ceases). The upper sections of this reach are confined within a narrow box canyon and are composed of deep (> 5 m) pools. The same effect would also be expected in lower reaches of the Middle Shuswap River.

Water level data from the Hatchery Site, which is located furthest upstream, was used as a surrogate to identify events and response times. The lag in response time between the Dam and Hatchery Site is expected to be less than 30 min, with increasing response times for the downstream sites. Decreasing water levels generally coincide with the onset of disruptions and decreases in Unit 2 flow. The lowest water levels consistently occur downstream of Wilsey Dam when Unit 2 flows reaches zero and the BPV is triggered. From this point, water levels tend to increase consistently over a 1 hour period until pre-outage levels are achieved. Secondary water level reductions are occasionally experienced (October 6, 2009, November 9, 2009 and February 10, 2011) and are expected to result from the switch between flow through the BPV (or spillway) and Unit 2. Similarly, the lowest water levels are experienced around the time of the switch, with consistent increases during ramping up of Unit 2. Water level plots are presented for each outage in Figures 5 to 12.

The duration of water level changes ranged from about 2 to 12 hrs. There were no relation between the magnitude or duration of water level change and pre-outage flows. The magnitude of water level reduction varied substantially between sites and outages, which is a function of differences in channel morphology, distance downstream, tributary inflows and the magnitude of flow disruption. The greatest reductions in water level (up to

7.2 cm) are consistently experienced at the Hatchery site which is a narrow, deep run and is the furthest upstream monitoring site. Conversely, the smallest reductions (up to 2.5 cm) were observed at the Wilsey 3X and Deer Pool sites, which are relatively wider pools with some level of buffering capacity. In general, the monitoring results suggest an apparent trend in the magnitude of water level change with distance downstream, but indicate that channel morphology is the most influential factor. Refer to Table 3 for a general description of channel morphology at each site.

The rates of water level reduction for all sites and outages range from 0.3 to 5.1 cm/hr. Similar to above, the highest rates of change consistently occur at the Hatchery site and the lowest at the Wilsey 3X and Deer Pool sites. This finding further confirms that channel morphology has the greatest influence on water level changes in the Middle Shuswap River. For most sites, the maximum 5 min and 15 min reduction rates are typically less than 1 cm per time period, however, there are some exceptions. The hatchery site frequently experiences higher rates, which can reach 2.9 cm/ 5 min and 4.2 cm/15 min. A summary of changes in water level at each site is presented in Tables 4 to 9.

The results from this assessment do not indicate a relationship between the magnitude or rate of change in water level and pre-outage flow. However, there is limited data for this analysis and a relatively narrow and constant range in pre-outage flows (~18 to 28 m^3/s), considering flows can reach upwards of 250 m^3/s. Likewise, there was no clear relationship between water level changes and seasons since most of the outages occurred after spring freshet, during the late summer through winter low flow period.

3.2 FISHERIES IMPACTS

The Middle Shuswap River, downstream of Wilsey dam, has fisheries resource value that provides critical spawning and rearing habitat for Chinook (*Oncorhynchus tshawytscha*), Coho (*O. kisutch*) and Sockeye Salmon (*O. nerka*), Rainbow trout (*O. mykiss*), Bull trout (*Salvelinus confluentus*), Kokanee (*O. nerka*) and Mountain whitefish (*Prosopium williamsoni*)[7]. The highest value spawning habitats in this system are generally associated with glide, run and riffle mesohabitat types. Juvenile (fry and parr) rearing habitat suitability and availability are also high in these mesohabitat types, particularly along the shallower margins of the river. Extensive braided sections and side channels throughout the Middle Shuswap River also provide valuable rearing habitat for juveniles. Adult habitat suitability and availability is generally highest in deeper pools, runs and glides. The Water Use Planning Consultative Committee (CC) has emphasized the protection of this valuable fisheries resource.

Rapid reductions in water level can dewater habitat and strand fish, which can lead to mortality through suffocation, desiccation, freezing and/or predation. Fish may become stranded in isolated pools, or in the

[7] BC Hydro. 2007. Consultative Committee Report: Shuswap River Water Use Plan.

interstices spaces in substrates. The Fish Technical Committee (FTC) involved in the SRGS WUP process outlined the following life stage specific, time-based risks of stranding[8]:

- Eggs buried in gravel are the least susceptible to damage from short-term dewatering;
- Damage to alevins occurs very quickly during dewatering due to their high oxygen demand;
- Mortality to juvenile fish occurs very quickly during dewatering due to high oxygen demands and predation; and
- Adult fish may be able to avoid stranding initially, but will also succumb rapidly to oxygen depletion and predation if they become trapped in small pools.

Interim flow ramping guidelines for hydroelectric projects in BC indicate a maximum reduction in water level of 2.5 cm/hr when fry are present and 5 cm/hr in all other instances[9]. BC Hydro has also identified a ramping guideline of 2.5 cm/hr for the SRGS. Compliance with these criteria were met 79% and %100 percent of the time during outages at the SRGS based on the maximum and average water level reduction rates, respectively. It is important to note that these ramping guidelines are intended for planned outages (only) and do not apply to forced (unplanned) outages as is the case in this assessment. Few hydropower projects have the capacity to meet these guidelines during forced outages. Having said this, the above comparisons are intended to provide some insight on the potential for adverse effects.

The above results suggest a reduced risk of stranding and impact at the Middle Shuswap River monitoring sites, particularly for adult fish. However, they provide little indication on the risk of stranding juvenile fish (fry and parr) in sensitive rearing habitats (e.g. shallow riffles, glides, braided sections and side channels) since all of the monitoring sites are located in deeper runs and pools. These results also suggest mixed results in terms of the potential risk of dewatering early life stages of fish such as eggs and alevins. For salmon species, the risk of dewatering and potential impacts are expected to be low since they typically spawn in deeper areas of the stream. However, the risk to smaller resident (i.e. bull trout, rainbow trout, kokanee and whitefish) could be elevated since these species may spawn in shallower areas.

Given the diverse range of species present in this system, there is no period which may be more or less sensitive to flow disruptions from a fisheries perspective alone. Eggs/alevins are incubating and fry are emerging and rearing throughout the year in this system, while spawning occurs only in the spring (April – May) and fall (September – November).

The overall risk of dewatering and stranding and the potential impacts on fish are difficult to determine given the available information. The extent of areas which are dewatered during an outage event and the characteristics and usage of these areas are unknown. In addition, all of the monitoring sites are located in runs and pools which

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[8] BC Hydro. 2007. Consultative Committee Report: Shuswap River Water Use Plan.

[9] Lewis, A., C.Zyla., and P. Gibeau. 2011. Flow Ramping Guidelines for Hydroelectric Projects: Developing, Testing, and Compliance Monitoring, Draft V1. Prepared for Clean Energy BC, Department of Fisheries and Oceans and the Ministry of Environment. Currently under review.

are less susceptible to rapid reductions than are riffles and glides. These results suggest that the magnitude and duration of flow disturbances, and the potential risk of stranding, is reduced during high flow conditions. However, most of the outage events occurred between August and March during relatively low flow periods, with only one outage event in July during high flows, so sensitivity comparisons between flow levels are limited.

Ideally, water level monitoring sites would be established within sensitive areas specific to each life stage and species of fish, and channel cross sections would be surveyed to provide context on changes in water level and estimates of dewatered areas. Fisheries presence/absence sampling would aid in the selection of these critical sites. Further considerations may also include critical flow levels and periods. The study described above would increase the confidence of determinations (expectations) on the potential risk of stranding discussed in this report. Assessments on (actual) fish mortality due to stranding are inherently challenging, particularly in a case such as this because there is often little notice.

Decreases in habitat suitability and availability due to flow and water level reductions caused by forced outages at the SRGS are expected. These conditions may cause temporary, short-term disruption and displacement of rearing fish. Given that these events are relatively infrequent, the potential impacts on rearing or spawning fish are likely minor.

Inflows from major tributaries located between Wilsey Dam and Mable Lake may mitigate (lessen) the adverse effects of flow disturbances downstream of their confluences. The mitigative capacity of these tributaries would largely depend on flows (and flow changes) in the Shuswap River and the relative proportion of tributary inflow. Tributary inflows would likely have little mitigative capacity during low flow periods (late summer through winter) or during a high magnitude flow disruption. The mitigative capacity would increase with distance downstream as more water enters the Shuswap River. The relative change in flow would not be effected at any location in the river.

3.3 BPV EFFECTIVENESS

The objectives of the BPV upgrades were to minimize the frequency and magnitude of flow disruptions and the resulting impacts on fish and fish habitat in the Middle Shuswap River. Performance measures for meeting these objectives are based on qualitative judgments, as outlined in the BC Hydro WUP[10]:

Major flow disruptions, where the flow through the generators is disrupted and the bypass valve fails, occurred 4 times per year prior to the initial BPV upgrades in 1999. After the completion of these upgrades, major flow disruptions were reduced to 2 per year. The results from this assessment indicate that this number has been

[10] BC Hydro. 2007. Consultative Committee Report: Shuswap River Water Use Plan.

further reduced to zero. Information on the frequency and magnitude of minor flow reductions, where the generators are disrupted and the BPV operates, is not available at this time so limited judgements can be made here. Limited information is also available on the duration of flow disturbances.

There has been substantial improvement; however, potential effects on incubating eggs/alevins and rearing juveniles cannot be fully evaluated based on the information provided.

4 CONCLUSIONS AND RECOMMENDATIONS

In summary, the potential impacts on fish in the Middle Shuswap River due to flow disturbances are mixed. The results presented above suggest the risk of stranding adult fish is negligible, but could be greater for juveniles. Dewatering of early life stages of fish (i.e. eggs and alevins) is unlikely for salmon, but may be more significant for other species such as bull trout, rainbow trout, kokanee and whitefish. The effects of temporary reductions in habitat suitability and availability during flow disruptions are likely low for all species and life stages. The overall effect on fisheries populations resulting from flow disruptions at the SRGS are expected to be minor, but there are significant uncertainties in this evaluation. Also the link between flow changes and long-term impacts on overall fish productivity is unknown.

The results from this assessment suggest the greatest risk of impact on fisheries populations occurs when flow in the generation units is disrupted and receding. If a more definitive assessment is desired the then following information should be incorporated to fill gaps:

- Location of monitoring sites in sensitive habitats;
- Presence/absence fisheries sampling;
- Surveys of channel cross sections at water level monitoring sites; and
- Determination of critical water levels and periods.

The instream flow requirements (IFR) for the Middle Shuswap River, downstream of Wilsey Dam were met during each of the outage events in 2009 and 2011.

Please feel free to contact me if you have any further questions or concerns with this this technical assessment.

Yours truly,

Adam Neil
Environmental Scientist

Brent Phillips, M.Sc., R.P. Bio
Senior Environmental Scientist

Attachment – Tables and Figures

Table 1. Summary of outages and available data

Outage Date	Duration (hrs)	Available Site Data					
		Hatchery	WSC	Wilsey 1X	Deer Pool	Wilsey 2X	Wilsey 3X
09-Jul-09	15						
30-Jul-09	n/a	n/a		n/a	n/a	n/a	n/a
07-Aug-09	> 10						
06-Oct-09	6						
09-Nov-09	> 17			n/a			
17-Nov-09	> 9						
10-Feb-11	9	n/a		n/a	n/a	n/a	n/a
13-Mar-11	1	n/a		n/a	n/a	n/a	n/a

"n/a" - data not available

">" - outage period is greater than indicated

Table 2. Flow data at the WSC site during SRGS outages.

Date	Time (24 hr)	Duration (hr)	Flow		
			Range[1] (m3/s)	Max Change[2] (m3/s)	(%)
09-Jul-09	8:30 - 23:55	3.0	61.4 - 63.3	1.9	3%
30-Jul-09	n/a	na	n/a	n/a	n/a
07-Aug-09	7:00 - 23:55	7.0	19.4 - 21.1	1.7	9%
06-Oct-09	6:30 - 11:00	5.5	16.6 - 18.2	1.6	9%
11-Nov-09	6:30 - 23:55	10.5	17.9 - 19.3	1.4	7%
17-Nov-09	9:00 - 17:00	5.0	18.1 - 19.1	1.0	5%
10-Feb-11	8:10 - 19:40	5.1	27.1 - 28.9	1.8	6%
13-Mar-11	14:00 - 16:00	2.0	27.4 - 27.6	0.2	1%

[1] Range in flow during an outage event (min and max)

[2] Maximum change in flow (onset to lowest)

"n/a" - data not available

Table 3. General discriptions of channel morphology for the monitoring sites.

Site	Distance Downstream[1] (km)	Mesohabitat Type
Hatchery	1.20	Run
WSC	1.46	Run
Wilsey 1X	2.25	Run
Deer Pool	3.09	Pool
Wilsey 2X	9.35	Pool
Wilsey 3X	18.88	Pool

[1] Distance from Wilsey dam

Table 4. Summary of water level changes at the Hatchery site.

Date	Time	Duration	Water Level		Water Level Reduction Rates					
			Range[1]	Max Change[2]	(cm/5 min)		(cm/15 min)		(cm/hour)	
	(24 hr)	(hr)	(m)	(cm)	Avg[3]	Max[4]	Avg	Max	Avg	Max
09-Jul-09	9:10 - 10:50	1.7	0.803 - 0.832	2.9	-0.7	-1.8	-0.7	-2.1	-0.7	-2.6
30-Jul-09	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
07-Aug-09	8:30-16:30	8.0	0.330 - 0.402	7.2	-0.1	-1.2	-0.3	-2.1	-0.5	-4.3
06-Oct-09	8:40-11:05 & 13:50-15:50	4.5	0.277 - 0.346	6.9	-0.6	-1.6	-1.1	-2.7	-2.4	-5.1
09-Nov-09	8:20-11:05 & 15:00-19:35	7.2	0.290 - 0.347	5.7	-0.7	-2.9	-1.2	-4.2	-1.9	-4.6
17-Nov-09	15:30-17:30	2.0	0.314 - 0.344	3.0	-1.0	-1.7	-1.8	-3.0	-1.5	-2.0

[1] Arbitrary range in stage elevation (min and max)
[2] Maximum change in w ater level (onset to low est)
[3] Average rate of change during w ater level recessions
[4] Maximum rate of change during w ater level recessions
"n/a" - data not available

Table 5. Summary of water level changes at the WSC site.

Date	Time	Duration	Water Level		Water Level Reduction Rates					
			Range[1]	Max Change[2]	(cm/5 min)		(cm/15 min)		(cm/hour)	
	(24 hr)	(hr)	(m)	(cm)	Avg[3]	Max[4]	Avg	Max	Avg	Max
09-Jul-09	8:00-11:00	3.0	4.164 - 4.183	1.9	n/a	n/a	-0.5	-0.5	-1.2	-1.9
30-Jul-09	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
07-Aug-09	7:00-14:00	7.0	3.590 - 3.623	3.3	n/a	n/a	-0.2	-0.3	-0.7	-1.2
06-Oct-09	6:30-11:00	5.5	3.530 - 3.564	3.4	n/a	n/a	-0.4	-0.6	-1	-2.4
09-Nov-09	6:30-11:00 & 14:00-20:00	10.5	3.557 - 3.587	3.0	n/a	n/a	-0.2	-0.4	-0.7	-1.5
17-Nov-09	9:00-11:00 & 14:00 -17:00	5.0	3.561 - 3.584	2.3	n/a	n/a	-0.3	-0.5	-0.6	-1.1
10-Feb-11	8:10-9:35 & 16:00-19:40	5	3.690 - 3.717	2.7	-0.2	-1.1	-0.4	-1.8	-0.8	-1.8
13-Mar-11	14:00-16:00	2.0	3.695 - 3.698	0.3	-0.1	-0.2	-0.1	-0.2	-0.1	-0.3

[1] Arbitrary range in stage elevation (min and max)
[2] Maximum change in w ater level (onset to low est)
[3] Average rate of change during w ater level recessions
[4] Maximum rate of change during w ater level recessions
"n/a" - data is not avalible

Table 6. Summary of water level changes at the Wilsey 1X site.

Date	Time (24 hr)	Duration (hr)	Water Level: Range[1] (m)	Water Level: Max Change[2] (cm)	Water Level Reduction Rates (cm/5 min): Avg[3]	(cm/5 min): Max[4]	(cm/15 min): Avg	(cm/15 min): Max	(cm/hour): Avg	(cm/hour): Max
09-Jul-09	9:20 - 10:55	1.6	0.619 - 0.635	1.6	-0.2	-0.3	-0.4	-0.9	-0.6	-1.5
30-Jul-09	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
07-Aug-09	8:40 - 16:30	7.8	0.173 - 0.202	2.9	-0.2	-0.3	-0.4	-0.8	-0.8	-1.5
06-Oct-09	8:55-11:15 & 14:10-18:55	10.0	0.834 - 0.878	4.4	-0.2	-0.5	-0.5	-1.1	-1.1	-2.6
09-Nov-09	8:45 - 12:20 & 15:20 - 19:30	7.8	0.851 - 0.883	3.2	-0.3	-0.8	-0.7	-2.3	-1	-2.6
17-Nov-09	16:05-18:10	2.1	0.864 - 0.879	1.5	-0.4	-0.5	-1.0	-1.4	-0.8	-1.0

[1] Arbitrary range in stage elevation (min and max)

[2] Maximum change in water level (onset to lowest)

[3] Average rate of change during water level recessions

[4] Maximum rate of change during water level recessions

"n/a" - data not available

Table 7. Summary of water level changes at the Deer Pool site.

Date	Time (24 hr)	Duration (hr)	Water Level: Range[1] (m)	Water Level: Max Change[2] (cm)	Water Level Reduction Rates (cm/5 min): Avg[3]	(cm/5 min): Max[4]	(cm/15 min): Avg	(cm/15 min): Max	(cm/hour): Avg	(cm/hour): Max
09-Jul-09	9:40 - 10:45	1.1	0.671 - 0.691	2.0	-0.6	-1.0	-0.9	-1.0	-1.0	-2.6
30-Jul-09	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
07-Aug-09	9:00-16:30	7.5	0.405 - 0.421	1.6	-0.1	-0.1	-0.1	-0.2	-0.4	-0.6
06-Oct-09	9:30-11:55 & 14:10-16:45	5.9	0.306 - 0.331	2.5	-0.1	-0.3	-0.3	-0.6	-0.6	-1.6
09-Nov-09	11:05-23:55	12.8	0.338 - 0.344	0.6	-0.1	-0.1	-0.1	-0.2	-0.1	-0.3
17-Nov-09	15:50-23:55	8.1	0.330 - 0.333	0.3	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1

[1] Arbitrary range in stage elevation (min and max)

[2] Maximum change in water level (onset to lowest)

[3] Average rate of change during water level recessions

[4] Maximum rate of change during water level recessions

"n/a" - data not available

Table 8. Summary of water level changes at the Wilsey 2X site.

Date	Time (24 hr)	Duration (hr)	Water Level: Range[1] (m)	Water Level: Max Change[2] (cm)	Water Level Reduction Rates (cm/5 min): Avg[3]	(cm/5 min): Max[4]	(cm/15 min): Avg	(cm/15 min): Max	(cm/hour): Avg	(cm/hour): Max
09-Jul-09	10:35 - 13:00	2.5	0.788 - 0.805	1.7	-0.5	-1.0	-0.5	-1.0	-0.6	-0.9
30-Jul-09	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
07-Aug-09	9:55 - 17:45	7.8	0.234 - 0.259	2.5	-0.1	-0.3	-0.2	-0.5	-0.6	-1.2
06-Oct-09	10:25-13:20 & 15:05-18:00	5.2	0.281 - 0.318	3.7	-0.3	-0.6	-0.4	-1.1	-1.3	-2.7
09-Nov-09	16:25-21:10	3.8	0.306 - 0.340	3.4	-0.3	-0.7	-0.4	-0.8	-0.9	-2.3
17-Nov-09	17:10-19:55	2.8	0.317 - 0.329	1.2	-0.2	-0.3	-0.2	-0.4	-0.4	-1.0

[1] Arbitrary range in stage elevation (min and max)

[2] Maximum change in w ater level (onset to low est)

[3] Average rate of change during w ater level recessions

[4] Maximum rate of change during w ater level recessions

"n/a" - data not available

Table 9. Summary of water level changes at the Wilsey 3x site.

Date	Time (24 hr)	Duration (hr)	Water Level: Range[1] (m)	Water Level: Max Change[2] (cm)	Water Level Reduction Rates (cm/5 min): Avg[3]	(cm/5 min): Max[4]	(cm/15 min): Avg	(cm/15 min): Max	(cm/hour): Avg	(cm/hour): Max
09-Jul-09	n/e	n/e	n/e	n/e	n/e	n/e	n/e	n/e	n/e	n/e
30-Jul-09	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
07-Aug-09	12:00-20:55	8.9	0.993 - 1.008	1.5	-0.1	-0.3	-0.2	-0.4	-0.4	-0.8
06-Oct-09	12:35 -20:15	7.7	0.902 - 0.920	1.8	-0.1	-0.3	-0.2	-0.4	-0.4	-1.0
09-Nov-09	18:50-23:55	5.1	0.920 - 0.944	2.4	-0.2	-0.3	-0.2	-0.5	-0.6	-1.0
17-Nov-09	19:30-23:55	4.4	0.930 - 0.936	0.6	-0.1	-0.2	-0.1	-0.3	-0.2	-0.4

[1] Arbitrary range in stage elevation (min and max)

[2] Maximum change in w ater level (onset to low est)

[3] Average rate of change during w ater level recessions

[4] Maximum rate of change during w ater level recessions

"n/e" - no visible effect during outage

"n/a" - data not available

Figure 1. Project Location.

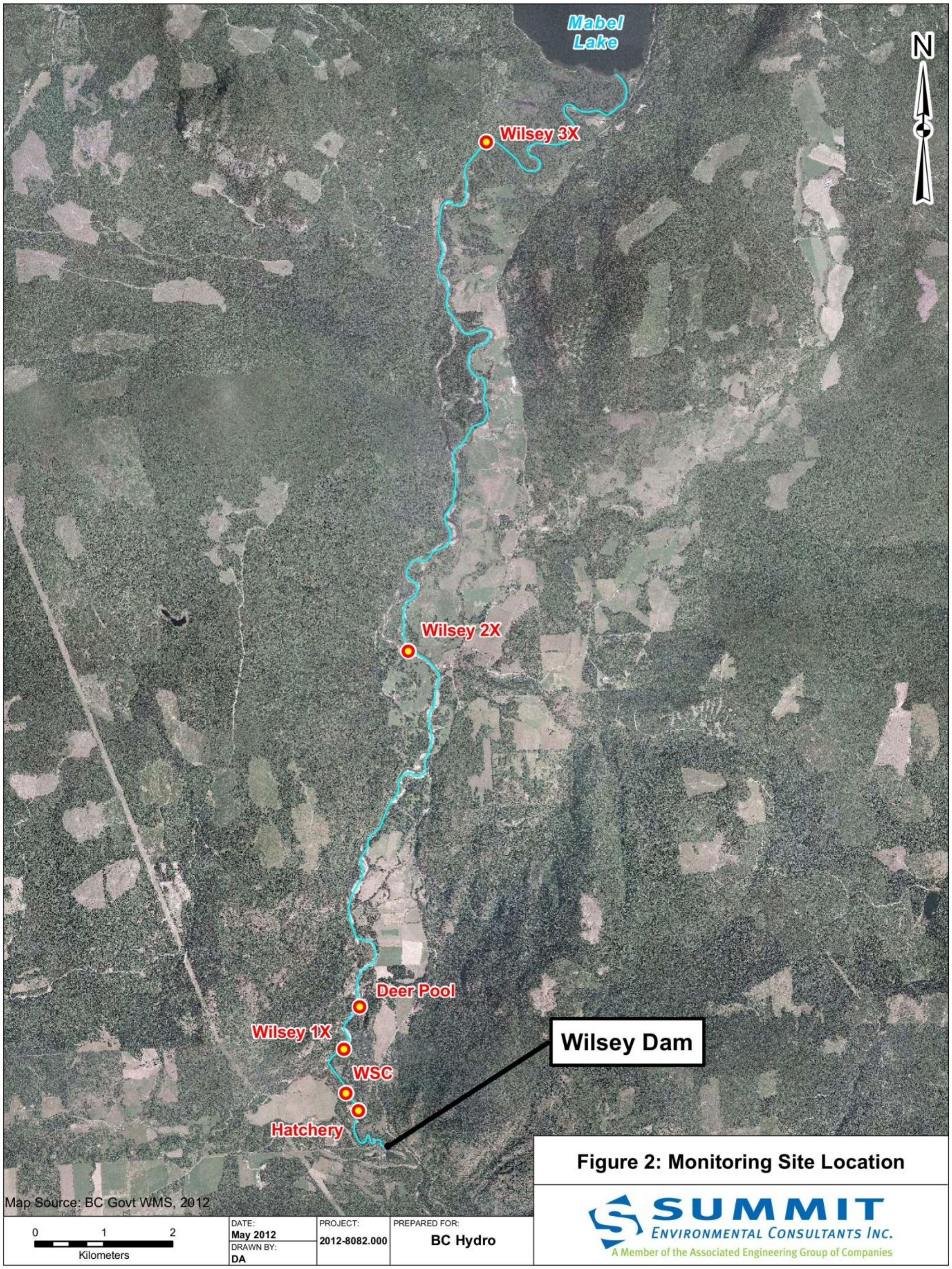

Figure 2. Monitoring site locations.

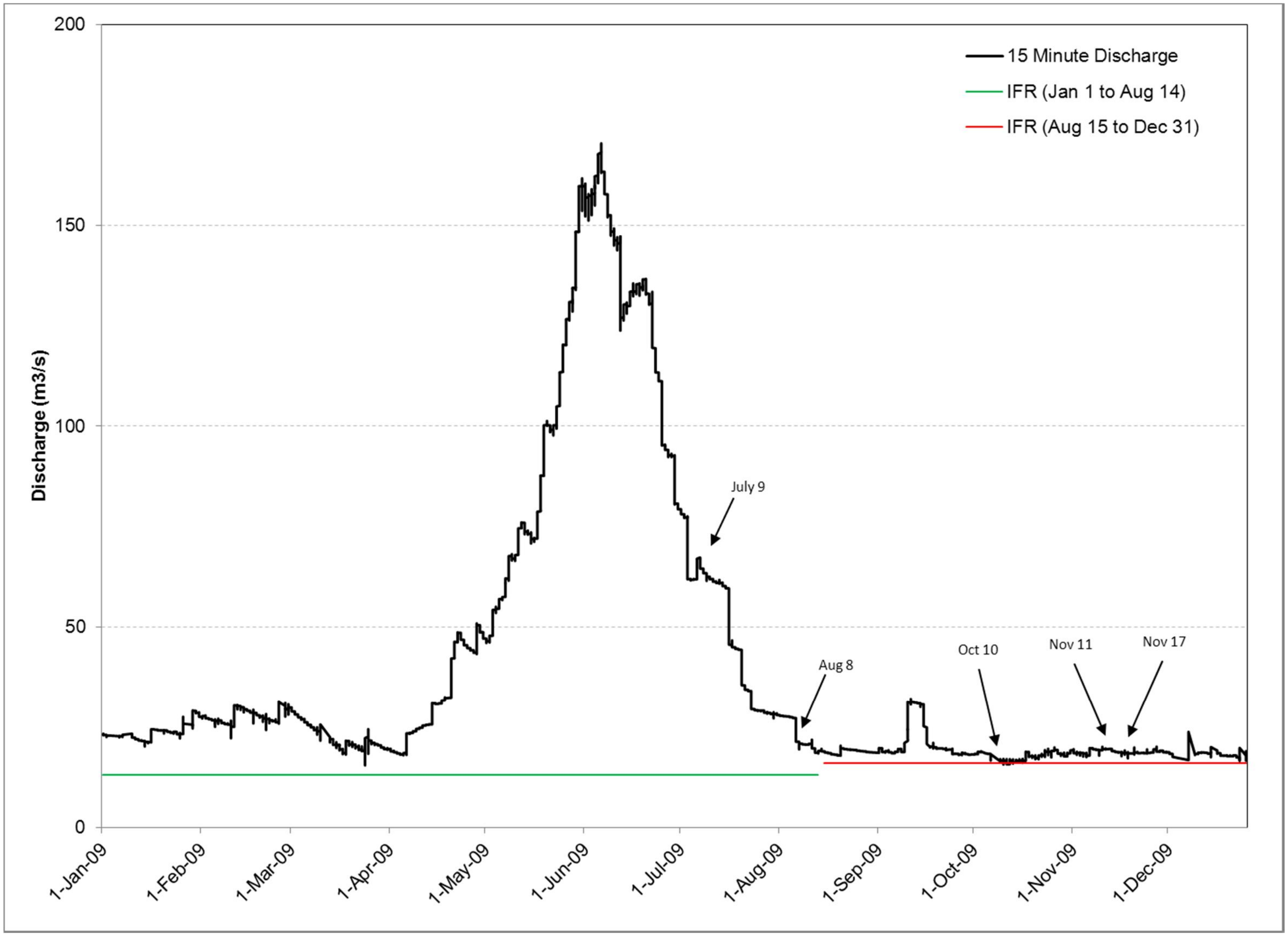

Figure 3. Annual hydrograph for WSC station, 2009.

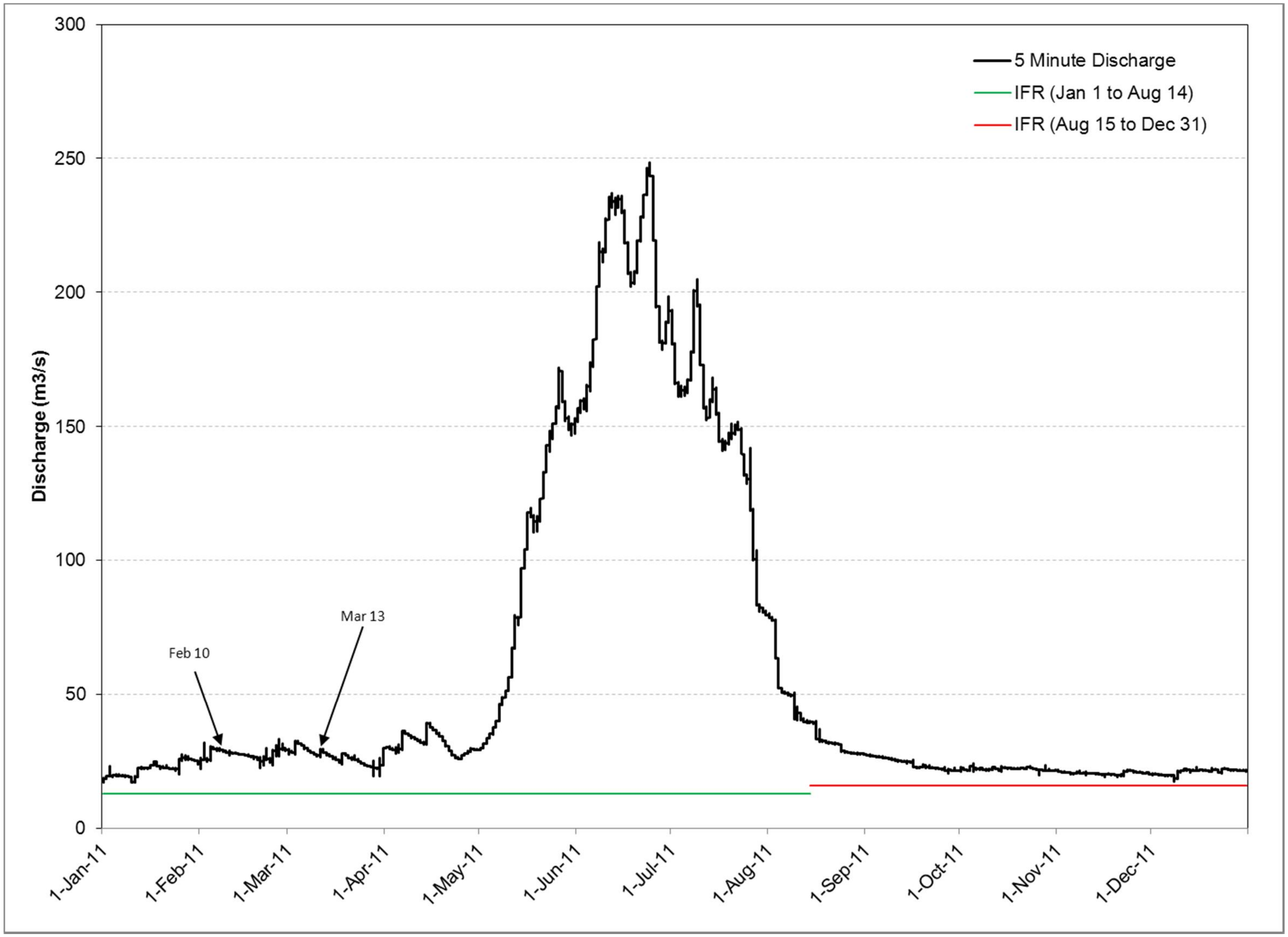

Figure 4. Annual hydrograph for WSC station, 2011.

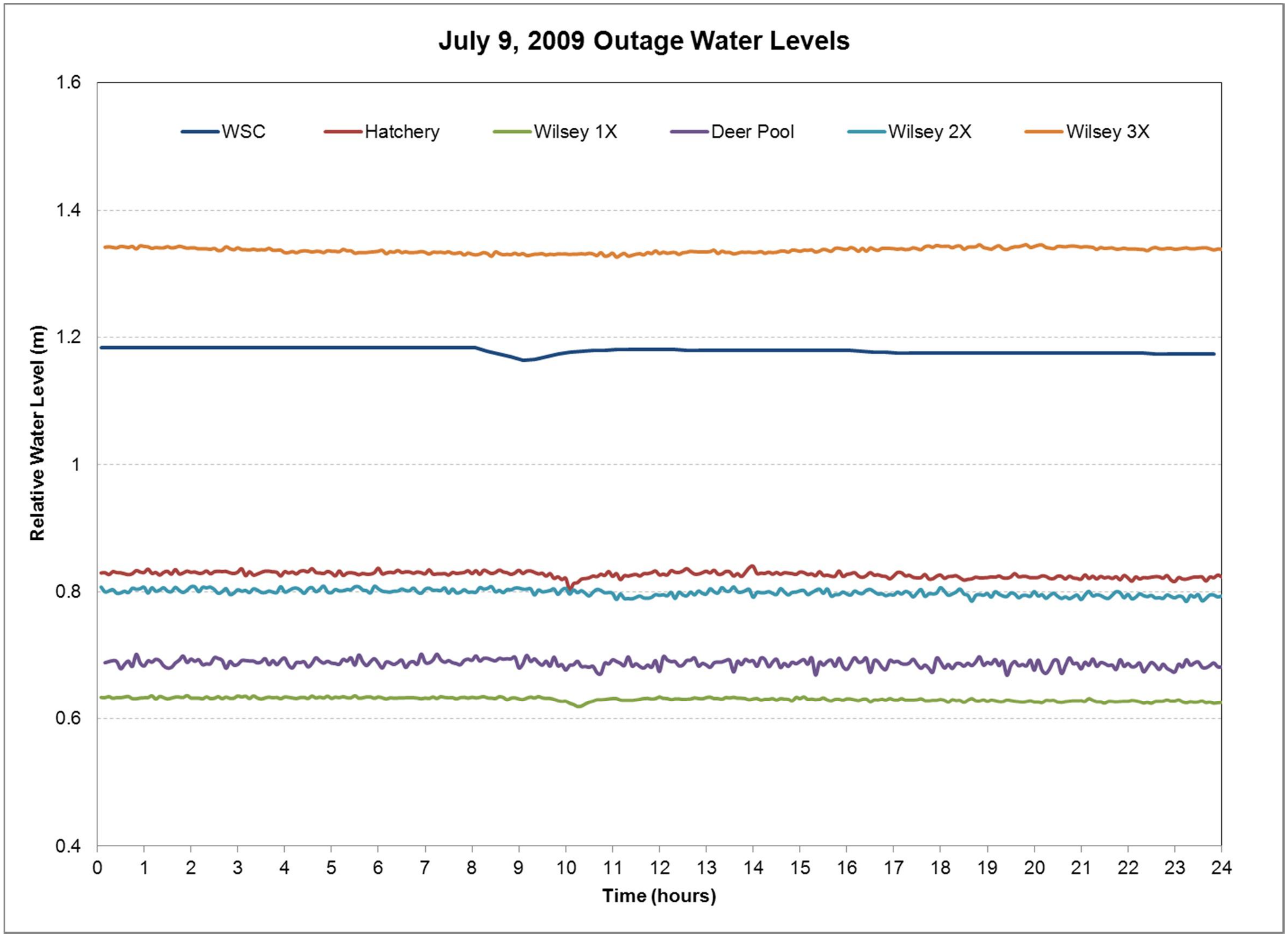

Figure 5. Water levels for July 9, 2009.

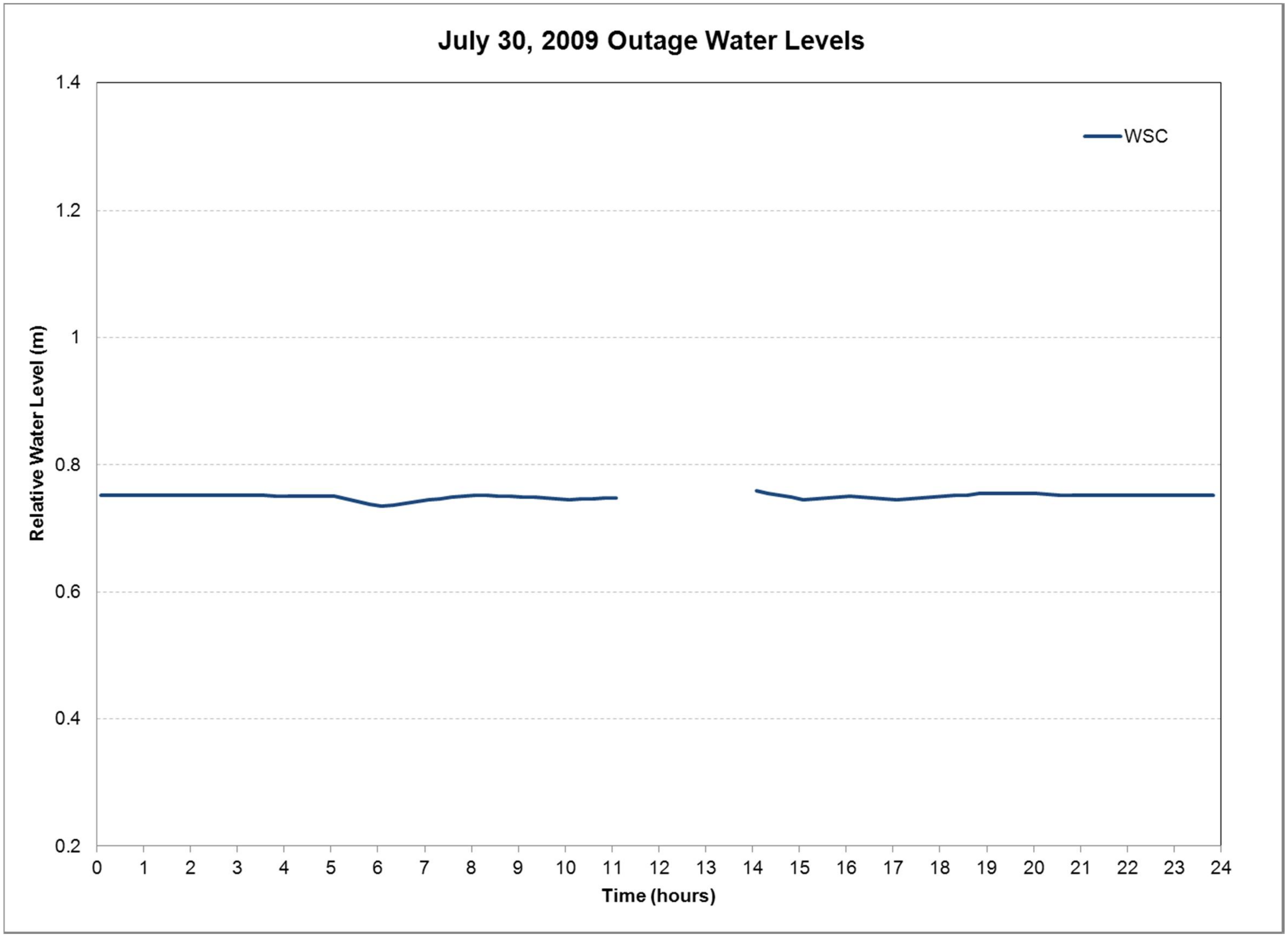

Figure 6. Water levels for July 30, 2009.

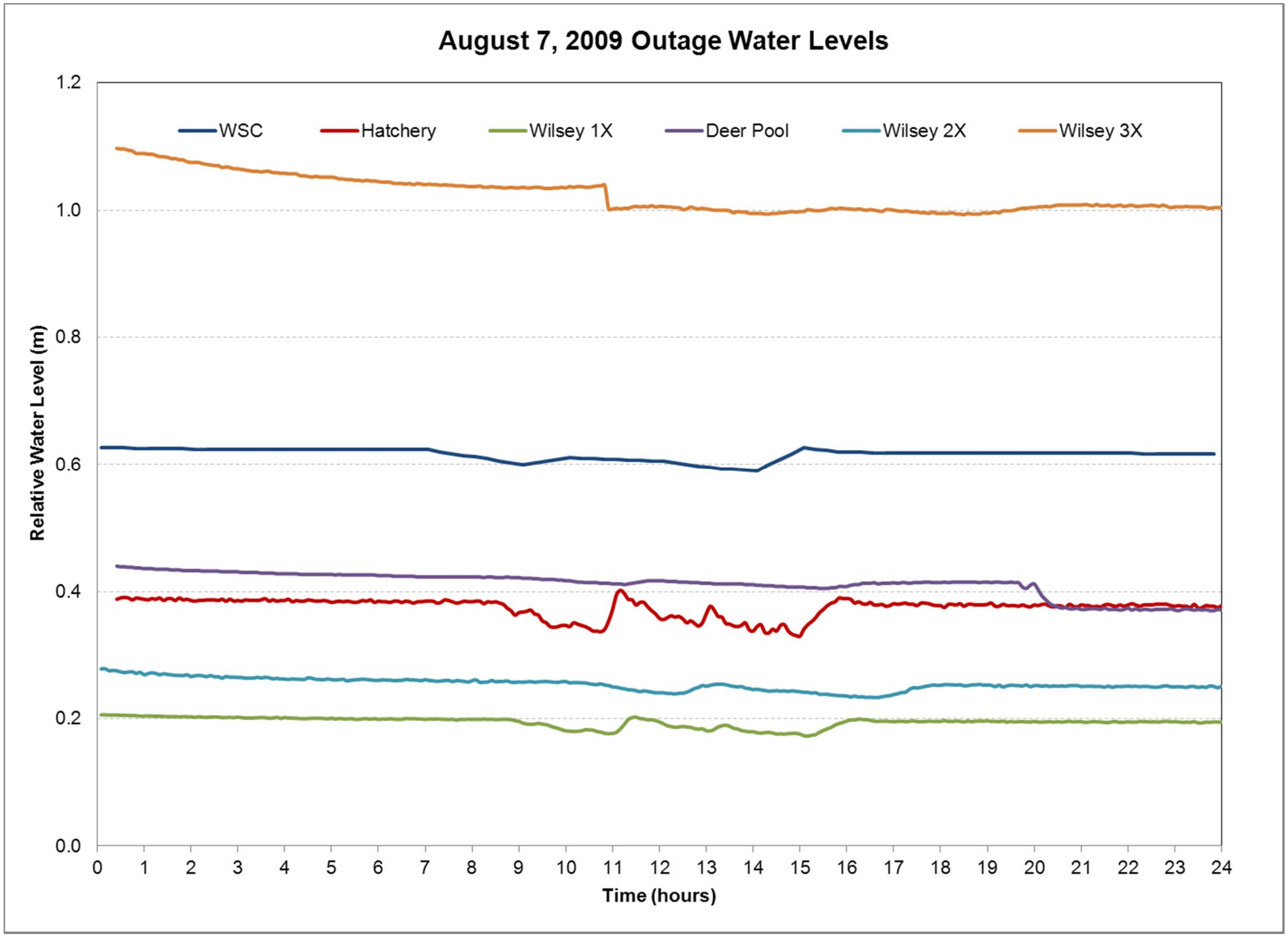

Figure 7. Water levels for August 7, 2009.

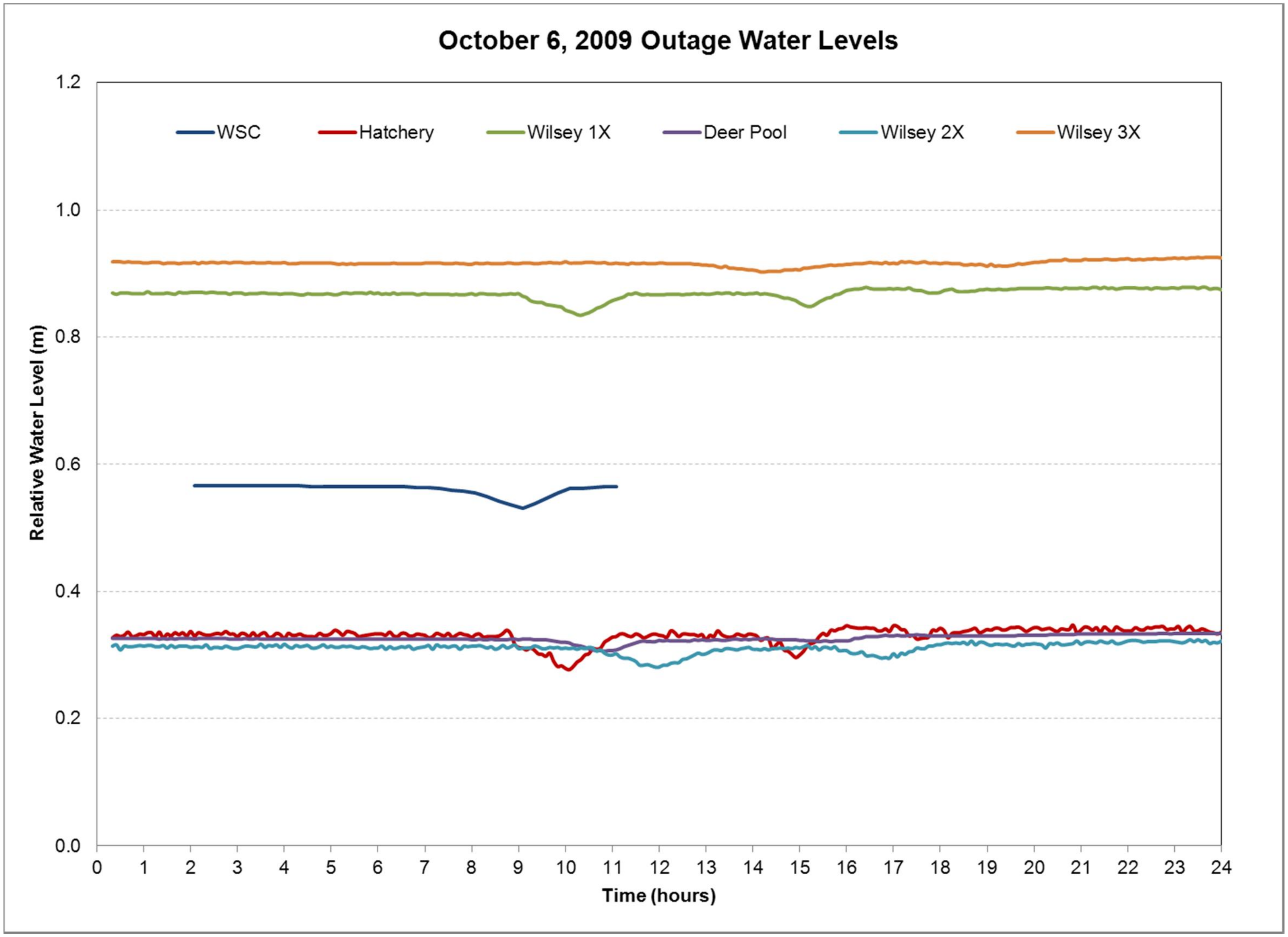

Figure 8. Water levels for October 6, 2009.

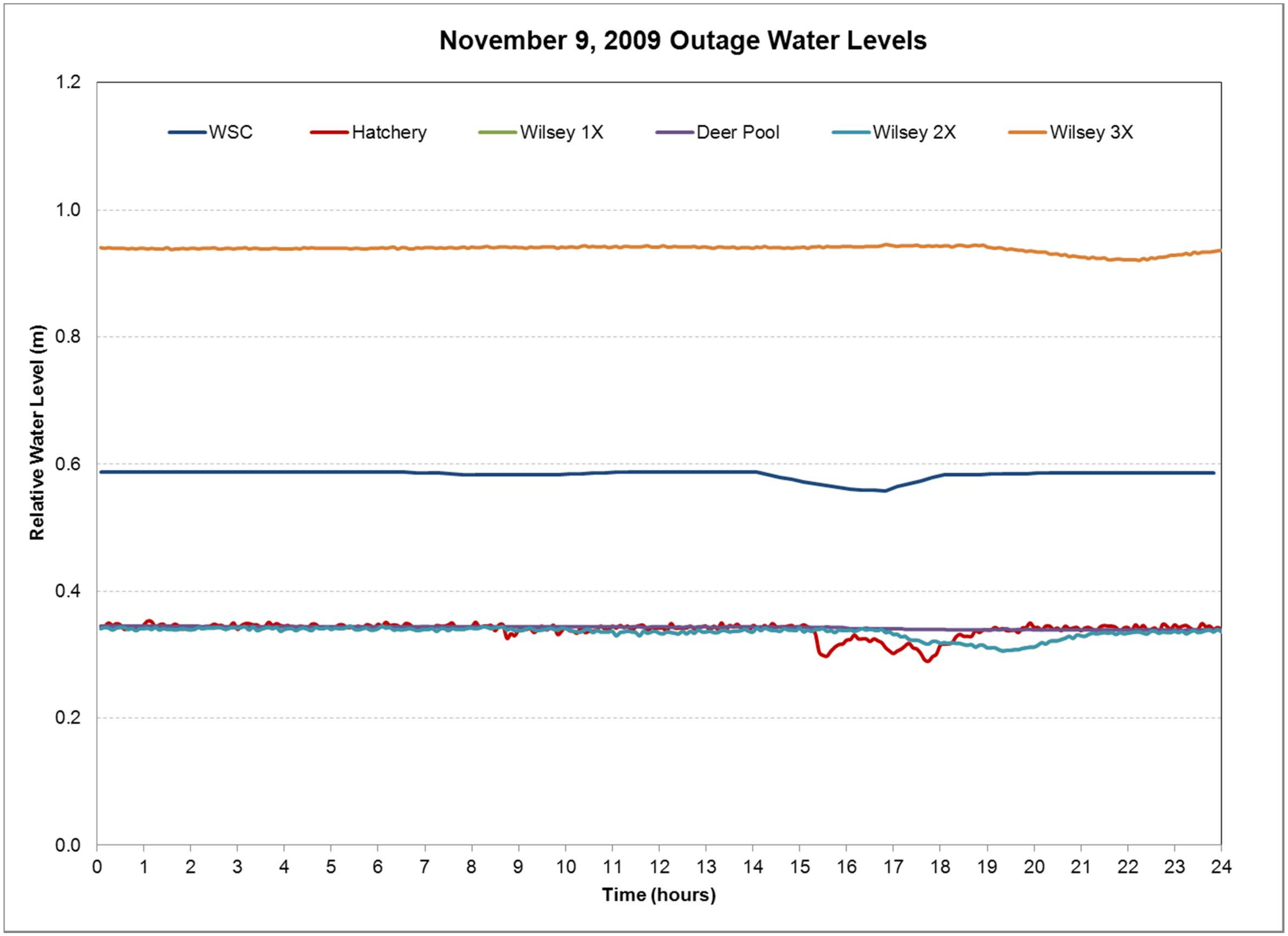

Figure 9. Water levels for November 9, 2009.

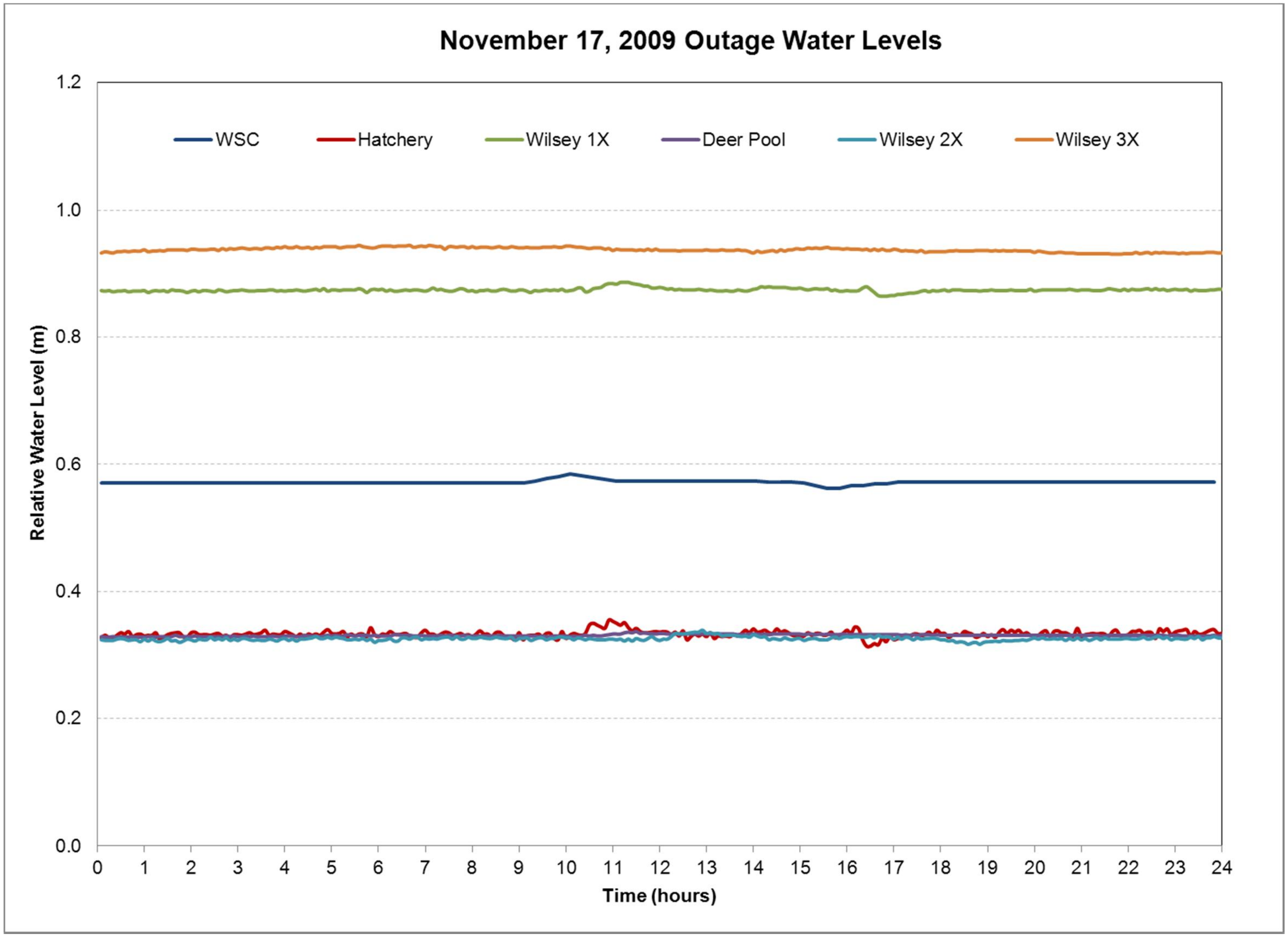

Figure 10. Water levels for November 17, 2009.

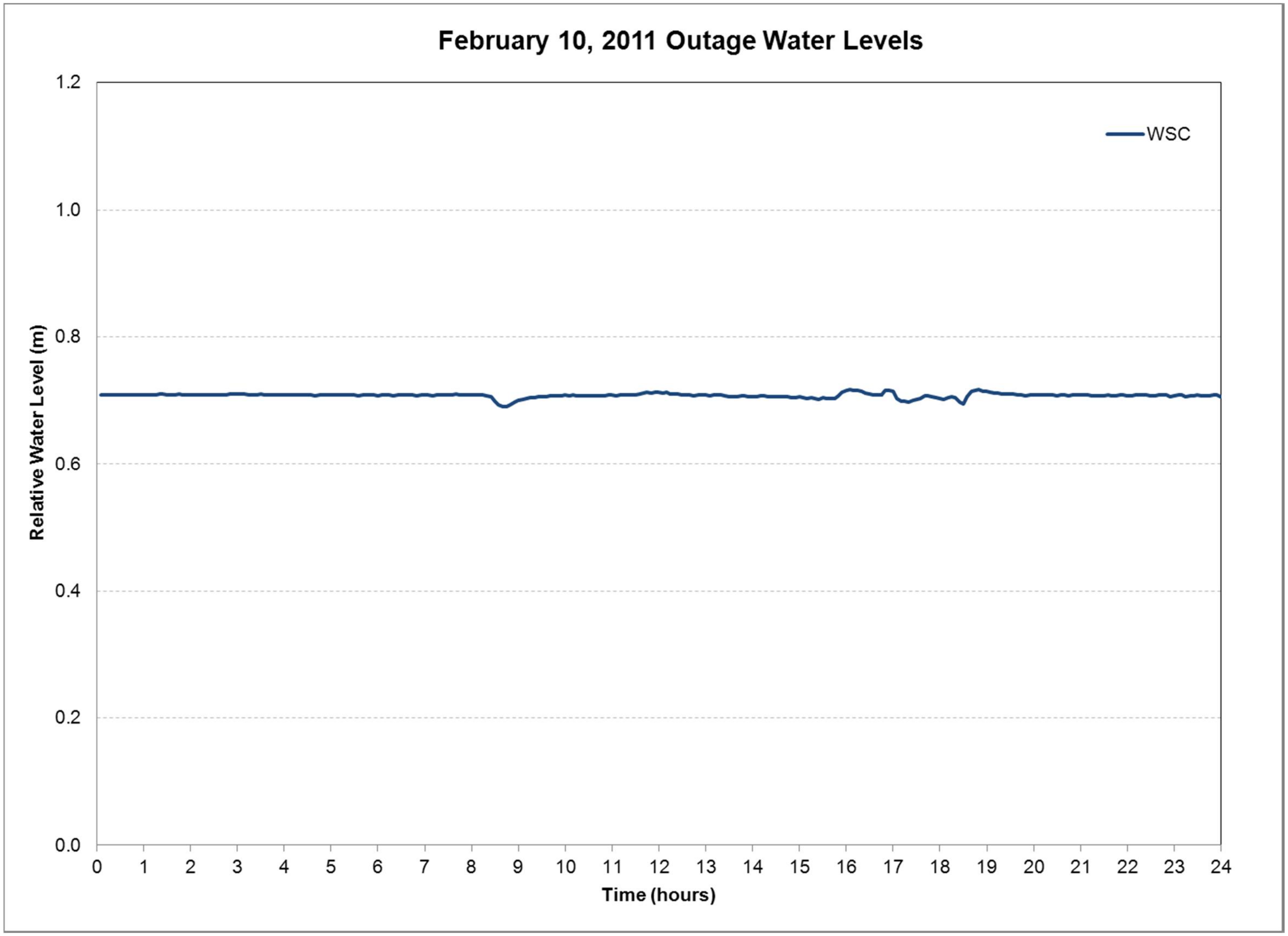

Figure 11. Water levels for February 10, 2011.

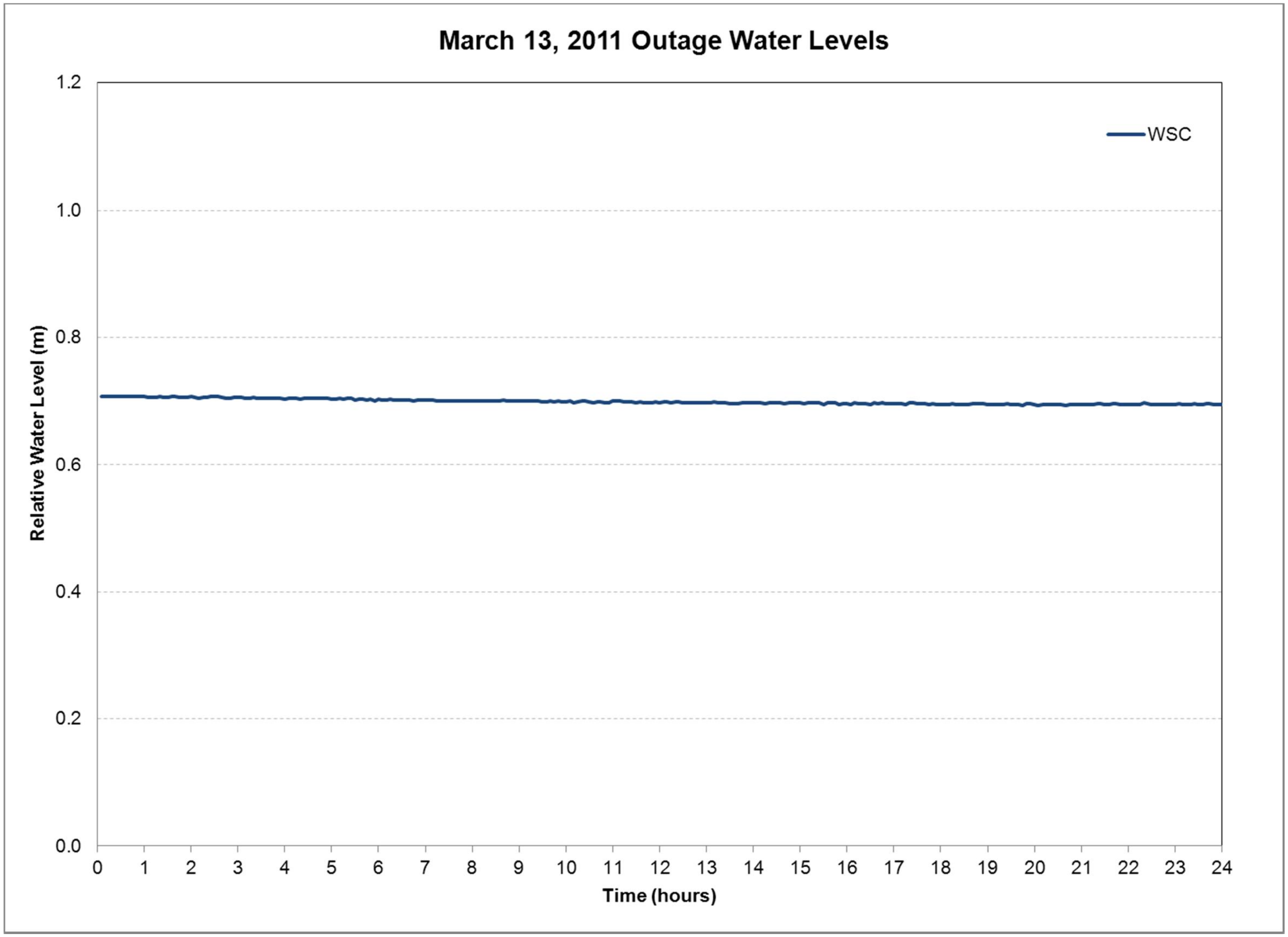

Figure 12. Water levels for March 13, 2011.