Peace Project Water Use Plan

Peace River Mainstem Stage Discharge

Implementation Year 2

Reference: GMSWORKS-6

Mainstem Stage Discharge 2013 Study

Study Period: 2013 January 1 – 2013 December 31

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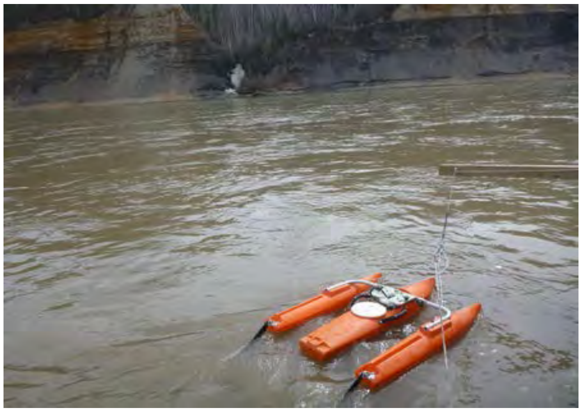

PEACE PROJECT WATER USE PLAN

GMSWORKS-6 Peace River Mainstem Stage Discharge 2013 Study

BC Hydro and Power Authority
6911 Southpoint Drive
Burnaby, BC

Final Report
2014 February 17

northwest hydraulic consultants

GMSWORKS-6
PEACE RIVER MAINSTEM STAGE DISCHARGE
- 2013 STUDY -

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Executive Summary

This study was initiated by BC Hydro to fulfill the recommendations of the Peace River Water Use Plan (WUP) Committee to monitor water levels and develop stage discharge relations for the Peace River Mainstem downstream of the Peace Canyon Dam (PCN) to the Pine River confluence.

The hydrometric program was initiated in 2009, with five long term satellite linked real-time water level gauge stations installed on the Peace River between 17 and 80 kilometres downstream of PCN. Installation and monitoring of these gauges has been guided by Grade A hydrometric standards as set by the BC Ministry of Environment (MOE) Resources Information Standards Committee (RISC) (2009). Rating curves were successfully developed for each hydrometric gauge, allowing for continuous discharge estimates.

This report outlines the quality control completed to finalise the stage and discharge time series from installation to December 31, 2012. This included gauge level checks with physical water level measurements and a system wide flow balance comparing discharge records for adjacent BC Hydro and local Water Survey of Canada (WSC) gauge data. The QA/QC comparison measurements, rating curves, and flow data sets from adjacent gauges was done within an Aquarius database (Aquatics Infomatics Inc.).

As the 2013 study, this report also outlines the gauge station maintenance, data quality checks, and additional field work completed from January 1 to December 31, 2013. Following is a list of work conducted in 2013 to support the GMSWORKS-6 program:

- April 27 and 28 maintenance and repairs were made to each of the gauges including replacement of desiccant, breather tubes, solar panels, and batteries.
- April 28 BC Hydro maintained a constant PCN discharge; using an ADCP discharge was measured at each of the five BC Hydro gauges.
- August 11 BC Hydro maintained a constant low PCN discharge and replacement pressure transducers were installed at two of the gauges (Peace 9 and Peace 25). On the same day a temporary levelogger was installed at the upstream most gauge (Peace 3).
- Comparison of hydrometric data between the five gauges and local WSC gauge data

In addition to the fieldwork, the hydrometric data from the current year were uploaded to the Aquarius database and analysed to verify gauge station and channel stability and data quality. Continuation of annual gauge maintenance is recommend for 2014 as well as replacement of the temporary levelogger at Peace 3 with a replacement sensor to restore remote data accessibility.

CREDITS AND ACKNOWLEDGEMENTS

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CITATION

NHC 2014. GMSWORKS-6 Peace River Mainstem Stage Discharge, 2013 Study. Prepared for BC Hydro. 2014 February 7.

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1 Introduction

The Peace River became regulated 1967 as a result of the construction of the W.A.C. Bennett Dam at the head of the Peace Canyon. Regulation resulted in changes to flow, specifically the timing and magnitude of floods, and the transport of sediment (Church 2005). Hydrologic changes include a reduction in the mean annual flood, an increase in winter flows (for power generation and ice control), reduced variability in seasonal flows, and increased diurnal variability (daily flow ramping or peaking). The regulated flow regime results in deposition of sediment and vegetation encroachment and thus decreased wetted area and side channel connectivity; which impacts the utility and value of side channels for fish habitat. In addition, rapid flow ramping (increase or decrease in discharge) experienced with diurnal variability, further detracts from habitat value.

The Peace River Water Use Plan Consultative Committee (WUP CC) recognized the resulting loss and continued degradation of fish habitat in side channels and recommended a plan to examine the potential to mitigate these impacts on the Peace River (Anon 2003). Acknowledging the important role of the Peace River generating facilities the WUP CC recommended the investigation of options to maintain habitat productivity in lieu of increasing base flows 50 to 100 percent during the summer period. Two alternatives to increasing base flows were identified to potentially mitigate these effects. That is,

1. The use of controlled and uncontrolled spill events to potentially restore side channel function and value (WUP's Flood Pulse Management Plan).
2. Restoration or further development of side channels to improve habitat under the present flow regime (WUP's Side Channel Management Plan).

The WUP set out a suite of monitoring and work programs intended to address the loss of side channel habitat through these two strategies. GMSWORKS-6 was presented and approved by the WUP CC and defined as a project to develop discharge relations for the Peace River Mainstem downstream of Peace Canyon Dam to the Pine River confluence. The objective was to collect the data needed to increase knowledge of the magnitude, timing, and rate of change in flow as well as local hydraulic response as spill flow or rapid changes in flow travelled and dispersed downstream. A specific benefit of this program inferred by the ToR, is the ability to monitor hydraulic response as ramping sequences are fine tuned to reduce fish stranding and consequently stress and mortality tolls on fish.

1.1 Setting

Hydroelectric generation from the Peace River produces nearly a third of British Columbia's electricity. The W.A.C. Bennett Dam was constructed at the head of the Peace River Canyon in 1967. Flow from the upstream reservoir – Williston Reservoir – generates electricity at the underground power house of the Gordon M. Shrum power station (GMS). Peace Canyon Dam (PCN) was constructed at the downstream end of the Peace River Canyon, 14 km downstream of W.A.C.

Bennett Dam. Water released from GMS is used for generation at PCN and released downstream without active storage between GMS and PCN.

1.2 Objectives

The Terms of Reference (ToR) documented by BC Hydro and Power Authority list the following deliverables (BC Hydro, 2008):

i. *Five (5) hydrometric stations installed with surveyed transects between PCN and Pine River.*

ii. *Stage discharge relations for each gauge covering PCN release flows between 283 and 2000 m^3/s.*

iii. *Schedule and protocol for maintenance and data quality checks.*

Installation of the five hydrometric stations, survey of transects, and stage-discharge relations were previously developed. This report addresses the final deliverable of the ToR; that is data quality checks and gauge maintenance for 2013.

1.3 Background

The Peace River Mainstem hydrometric program was initiated in October 2009; five long term satellite linked real-time water level gauge stations were installed on the Peace River between 17 and 80 kilometres downstream of PCN. In addition there are four local Water Survey of Canada (WSC) gauges, two on the mainstem of Peace River and two on major tributaries downstream of PCN and upstream of Taylor. WSC gauge data has not been published since December 31, 2011; due to the uncertainty in the data the preliminary WSC gauge data was used in data comparison but not to formally evaluate data quality. A summary of gauges is given in **Table 1**.

Hydrometric station nomenclature is based on nearest Peace River cross-section surveys conducted by BC Hydro and Northwest Hydraulic Consultants Ltd. (NHC), and includes cross sections 3, 9, 25, 29, and 35a. Location of each station is shown in **Figure 1**.

Table 1 Peace River gauges downstream of PCN to Taylor

Station Name	Station No.	Distance from PCN (km)	Notes on Location Selection Rational
Peace River at Hudson's Hope	WSC 07EF001	7.644	
Peace 3	1	17.768	• Downstream of Lynx Creek • Large channel complex located immediately downstream • Stable nature of the bank, river bed, and hydraulic control
Peace 9	2	30.318	• Downstream of Farrell Creek • Downstream end of side channel complex 27.2R (as defined in GMSWORKS #3)
Peace 25	3	55.722	• Downstream of Halfway River • Proximity to side channel complex 58.0L
Peace 29	4	64.419	• Downstream of Cache Creek
Peace 35a	5	80.913	• Downstream of Wilder Creek
Peace River above Pine River	WSC 07FA004	92.123	

1.4 Scope of 2013 work

A summary of tasks completed in 2013 under GMSWORKS-6 is provided in the following subsections. All items were successfully completed.

1.4.1 Data quality review 2009 to 2012

Past data up to the end of 2011 had previously been checked for obvious errors and rating curve consistency. However, a more detailed quality assurance/quality control (QA/QC) review was conducted in 2013. Data were incorporated into NHC's Aquarius database (Aquatics Infomatics Inc.) and compared for both temporal and spatial inconsistencies. Comparison was made with other BC Hydro Peace River gauges and the local WSC gauges with the flow balance assessed as part of the QA/QC process.

1.4.2 2013 equipment maintenance

In order to ensure the ongoing functionality of the hydrometric stations, the following equipment maintenance was completed in 2013:

- Peace 3: Install temporary levelogger
- Peace 9: Replaced pressure transducer, solar panel, battery, desiccant, lock, breather tube

- Peace 25: Replaced pressure transducer, solar panel, battery, desiccant, and breather tube
- Peace 29: Replaced desiccant and breather tube
- Peace 35a: Replaced solar panel, desiccant, and breather tube

1.4.3 2013 gauge maintenance

In order to ensure the hydrometric stations are in compliance with BC Ministry of Environment (MOE) Resources Information Standards Committee (RISC) Grade A Hydrometric Standards (RISC, 2009), the following yearly gauge maintenance was completed in 2013:

- Collection of at minimum one flow measurement and water surface level survey at each hydrometric station.
- Quality review of 2013 data including data reviewed for anomalies, results compared between the other four gauges, flow measurements compared with past results (i.e. stage discharge rating curve), and level surveys compared with recorded data.

1.4.4 Reporting

Reporting includes documentation of the data quality review from 2009 to 2012 and detailed descriptions of the gauge and equipment maintenance completed in 2013. A description of the compiled data including gauge instrumentation and history, a data summary, and review of rating curve development for each gauge is also included.

2 Equipment maintenance

Regular equipment maintenance and replacement is required to ensure the continued functionality of the hydrometric stations and prevent data loss. Service life expectancies of each component are as follows:

- Enclosure desiccant replaced annually or more frequently
- Breather tubes replaced annually or more frequently
- Batteries replaced every 2 to 5 years depending on solar panel performance and temperature cycles
- Solar panels replaced when damaged or stolen
- Data loggers / transceivers are expected to require replacement every 10+ years
- Water level sensors are expected to require replacement every 5+ years; subject to potential early failure due to damage from ice debris, wood debris, sediment, or freeze-thaw cycles

This section of the report outlines maintenance, replacement, and repairs conducted to the gauge station equipment in 2013 and proposed for 2014. A set of tables at the end of the document present the timeline of instrument installation and past maintenance (**Table 6**, **Table 9**, **Table 12**, **Table 15**, and **Table 18**).

2.1 2013 equipment maintenance

Annual station maintenance involved checking components of each station, including battery voltage checks to ensure the solar panels and batteries were fully functional, desiccant pack replacement for moisture absorption, and repair and replacement of other equipment as required. A list of maintenance work completed in 2013 is given in **Table 2**.

Initial 2013 station maintenance, including desiccant and breather tube replacement at each gauge and battery and solar panel replacement at Peace 9 and Peace 35a, was conducted by NHC on April 27-28, 2013. At the time of this inspection it was confirmed that sensors at Peace 3 and Peace 9 were malfunctioning or destroyed and the sensor at Peace 25 was also destroyed by transported wood debris or ice and would need replacement. Subsequent inspections and maintenance were conducted in conjunction with other fieldwork in the region and with a low flow release scheduled by BC Hydro for August 11.

Low flow is required to install the sensors to a depth that ensures coverage for the full range of operational flows and to limit the potential for damage from future debris or ice transported near/over the sensors. Two replacement water level sensors (OTT PLS) were approved, ordered, and installed for Peace 9 and Peace 25. The temporary levelogger from Peace 9 was also relocated to Peace 3 during the August 11 low flow. Peace 3 was selected for the manual download levelogger as it is accessible by car whereas Peace 9 and Peace 25 are only accessible by boat.

Additional equipment maintenance activities, including battery and desiccant replacement at Peace 29 and logger initialization at Peace 25, were completed during field visits in June and October 2013.

Table 2 Summary of equipment maintenance completed in 2013

Station Name	Date	Maintenance work completed
Peace 3	2013-Apr-28	• Replaced desiccant in enclosure • Replaced breather tube
	2013-Aug-11	• Installed temporary levelogger
Peace 9	2013-Apr-27	• Adjusted temporary levelogger to a lower elevation • Replaced solar panel • Replaced battery • Replaced desiccant in enclosure • Replaced breather tube
	2013-Aug-11	• Installed permanent pressure transducer • Replaced lock
Peace 25	2013-Apr-28	• Replaced desiccant in enclosure • Replaced breather tube
	2013-Aug-11	• Installed permanent pressure transducer
	2013-Aug-12	• Replaced solar panel • Replaced battery
	2013-Oct-02	• Initialized logger
Peace 29	2013-Jun-11	• Replaced battery • Replaced desiccant in enclosure • Replaced breather tube
Peace 35a	2013-Apr-27	• Replaced battery • Replaced solar panel • Replaced desiccant in enclosure • Replaced breather tube

2.2 Recommended 2014 equipment maintenance

In order to ensure the ongoing functionality of the hydrometric stations it is recommended the desiccant and breather tubes be replaced at each gauge and that the pressure transducers, solar panels, and batteries be checked. Onsite downloads of data stored in each logger is recommended at least once per year, particularly at Peace 3 as the memory for the temporary levelogger will likely be exhausted by spring, 2014. The levelogger sensor at Peace 3 should be replaced with a permanent pressure transducer.

3 Gauge maintenance completed in 2013

To maintain Grade A standards (Resources Information Standards Committee, 2009) a minimum of one physical water level check and one flow measurement are required per gauge per year. This is the minimum annual measurements to identify settlement, shifts, or changes to the sensors, benchmarks, or channel hydraulics. Additional measurements are recommended to avoid loss of large periods of data (i.e. a year), which can occur if the site is not stable or equipment malfunctions. Although frost heave and channel scour can shift benchmarks or sensor position, the budgeted single measurement per gauge may be acceptable due to the channel stability under the regulated flow regime and the number of gauges on the Peace River Mainstem.

One flow measurement and one water level measurement were collected at each gauge on April 28, 2013. Flow release from PCN was held constant by BC Hydro for the day to limit antecedent effects on the level-discharge measurements. Additional level checks were collected at selected gauges on June 10, June 11, and August 11, 2013. A summary of gauge maintenance completed in 2013 is given in **Table 3**.

Table 3 Summary of gauge maintenance completed in 2013

Station Name	Date	Maintenance work completed in 2013
Peace 3	2013-Apr-28	• Flow measurement • Level check
	2013-Jun-10	• Level check
Peace 9	2013-Apr-28	• Flow measurement • Level check
	2013-Jun-10	• Level check
	2013-Aug-11	• Level check
Peace 25	2013-Apr-28	• Flow measurement • Level check
	2013-Jun-10	• Level check
	2013-Aug-11	• Flow measurement • Level check
Peace 29	2013-Apr-28	• Flow measurement • Level check
	2013-Jun-11	• Level check
Peace 35a	2013-Apr-28	• Flow measurement • Level check
	2013-Jun-11	• Level check

3.1 Recommended gauge maintenance for 2014

In order to continue meeting Grade A standards(Resources Information Standards Committee, 2009), a minimum of one gauge level check and one flow measurement are required per gauge in 2014. If future level checks or flow measurements are inconsistent with the existing stage-discharge rating curve then typically a minimum of four additional flow measurements are required to maintain Grade A standards. The data should also be subjected to a quality review that includes identification of anomalies, comparison of data with that from other local gauges (BC Hydro and WSC), and comparison with past results (i.e. stage-discharge rating curves).

4 Data quality review

Quality review of the Peace River Mainstem hydrometric data involved comparison of stage data from the gauge compared with physical water level measurements, level of agreement in regression for the development and verification of the stage-discharge rating curves, and comparison of discharge record between stations (BC Hydro and WSC). The review was done within NHC's Aquarius database allowing graphical comparison and alteration (i.e. timing shifts). Comparison of the data was also used to develop a system wide flow balance as a further tool for QA/QC.

High frequency (15 minute) and daily discharge hydrographs for each of the five BC Hydro gauges were compared visually on a month by month basis to identify inconsistencies in the relation between stations. Five day moving average hydrographs were also compared as daily hydrographs included large fluctuations.

Inflows between each of the five BC Hydro gauges were calculated on a high frequency and daily time step to identify periods of gauge instability and to assist in quantifying confidence in discharge series. Two WSC gauges on the Peace River Mainstem (Peace River at Hudson's Hope - WSC Hudson and Peace River above Pine River – WSC Pine) and two WSC gauges on major tributaries (Halfway River near Farrell Creek - WSC Halfway and Moberly River near Fort St John - WSC Moberly) were included in the comparison of flow between subsequent gauges. Although published and preliminary WSC data were initially compared with BC Hydro gauge data to identify gross anomalies, only published WSC data were considered for assessing data quality; due to the uncertainty in the unpublished WSC data.

4.1 Flow Balance

The balance of flow between subsequent gauges is used to verify the adjacent data records. Such a flow balance can be used to identify gaining and losing reaches (i.e. reaches that receive additional flow or lose flow to groundwater) and to quantify inflows.

Development of the flow balance for this study is based on the following reaches:

- WSC Hudson to Peace 3
- Peace 3 to Peace 9
- Peace 9 to Peace 25 incorporating WSC Halfway flows
- Peace 25 to Peace 29
- Peace 29 to Peace 35a
- Peace 35a to WSC Pine incorporating WSC Moberly flows

Gauge by gauge comparisons and inflows could only be calculated for periods with data overlap; several of the gauge records contain periods of missing data (**Table 7**, **Table 10**, **Table 13**, **Table 16** and **Table 19**). **Table 4** outlines the period of record for each of the BC Hydro and WSC gauges, the percent of data coverage within the 2009 – 2012 period and the 2013 period, and the percent of data coverage for the calculated inflows within each period.

Table 4 Summary of BC Hydro and WSC gauge record length and percent data coverage

Station Name	Start date*	End date*	% data coverage 2009 Oct 1 to 2012 Dec 12*	% data coverage 2013 Jan 1 to 2013 Oct 19*	Drainage Area (km^2)
WSC Hudson	2009-Oct-01	2011-Dec-31**	69**	0.0**	73,100
Peace 3	2009-Sep-04	2013-May-03	99	42	73,493
Peace 9	2009-Oct-07	2013-Oct-19	28	74	74,289
WSC Halfway	2009-Oct-01	2011-Dec-31**	69**	0.0**	9,340
Peace 25	2009-Sep-24	2013-Oct-19	83	5.8	83,976
Peace 29	2009-Sep-24	2013-Oct-19	80	45	84,932
Peace 35a	2009-Sep22	2013-Oct-19	81	60	95,174
WSC Moberly	2009-Oct-01	2011-Dec-31**	69**	0.0**	1,520
WSC Pine	2009-Oct-01	2011-Dec-31**	69**	0.0**	87,200
Calculated Inflows					
Peace 3 – WSC Hudson	2009-Oct-01	2011-Dec-31**	68**	0.0**	393
Peace 9 – Peace 3	2009-Oct-07	2013-May-03	28	18	796
Peace 9 – Peace 3 – WSC Halfway	2009-Oct-07	2011-Dec-31**	21**	0.0**	347
Peace 25 – Peace 29	2009-Sep-24	2013-Oct-19			
Peace 29 – Peace 25	2009-Sep-24	2013-Oct-19	80	6	956
Peace 35 – Peace 29	2009-Sep-24	2013-Oct-19	73	45	242
WSC Pine - Peace 35 - WSC Moberly	2009-Oct-01	2011-Dec-31**	63**	0.0**	506

* based on daily flow record
** preliminary data not considered

Variability in calculated inflows can be the result of ramping as well as tributary inflow. The distance between gauges leads to varying lag times and flow dispersion/attenuation as ramping events translate downstream. It is not practical to consistently, accurately account for variations in lag time and dispersion or attenuation of changes in flow when comparing flow between subsequent gauges. Errors in estimating lag time can lead to negative inflow between gauges, generally short duration and/or small magnitude. Negative inflow between gauges may at times indicate a decrease in discharge (i.e. a “losing reach”), but is more frequently caused by negligible inflows in conjunction with variability in the discharge time series. When using high frequency discharge series to compare flow patterns between subsequent gauge stations an average lag time is approximated to align timing of flow records although the lag time varies with discharge. The error associated with such method diminishes as the sample period increases, such as using daily flow record.

Throughout the reach there are a number of tributaries, two of which are gauged by WSC (Halfway River and Moberly River). Ungauged tributary inflow is generally less than 1% of the mainstem flow and is not expected to substantially influence the flow balance. Ungauged tributary inflow was therefore not explicitly calculated during this study. The following table (**Table 5**) provides an approximation of tributary inflow[1]. Watershed areas include the total increase in watershed area since the upstream most tributary, refer to **Figure 1**.

Table 5 Peace River tributaries with approximate drainage area and mean annual discharge (MAD) contribution between itself and next upstream tributary

Tributary	River Station from PCN (km)	Drainage Area (km^2)	MAD Unit Runoff[1] ($l/s/km^2$)	MAD (m^3/s)
Maurice Creek	7,347	388	3.7	1.4
Lynx Creek	13,810	338	3.7	1.3
Farrell Creek	23,536	784	2.6	2.0
Halfway River	45,600	9,611	7.7	74
Cache Creek	61,662	1,072	3.7	4.0
Wilder Creek	72,803	179	3.7	0.7
Tea Creek	79,505	65	3.7	0.2
Moberly River	85,040	1,871	6.5	12

4.2 2009 to 2012 data

Inflows were calculated on a daily and high frequency time step between October 1, 2009 and December 31, 2012. A 5% uncertainty in discharge time series was deemed acceptable; that is a difference of 10% between subsequent stations is considered within the acceptable error. For comparison, the discharge rating accuracy of less than or equal to 7% is recommended for Grade A hydrometric standards (Resources Information Standards Committee, 2009).

Visual inspection of hydrographs for adjacent gauges and calculated inflows between the gauges enabled periods of instability and/or shifts in the data records to be identified. Subsequently, periods of instability were removed and shifts were accounted for.

4.2.1 WSC Peace River at Hudson's Hope to Peace 3 reach

Peace 3 is 10.1 km downstream of the WSC Hudson gauge with a 393 km^2 increase in contributing watershed area. Lynx Creek (288 km^2) [2] is the only major tributary between the two gauges. Comparison of overlapped daily hydrographs from WSC Hudson and Peace 3 track well visually with higher flows observed at the lower gauge (Peace 3).

[1] Inflow unit runoff based on KPL 2011

[2] Watershed area of tributary at confluence with the Peace River as reported by KPL, 2011.

Calculated daily inflows ranged from -121 to 283 m^3/s (-16 to 37% of Peace 3 flows, **Figure 2**); negative inflows occurred 1.6% of the time. Negative daily inflows are infrequent and of short duration suggesting they are the result of the averaged lag time throughout the range of flow compounded by attenuation of flow changes between the gauges. Inflows do not suggest flow loss and uncertainty in the discharge time series is low.

4.2.2 Peace 3 to Peace 9 reach

Peace 9 is 12.6 km downstream of Peace 3 with a 796 km^2 increase in contributing watershed area. Farrell Creek (617 km^2)[2] is the only major tributary between the two gauges. Limited data coverage at Peace 9 constrains the assessment of inflows between Peace 3 and Peace 9; data are available for both gauges for 28% of the time between October 1, 2009 and December 31, 2012 (**Table 4**). Comparison of overlapped daily and high frequency hydrographs from Peace 3 and Peace 9 show flow attenuation between the gauges with lower, broader peaks observed Peace 9. A -0.15 m offset was applied to Peace 9 stage values from November 23, 2012 onwards to account for a discrepancy in the relation between Peace 3 and Peace 9. The shift is expected to be a result of the temporary levelogger position shifting and hence only the stage data was adjusted (i.e. not adjustments were made to the stage-discharge rating curve).

Calculated daily inflows between Peace 3 and Peace 9 ranged from -66 to 122 m^3/s (-6 to 7% of Peace 9 flows, **Figure 3**) while calculated high frequency inflows ranged from -173 to 200 m^3/s (-28 to 20% of Peace 9 flows). A 1.25 hour time lag was applied to high frequency Peace 3 data and a 2.75 hour time lag was applied to high frequency Peace 9 data. Negative daily inflows occurred 41% of the time while negative high frequency inflows occurred 32% of the time. Daily inflows less than -5% of Peace 9 flows occurred 0.3% of the time while high frequency inflows less than -5% of Peace 9 flows occurred 2.5% of the time. Large negative inflows (less than -5% of Peace 9 flows) are infrequent and short duration suggesting they are the result of variations in time lags and flow attenuation/dispersion between the gauges. Small negative inflows (more than -5% of Peace 9 flows) are more frequent and of longer duration suggesting inflows between Peace 3 and Peace 9 are small and uncertainty in the Peace 9 discharge time series may be up to 5%.

4.2.3 Peace 9 to Peace 25 reach

Peace 25 is 25.4 km downstream of Peace 9 with a 9,687 km^2 increase in contributing watershed area. Halfway River (9,389 km^2)[2] is the only major tributary between the two gauges and there is a WSC gauge located on Halfway River approximately 22 km upstream of its confluence with Peace River(9,340 km^2). Limited data coverage at Peace 9 constrains the assessment of inflows between Peace 9 and Peace 25 (**Table 4**). Overlapped hydrographs show flow attenuation between Peace 9 and Peace 25. A period of instability at Peace 25 was identified between February 9 and February 24, 2010; Peace 25 stage data from this time are therefore uncertain and not included in this report (**Table 13**). During this time the sensor elevation changed 0.13 m; this shift is accounted for in the stage record until the gauge was reinstalled at a lower elevation June 16, 2010. The shift appears to have been a result of sensor settlement (not channel changes) and therefore the stage-discharge rating curve was not adjusted.

Calculated daily inflows between Peace 9 and Peace 25, with WSC Halfway flows accounted for, ranged from -116 to 94 m^3/s (-12 to 18% of Peace 25 flows, **Figure 4**). Negative daily inflows occurred 47% of the time with inflows less than -5% of Peace 25 flows occurring 6.9% of the time. Large negative inflows (less than -5% of Peace 25 flows) are infrequent and short duration suggesting they are the result of variations in lag time with fluctuating flow and attenuation of flow changes between the gauges. Small negative inflows (more than -5% of Peace 25 flows) are more frequent and of longer duration suggesting inflows between Peace 9 and Peace 25 are small and uncertainty in the Peace 9 and Peace 25 discharge time series may be up to 5%.

4.2.4 Peace 25 to Peace 29 reach

Peace 29 is 9.7 km downstream of Peace 25 with a 956 km^2 increase in contributing watershed area. Cache Creek (904 km^2)[2] is the only major tributary between the two gauges. Comparison of vverlayed daily and high frequency hydrographs show flow attenuation between Peace 25 and Peace 29. The period of instability at Peace 25 between February 9 and February 25, 2010 was not included in the comparison with Peace 29 due to uncertainty in the stage record as the Peace 25 sensor was settling (**Table 16**).

Calculated daily inflows between Peace 25 and Peace 29 ranged from -192 to 108 m^3/s (-18 to 5% of Peace 29 flows, **Figure 5**) while calculated high frequency inflows ranged from -246 to 187 m^3/s (-25 to 18% of Peace 29 flows). A 6 hour time lag was applied to high frequency Peace 25 data and a 7 hour time lag was applied to high frequency Peace 29 data for comparison with other gauge data. Negative daily inflows occurred 79% of the time while negative high frequency inflows occurred 82% of the time. Daily inflows less than -5% of Peace 29 flows occurred 5% of the time while high frequency inflows less than -5% of Peace 29 flows occurred 19% of the time. Large negative inflows (less than -5% of Peace 29 flows) are again attributed to variations in lag time and flow attenuation between the gauges. Small negative inflows (more than -5% of Peace 29 flows) are frequent and of longer duration, which is likely due to the expected level of uncertainty in comparison with expected inflow between the gauges.

4.2.5 Peace 29 to Peace 35a reach

Peace 35a is 16.5 km downstream of Peace 29 with a 242 km^2 increase in contributing watershed area. Wilder Creek (100 km^2) and Tea Creek (32 km^2) are the major tributaries between the gauges. Comparison of overlapped daily and high frequency hydrographs show flow attenuation between Peace 29 and Peace 35a. A period of instability was identified for Peace35a between April 5 and June 18, 2010 (**Table 19**). During this time the sensor elevation appears to have changed 0.11 m; this shift was accounted for in the stage record. The shift was only applied to data prior to the reinstallation and lowering of the sensor (June 18, 2010) and only to the stage data; that is the stage-discharge rating curve was not affected.

Calculated daily inflows between Peace 29 and Peace 35a ranged from -115 to 224 m^3/s (-20 to 20% of Peace 35a flows, **Figure 6**) while calculated high frequency (15 minute) inflows ranged from -307 to 256 m^3/s (-40to 32% of Peace 35a flows). A 7 hour time lag was applied to high frequency Peace 29 data and a 9.25 hour time lag was applied to high frequency Peace 35a data. Negative daily inflows occurred 29% of the time while negative high frequency inflows occurred 20% of the time. Daily inflows less than -5% of Peace 35a flows occurred 3.7% of the time while high frequency inflows less than -5% of Peace 35a flows occurred 5.6% of the time. Large negative inflows (less than -5% of Peace 35a flows) are again attributed to variations in lag time and flow attenuation between the gauges. Small negative inflows (more than -5% of Peace 35a flows) are more frequent and of longer duration, which is likely due to the expected level of uncertainty in comparison with expected inflow between the gauges.

4.2.6 Peace 35a to WSC Peace River above Pine River reach

WSC Pine is 11.2 km downstream of Peace 35a with a 2,026 km^2 increase in contributing watershed area. Moberly River (1851 km^2)[2] is the only major tributary between the two gauges.There is a WSC gauge located on Moberly River approximately 31 km upstream of its confluence with Peace River (1,520 km^2). Comparison of overlapped hydrographs show flow attenuation between Peace 35a and WSC Pine.

Calculated difference in inflows between Peace 35a, WSC Pine, and WSC Halfway ranged from -211 to 527 m^3/s (-20 to 16% of WSC Pine flows). Negative daily inflows occurred 75% of the time with inflows less than -5% of WSC Pine flows occurring 26% of the time. While some of the large negative inflows (less than -5% of Peace 25 flows) are the result of variations in time lags and flow attenuation/dispersion between the gauges, they are more frequent than expected suggesting unaccounted for shifts in sensor elevation or stage-discharge rating curves. Small negative inflows (more than -5% of Peace 25 flows) are also frequent and of long duration suggesting inflows between Peace 35a and WSC Pine are small and uncertainty in the Peace 35a discharge time series may be upwards of 5%.

4.2.7 Summary of 2009 – 2012 data review and flow balance

The flow balance showed acceptable uncertainty, with less than or equal to 5% error in the Peace 3, Peace 9, Peace 25, Peace 29, and Peace 35a discharge series. Peace35a exhibits slightly greater uncertainty. Comparison of discharge between Peace 35a and Peace 29 generally showed error less than 5% between the two gauges with a relatively lengthy period (summer 2011) of error within 10% (**Figure 6**). Comparison of discharge between Peace 35a and the downstream WSC gauges show a similar –yet opposite – error during the same period (summer 2011, **Figure 7**) suggesting the error is with Peace 35a.

Ungauged tributary inflows were ignored in the flow balance; incorporating the inflow with any discrepancy between subsequent flow records. This is appropriate as tributary inflow is generally less than 1% of the mainstem flow, below the accepted 5% level of uncertainty.

4.3 2013 data

Approved WSC data for 2013 are not yet available for the local WSC gauges. Lack of approved WSC data and periods of missing data in the BC Hydro discharge records limits the gauge by gauge comparison and inflow calculations for 2013. Development of a comprehensive system wide flow balance was not viable as sufficient data coverage for comparison between gauges was only available between Peace 29 and Peace 35a (**Table 4**). Comparison of overlapped daily and high frequency hydrographs were conducted between all gauges when concurrent datasets exist. Visual inspection of overlapped hydrographs and calculation of inflows for 2013 did not identify any periods of instability, shifts, or changes to the stage-discharge rating curves. Although preliminary WSC gauge data was used for cursory comparison with the BC Hydro gauge records, afurtherl comparison to WSC data is recommended once the WSC data is finalised / approved..

5 Station history and stage-discharge relationships

5.1 Peace 3

5.1.1 Instrumentation and gauge history

A Keller Series 500 SDI-12 pressure transducer, connected to a Sutron Satlink 2 data logger, was installed at Peace 3 on September 3, 2009 by Via-Sat Data Systems. The logger was set to record an average of ten values collected over a period of 100 seconds every 15 minutes. On June 16, 2010 the sensor was lowered 0.361 m to prevent stranding. On May 4, 2013 the sensor malfunctioned and data collection ceased. A temporary archiving water level sensor, consisting of a paired Solinst levelogger and barologger set to record every 5 minutes, was installed on August 11, 2013. Data from this logger are not accessible remotely, but is scheduled to be downloaded April 2014. A summary of Peace 3 site visits and gauge level checks is given in **Table 6**.

Seven benchmarks have been installed near Peace 3 (**Table 21**). Benchmark locations are shown in **Figure 8**.

5.1.2 Data summary and rating curve development

The current Peace 3 stage time series extend from September 3, 2009 to May 4, 2013 (**Figure 9**). Between September 3, 2009 and June 16, 2010, water levels lower than 445.259 m were below the sensor, resulting in missing data (**Table 7**). Data from the temporary levelogger (installed on August 11, 2013) are expected to be available spring of 2014 following manual download.

Sixteen discharge measurements have been collected at Peace 3, covering a range of flows from 319 m^3/s at a stage of 445.159 m to 1,970 m^3/s at a stage of 447.259 m. Discharge values calculated for stages outside of this range are extrapolated estimates; the current stage record ranges from 445.173 m to 448.273 m (calculated as 325 to 3,182 m^3/s). The rating curve is shown in **Figure 10** and the residuals between the measured discharge and the discharge calculated from the rating curve are given in **Table 8**. The current rating curve shows excellent fit (1.8% root mean square of errors). The final stage-discharge relation for Peace 3 is as follows:

$$Q(S) = 237.941(S - 443.980)^{1.780}$$

The calculated discharge record using the above equation and the Peace 3 stage record is shown in **Figure 11**.

5.2 Peace 9

5.2.1 Instrumentation and gauge history

A Keller Series 500 SDI-12 pressure transducer, connected to a Sutron Satlink 2 data logger, was installed at Peace 9 on October 6, 2009 by Via-Sat Data Systems. The logger was set to record an average of ten values collected over a period of 100 seconds every 15 minutes. On June 16, 2010 the sensor was lowered 0.868 m to prevent stranding. On July 17, 2010 the sensor shifted and subsequent data (to August 15, 2011) are of unknown quality and are not included in this report. August 15, 2011 the station was damaged and ceased to provide data. A temporary water level sensor, consisting of a paired Solinst levelogger and barologger set to record every 5 minutes, was installed on June 25, 2012. Data from this logger were not accessible remotely. Flow conditions prevented installation of the temporary levelogger at a site fully connected with all levels of Peace River Mainstem flows. February 24, 2013 the logger memory filled. The logger was downloaded and re-launched on April 27, 2013 at an elevation 1.13 m lower to prevent stranding, but still at an elevation not fully connected with all levels of Peace River Mainstem flows. The temporary levelogger was downloaded on June 10, 2013 and again on August 11, 2013.

On August 11, 2013 a permanent OTT pressure transducer was installed and connected with the Sutron Satlink 2 data logger. Data were last remotely accessed on October 21, 2013[3]. A summary of Peace 9 site visits and gauge level checks is given in **Table 9**.

Four benchmarks have been installed near Peace 9 (**Table 21**). Benchmark locations are shown in **Figure 12**.

5.2.2 Data summary and rating curve development

The current Peace 9 stage time series extends from October 6, 2009 to October 21, 2013 with several data gaps in which data were not included in this report (**Figure 13**). Data gaps include when water level was lower than 436.489 m between October 6, 2009 and June 16, 2010 and when water level was lower than 435.580 m between June 26, 2012 and April 28, 2012 (**Table 10**). Data gaps also include July 17, 2010 to June 25, 2012, a 709 day data gap, and February 24, 2013 to April 27, 2013, a 66 day data gap.

Fifteen discharge measurements have been collected at Peace 9, covering a range of flows from 319 m^3/s at a stage of 436.163 m to 1970 m^3/s at a stage of 438.709 m. Discharge values calculated for stages outside of this range are extrapolated estimates. The current stage record ranges from 436.214 m to 439.800 m (calculated as 336 to 3,300 m^3/s). The rating curve is shown in **Figure 14** and the residuals between the measured discharge and the discharge calculated from the rating curve are given in **Table 11**. The current rating curve shows excellent fit (2.0% root mean square of errors). The final stage-discharge relation for Peace 9 is as follows:

$$Q(S) = 22.722(S - 433.510)^{2.707}$$

The calculated discharge record using the above equation and the Peace 9 stage record is shown in **Figure 15**.

[3] Last data request to/supply from BC Hydro conducted in 2013.

5.3 Peace 25

5.3.1 Instrumentation and gauge history

A Keller Series 500 SDI-12 pressure transducer, connected to a Sutron Satlink 2 data logger, was installed at Peace 25 on September 23, 2009 by Via-Sat Data Systems. The logger was set to record an average of ten values collected over a period of 100 seconds every 15 minutes. On February 8, 2010 the sensor appears to have become unstable. On February 25, 2010 it appeared to have settled at an elevation 0.13 m higher than its original deployment elevation. On June 17, 2010 the sensor was lowered 0.658 m to prevent stranding. On June 3, 2012 the sensor and battery failed. A permanent OTT pressure transducer was installed on August 11, 2013 and the battery and solar panel were replaced on August 12, 2013. Initiation of the data logger failed, with the logger subsequently re-started October 2, 2013. Data were last remotely accessed on October 20, 2013. A summary of Peace 25 site visits and gauge level checks is given in **Table 12**.

Five benchmarks have been installed near Peace 25 (**Table 21**). Benchmark locations are shown in **Figure 16**.

5.3.2 Data summary and rating curve development

The current Peace 25 stage time series extends from September 23, 2009 to October 20, 2013 with two data gaps in which data were not included in this report (**Figure 17**). Data gaps are February 8, 2010 to February 25, 2010, a 16 day data gap, and July 3, 2012 to October 2, 2013, a 456 day data gap (**Table 13**).

Sixteen discharge measurements have been collected at Peace 25, covering a range of flow from 354 m^3/s at a stage of 424.296 m to 1980 m^3/s at a stage of 426.416 m. Discharge values calculated for stages outside of this range are extrapolated estimates; the current stage record ranges from 424.184 m to 427.588 m (calculated as 308 to 3,560 m^3/s). The rating curve is shown in **Figure 18** and the residuals between the measured discharge and the discharge calculated from the rating curve are given in **Table 14**. The current rating curve shows excellent fit (1.8% root mean square of errors). The final stage-discharge relation for Peace 9 is as follows:

$$Q(S) = 85.938(S - 422.430)^{2.270}$$

The calculated discharge record using the above equation and the Peace 25 stage record is shown in **Figure 19**.

5.4 Peace 29

5.4.1 Instrumentation and gauge history

A Keller Series 500 SDI-12 pressure transducer, connected to a Sutron Satlink 2 data logger, was installed at Peace 29 on September 23, 2009 by Via-Sat Data Systems. The logger was set to record an average of ten values collected over a period of 100 seconds every 15 minutes. February 8, 2010 the sensor appears to have begun shifting. On February 25, 2010 it appears to have settled at an elevation 0.05 m higher than its original deployment elevation. June 17, 2010 the sensor was lowered 0.390 m to prevent stranding. May 21, 2012 the battery failed. June 11, 2013 the battery was replaced and the logger was re-started. Data were last remotely accessed on October 20, 2013. A summary of Peace 29 site visits and gauge level checks is given in **Table 15**.

Eight benchmarks have been installed near Peace 29 (**Table 21**). Two of these benchmarks were found to be unstable. Benchmark locations are shown in **Figure 20**.

5.4.2 Data summary and rating curve development

The current Peace 29 stage time series extends from September 23, 2009 to October 20, 2013 with two data gaps in which data were not included in this report (**Figure 21**). Data gaps are February 8, 2010 to February 25, 2010, a 16 day data gap, and May 21, 2012 to June 11, 2013, a 386 day data gap (**Table 16**).

Fourteen discharge measurements have been collected at Peace 29, covering a range of flow from 354 m^3/s at a stage of 419.443 m to 1970 m^3/s at a stage of 421.860 m. Discharge values calculated for stages outside of this range are extrapolated estimates; the current stage record ranges from 419.367 m to 422.787 m (calculated as 327 to 3,043 m^3/s). The rating curve is shown in **Figure 22** and the residuals between the measured discharge and the discharge calculated from the rating curve are given in **Table 17**. The current rating curve shows excellent fit (1.3% root mean square of errors). The final stage-discharge relation for Peace 29 is as follows:

$$Q(S) = 40.721(S - 417.040)^{2.467}$$

The calculated discharge record using the above equation and the Peace 29 stage record is shown in **Figure 23**.

5.5 Peace 35a

5.5.1 Instrumentation and gauge history

A Keller Series 500 SKI-12 pressure transducer, connected to a Sutron Satlink 2 data logger, was installed at Peace 35a on September 21, 2009 by Via-Sat Data Systems. The logger was set to record an average of ten values collected over a period of 100 seconds every 15 minutes. April 5, 2010 the sensor appears to have begun shifting. June 18, 2010 it settled at an elevation 0.342 m higher than its original deployment elevation. August 4, 2012 the battery failed. April 27 the battery was replaced and the logger was re-started. Data were last remotely accessed October 20, 2013. A summary of Peace 35a site visits and gauge level checks is given in **Table 18**.

Four benchmarks have been installed near Peace 35a (**Table 21**). Benchmark locations are shown in **Figure 24**.

5.5.2 Data summary and rating curve development

The current Peace 35a stage time series extends from September 21, 2009 to October 20, 2013 with two data gaps in which data were not included in this report (**Figure 25**). The two data gaps are April 5, 2010 to June 18, 2010, a 74 day data gap, and August 4, 2012 to April 27, 2013, a 267 day data gap (**Table 19**).

Fourteen discharge measurements have been collected at Peace 35a, covering a range of flows from 373 m^3/s at a stage of 411.869 m to 2020 m^3/s at a stage of 413.969 m. Discharge values calculated for stages outside of this range are extrapolated estimates; the current stage record ranges from 411.779 m to 415.123 m (calculated as 333 to 3,529 m^3/s). The rating curve is shown in **Figure 26** and the residuals between the measured discharge and the discharge calculated from the rating curve are given in **Table 20**. The current rating curve shows excellent fit (3.1% root mean square of errors). The final stage-discharge relation for Peace 29 is as follows:

$$Q(S) = 120.504(S - 410.160)^{2.108}$$

The calculated discharge record using the above equation and the Peace 35a stage record is shown in **Figure 27**.

6 Summary and Recommendations

Initiation of GMSWORKS-6 led to the installation of 5 gauges on the Peace River Mainstem between PCN and the Pine River September/October 2009. Initially, it was planned that the stations be maintained for 10 years with a budget of $50,000. The budget did not adequately reflect the level of effort required to meet provincial standards for hydrometric stations. RISC Grade A standards (Resources Information Standards Committee, 2009) requires a minimum of five discharge measurements and 2 water level checks conducted annually until a stable rating curve can be developed. After which one discharge measurement and water level check is required per year as long as station and channel remain stable. This being said, a minimum of eight to ten discharge measurements is desirable to develop a stage-discharge rating curve and the ToR states a minimum of ten discharge measurements.

Between July 2009 and March 2010, ten to twelve discharge measurements were taken at each gauge station and stage-discharge rating curves/relationships were developed. Three additional discharge measurements were taken November 2011 to confirm rating curve stability throughout the range of flow. Limited to no maintenance was conducted in 2012 as the maintenance requirements and budget were being reconsidered. April 2013 annual discharge and water level measurements and equipment maintenance was reinstated and expected to continue at least through 2014.

A more detailed QA/QC review of 2009 to 2012 data, including development of a system wide flow balance, was completed in 2013. This process identified periods of sensor instability and/or sensor shifts in the Peace 9, Peace 25, Peace 29 and Peace 35a records. Periods of sensor instability were removed and sensor shifts were accounted for in the stage record. Uncertainty limit of 5% was selected for the discharge records. This is less than the 7% recommend for RISC Grade A, but provides a reasonable benchmark when comparing data from equally uncertain sources (i.e. flow data from adjacent gauges). The flow balance showed acceptable uncertainty in the Peace 3, Peace 9, Peace 25, Peace 29, and Peace 35a discharge series. Peace 35a discharge series showed the greatest uncertainty; identifiable in its comparison with the Peace 29 and WSC Peace River above the Pine River data sets.

Scheduled for 2014 is a single flow measurement, water level check, and year end data review and reporting. During the site inspections the desiccant and breather tubes will be checked and/or replaced at each gauge and that the pressure transducers, solar panels and batteries will also be checked. Downloads of data stored in each logger is also recommended while on site. This is particularly required at Peace 3, the temporary levelogger that is not remotely accessible. The levelogger sensor at Peace 3 should be replaced with a permanent pressure transducer when BC Hydro is able to maintain a low flow.

Data collected in 2012 and 2013 should be compared to published local WSC gauge data when it becomes available. Similar to what was done in 2013, data collected in 2014 is to be subjected to a quality review that includes identification of anomalies, comparison of data with that from other local gauges (BC Hydro and WSC), and comparison with past results (i.e. stage-discharge rating curves).

The stage-discharge relationships have been stable, thus allowing annual discharge and water level measurements as per RISC Grade A standards (Resources Information Standards Committee, 2009). However, the lengthy delay between annual checks provides potential for lengthy periods of undetected instability or equipment malfunction which results in lengthy periods of lost or unusable data. The stability of the channel and number of gauges along the Peace River Mainstem may justify the risk of lost data. However, additional site checks – measurement of water level and equipment function checks – could be incorporated to reduce the potential extent of data loss.

At the end of 2014, five years of hydrometric data will have been collected along the Peace River Mainstem. Although only half of the ten year minimum record length defined in the ToR work plan, the five years of data should be able to address much of objectives of the program. The data can be used to validate hydraulic models of the mainstem, such as that developed under GMSWORKS-5. Daily peaking events through a range of flows as well as spill flow events – such as occurred in 2012 – can be used to further calibrate and validate the models ability to simulate the dispersion and timing of such events as they translate from PCN to the Pine River confluence. Adjustments or calibration of the model using the discharge and level data may improve its ability to simulate such events; however any substantial calibration changes are expected to require additional survey of channel sections.

The hydraulic model, collected data, and previously identified side channel habitat (GMSWORKS-3) can be used to improve on past evaluations of when side channels are inundated or isolated from mainstem flow and the local response of flow ramping effects at various discharges on side channel habitats. However, additional survey data and model refinement – and potentially the development of site specific 2D models – will generally be needed to confirm specific side channel hydraulic response versus mainstem response to flow ramping events. To the author’s knowledge, fine tuning of ramping sequences – a benefit of the work program as defined by the ToR – has not yet been implemented either through model simulations or operational tests. Use of the gauge stations to collect data during such an operational test would be beneficial. Additional leveloggers temporarily installed at identified high value habitat sites should be considered to supplement data collection if such a test program is implemented.

7 Literature Cited

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Tables not included in the text

Table 6 Summary of Peace 3 site visits and gauge level checks

Date	Level Check	Offset (m)	Flow Measured	Maintenance/Repairs
2009-Jul-29	N/A	N/A	Y	
2009-Jul-30	N/A	N/A	Y	
2009-Sep-03	N/A	N/A	N	Sensor installed
2009-Sep-13	N	N/A	Y	
2009-Sep-20	Y	0.02	Y	
2010-Jan-26	Y	0.02	Y	
2010-Mar-04	Y	0.00	Y	
2010-Mar-05	Y	-0.01	Y	
2010-Mar-06	Y	-0.03	Y	
2010-Mar-07	Y	0.00	Y	
2010-Mar-19	Y	0.00	Y	
2010-Mar-20	Y	-0.01	Y	
2010-Mar-21	Y	-0.01	Y	
2010-Jun-16	Y	0.00	N	Pressure transducer lowered by 0.361 m
2011-Nov-20	Y	0.00	Y	
2011-Nov-21	Y	0.02	Y	
2011-Nov-22	Y	0.00	Y	
2012-May-9	Y	-0.03	N	
2013-Apr-28	Y	0.01	Y	
2013-Jun-10	Y	N/A	N	Sensor failed on May 4, 2013
2013-Aug-11	Y	N/A	N	Temporary levelogger installed

Table 7 Summary of Peace 3 data gaps. On June 16, 2010 the sensor was lowered to prevent further stranding

From time	To time	Hours affected	Days affected	Notes
2009-Sep-12 14:24	2009-Sep-13 14:54	25	1.0	Stranded
2010-Jun-03 02:39	2010-Jun-03 06:24	4	0.2	Stranded
2010-Jun-04 02:39	2010-Jun-04 06:24	4	0.2	Stranded
2010-Jun-04 07:39	2010-Jun-04 08:09	1	0.0	Stranded
2010-Jun-04 19:09	2010-Jun-04 19:39	1	0.0	Stranded
2010-Jun-04 20:39	2010-Jun-05 04:39	8	0.3	Stranded
2010-Jun-05 04:39	2010-Jun-05 05:09	1	0.0	Stranded
2010-Jun-05 19:39	2010-Jun-06 01:24	6	0.2	Stranded
2010-Jun-06 20:09	2010-Jun-07 00:09	4	0.2	Stranded
2010-Jun-09 02:39	2010-Jun-09 07:09	5	0.2	Stranded
2010-Jun-09 23:24	2010-Jun-10 05:54	7	0.3	Stranded
2010-Jun-10 06:39	2010-Jun-10 07:39	1	0.0	Stranded
2010-Jun-10 19:39	2010-Jun-11 08:39	13	0.5	Stranded
2010-Jun-11 19:09	2010-Jun-12 10:09	15	0.6	Stranded
2010-Jun-12 20:39	2010-Jun-13 05:24	9	0.4	Stranded
2010-Jun-13 05:24	2010-Jun-13 06:09	1	0.0	Stranded
2010-Jun-13 06:09	2010-Jun-13 08:39	3	0.1	Stranded
2010-Jun-14 05:09	2010-Jun-14 08:54	4	0.2	Stranded
2010-Jun-14 21:39	2010-Jun-15 03:39	6	0.3	Stranded
2010-Jun-15 21:24	2010-Jun-16 06:39	9	0.4	Stranded
2010-Jun-16 08:09	2010-Jun-16 11:54	4	0.2	Stranded

Table 8 Summary of flow measurements used in developing the Peace 3 rating curve

Date/Time	Stage (m)	Discharge (m^3/s)	R Error (%)	R Error Value (m^3/s)
2009-Sep-13 10:10	445.159	319	0.0	0.0
2013-Apr-28 11:25	445.407	461	3.0	13.3
2009-Sep-20 09:24	445.718	616	-3.2	-20.2
2010-Mar-21 07:54	446.112	888	-3.0	-27.9
2009-Jul-30 09:51	446.265	1060	2.2	23.2
2009-Jul-29 16:11	446.286	1080	2.7	28.8
2010-Mar-20 07:51	446.479	1210	-0.4	-4.8
2011-Nov-20 11:00	446.587	1320	0.5	6.7
2010-Mar-07 08:34	446.596	1330	1.1	14.1
2010-Mar-06 09:03	446.765	1500	1.9	27.2
2010-Mar-05 08:54	446.918	1600	-1.0	-16.5
2010-Jan-26 15:00	446.952	1640	-0.9	-14.5
2011-Nov-21 09:45	446.943	1650	0.0	-0.3
2010-Mar-04 09:40	447.100	1810	0.6	10.4
2011-Nov-22 09:30	447.225	1960	1.4	27.6
2010-Mar-19 08:30	447.259	1970	0.0	0.5

Table 9 Summary of Peace 9 site visits and gauge level checks

Date	Level Check	Offset (m)	Flow Measured	Maintenance/Repairs
2009-Jul-29	N/A	N/A	Y	
2009-Jul-30	N/A	N/A	Y	
2009-Sep-13	N/A	N/A	Y	
2009-Sep-20	N/A	N/A	Y	
2009-Oct-06	N/A	N/A	N	Sensor installed
2010-Mar-04	Y	0.01	Y	
2010-Mar-05	Y	-0.03	Y	
2010-Mar-06	Y	-0.01	Y	
2010-Mar-07	Y	0.02	Y	
2010-Mar-19	Y	-0.01	Y	
2010-Mar-20	Y	-0.01	Y	
2010-Mar-21	Y	0.00	Y	
2010-Jun-16	Y	0.00	N	Pressure transducer lowered by 0.868 m
2011-Nov-20	Y	N/A	Y	Sensor unstable July 17, 2010 to June 25, 2012
2011-Nov-21	Y	N/A	Y	
2011-Nov-22	Y	N/A	Y	
2012-Jun-25	N	N/A	N	Temporary levelogger installed
2013-Apr-27	N	N/S	N	Temporary levelogger lowered by 1.13 m Replaced solar panel and battery
2013-Apr-28	N	N/A	Y	
2013-Jun-10	Y	0.02	N	
2013-Aug-11	Y	0.00	N	Temporary logger removed Permanent OTT pressure transducer installed

Table 10 Summary of Peace 9 data gaps

From time	To time	Hours affected	Days affected	Notes
2009-Nov-18 10:58	2009-Nov-19 13:13	26	1.1	Logger malfunction
2010-May-30 15:58	2010-May-30 19:43	4	0.2	Stranded
2010-Jun-02 02:28	2010-Jun-02 09:13	7	0.3	Stranded
2010-Jun-03 02:13	2010-Jun-04 10:28	32	1.3	Stranded
2010-Jun-04 17:58	2010-Jun-06 06:58	37	1.5	Stranded
2010-Jun-06 09:28	2010-Jun-07 11:28	26	1.1	Stranded
2010-Jun-07 12:13	2010-Jun-07 16:13	4	0.2	Stranded
2010-Jun-08 01:28	2010-Jun-08 08:58	8	0.3	Stranded
2010-Jun-09 03:28	2010-Jun-09 10:28	7	0.3	Stranded
2010-Jun-09 20:58	2010-Jun-10 08:13	11	0.5	Stranded
2010-Jun-10 15:58	2010-Jun-11 09:28	18	0.7	Stranded
2010-Jun-11 18:58	2010-Jun-12 13:58	19	0.8	Stranded
2010-Jun-12 13:58	2010-Jun-13 23:28	34	1.4	Stranded
2010-Jun-14 04:43	2010-Jun-14 12:43	8	0.3	Stranded
2010-Jun-14 22:13	2010-Jun-15 13:43	16	0.6	Stranded
2010-Jun-15 22:13	2010-Jun-16 16:28	18	0.8	Stranded
2010-Jul-17 00:58	2012-Jun-25 14:38	17030	709.6	Logger shifting, stage data inaccurate
2012-Jun-26 04:05	2012-Jun-26 06:45	3	0.1	Stranded
2012-Jul-15 14:05	2012-Jul-15 16:10	2	0.1	Stranded
2012-Jul-17 01:20	2012-Jul-17 10:20	9	0.4	Stranded
2012-Jul-18 01:10	2012-Jul-18 09:40	9	0.4	Stranded
2012-Jul-19 01:40	2012-Jul-19 08:50	7	0.3	Stranded
2012-Jul-20 01:55	2012-Jul-20 09:40	8	0.3	Stranded
2012-Jul-21 00:40	2012-Jul-21 10:35	10	0.4	Stranded
2012-Jul-21 23:25	2012-Jul-22 10:35	11	0.5	Stranded
2012-Jul-23 01:10	2012-Jul-23 09:15	8	0.3	Stranded
2012-Jul-24 00:00	2012-Jul-24 10:20	10	0.4	Stranded
2012-Jul-25 03:00	2012-Jul-25 08:30	6	0.2	Stranded
2012-Jul-26 03:40	2012-Jul-26 09:05	5	0.2	Stranded
2012-Jul-27 03:25	2012-Jul-27 09:15	6	0.2	Stranded
2012-Jul-28 02:35	2012-Jul-28 09:35	7	0.3	Stranded
2012-Jul-29 02:15	2012-Jul-29 12:35	10	0.4	Stranded
2012-Jul-30 02:35	2012-Jul-30 08:10	6	0.2	Stranded

From time	To time	Hours affected	Days affected	Notes
2012-Jul-31 02:15	2012-Jul-31 08:50	7	0.3	Stranded
2012-Aug-01 02:50	2012-Aug-01 07:55	5	0.2	Stranded
2012-Aug-02 02:20	2012-Aug-02 08:10	6	0.2	Stranded
2012-Aug-03 01:05	2012-Aug-03 11:25	10	0.4	Stranded
2012-Aug-04 00:00	2012-Aug-04 13:30	14	0.6	Stranded
2012-Aug-05 01:40	2012-Aug-05 10:15	9	0.4	Stranded
2012-Aug-06 02:15	2012-Aug-06 12:50	11	0.4	Stranded
2012-Aug-07 00:40	2012-Aug-07 10:15	10	0.4	Stranded
2012-Aug-08 02:15	2012-Aug-08 16:45	15	0.6	Stranded
2012-Aug-09 02:40	2012-Aug-09 14:45	12	0.5	Stranded
2012-Aug-09 22:35	2012-Aug-10 11:00	12	0.5	Stranded
2012-Aug-10 22:10	2012-Aug-11 11:50	14	0.6	Stranded
2012-Aug-12 01:30	2012-Aug-12 09:50	8	0.3	Stranded
2012-Aug-13 01:40	2012-Aug-13 13:40	12	0.5	Stranded
2012-Aug-14 01:50	2012-Aug-14 11:45	10	0.4	Stranded
2012-Aug-15 02:15	2012-Aug-16 08:30	30	1.3	Stranded
2012-Aug-17 02:45	2012-Aug-17 09:10	6	0.3	Stranded
2012-Aug-18 00:45	2012-Aug-18 09:35	9	0.4	Stranded
2012-Aug-19 01:55	2012-Aug-19 10:55	9	0.4	Stranded
2012-Aug-20 00:45	2012-Aug-20 10:15	10	0.4	Stranded
2012-Aug-21 00:40	2012-Aug-21 10:00	9	0.4	Stranded
2012-Aug-22 01:10	2012-Aug-22 11:25	10	0.4	Stranded
2012-Aug-23 00:10	2012-Aug-23 10:55	11	0.4	Stranded
2012-Aug-23 23:00	2012-Aug-24 10:05	11	0.5	Stranded
2012-Aug-24 23:05	2012-Aug-25 12:05	13	0.5	Stranded
2012-Aug-26 02:10	2012-Aug-26 12:30	10	0.4	Stranded
2012-Aug-27 00:55	2012-Aug-27 10:25	10	0.4	Stranded
2012-Aug-28 00:45	2012-Aug-28 15:25	15	0.6	Stranded
2012-Aug-29 01:05	2012-Aug-29 10:45	10	0.4	Stranded
2012-Aug-29 23:35	2012-Aug-30 10:45	11	0.5	Stranded
2012-Aug-31 02:25	2012-Aug-31 12:30	10	0.4	Stranded
2012-Aug-31 22:05	2012-Sep-03 13:45	64	2.7	Stranded
2012-Sep-04 02:25	2012-Sep-04 13:30	11	0.5	Stranded
2012-Sep-05 01:40	2012-Sep-05 09:35	8	0.3	Stranded
2012-Sep-05 22:55	2012-Sep-06 12:45	14	0.6	Stranded

From time	To time	Hours affected	Days affected	Notes
2012-Sep-07 00:20	2012-Sep-07 12:35	12	0.5	Stranded
2012-Sep-08 02:15	2012-Sep-08 17:50	16	0.6	Stranded
2012-Sep-09 00:45	2012-Sep-10 10:40	34	1.4	Stranded
2012-Sep-11 22:15	2012-Sep-12 08:25	10	0.4	Stranded
2012-Sep-13 02:50	2012-Sep-13 08:05	5	0.2	Stranded
2012-Sep-15 02:50	2012-Sep-15 09:40	7	0.3	Stranded
2012-Sep-16 23:15	2012-Sep-17 10:50	12	0.5	Stranded
2012-Sep-19 02:35	2012-Sep-19 10:40	8	0.3	Stranded
2012-Sep-19 12:00	2012-Sep-19 18:15	6	0.3	Stranded
2012-Sep-20 03:05	2012-Sep-20 17:30	14	0.6	Stranded
2012-Oct-09 06:00	2012-Oct-09 09:45	4	0.2	Stranded
2012-Oct-10 01:30	2012-Oct-10 06:25	5	0.2	Stranded
2012-Oct-11 01:40	2012-Oct-11 07:15	6	0.2	Stranded
2012-Oct-12 02:05	2012-Oct-12 08:00	6	0.2	Stranded
2012-Oct-13 04:05	2012-Oct-13 09:25	5	0.2	Stranded
2012-Oct-13 17:25	2012-Oct-14 19:15	26	1.1	Stranded
2012-Oct-15 00:55	2012-Oct-15 13:00	12	0.5	Stranded
2012-Oct-16 00:20	2012-Oct-16 14:05	14	0.6	Stranded
2012-Oct-16 21:00	2012-Oct-17 01:55	5	0.2	Stranded
2012-Oct-17 03:45	2012-Oct-17 07:35	4	0.2	Stranded
2012-Oct-18 20:45	2012-Oct-19 05:10	8	0.4	Stranded
2012-Oct-19 23:35	2012-Oct-20 08:20	9	0.4	Stranded
2012-Oct-21 02:25	2012-Oct-21 08:15	6	0.2	Stranded
2012-Oct-22 02:35	2012-Oct-22 08:10	6	0.2	Stranded
2012-Oct-23 02:40	2012-Oct-23 07:35	5	0.2	Stranded
2012-Oct-24 00:55	2012-Oct-24 08:35	8	0.3	Stranded
2012-Oct-25 02:35	2012-Oct-25 08:25	6	0.2	Stranded
2012-Oct-26 00:25	2012-Oct-26 07:50	7	0.3	Stranded
2012-Oct-26 23:40	2012-Oct-27 07:35	8	0.3	Stranded
2012-Oct-27 16:30	2012-Oct-27 18:40	2	0.1	Stranded
2012-Oct-28 01:30	2012-Oct-28 11:55	10	0.4	Stranded
2012-Oct-28 16:25	2012-Oct-28 20:20	4	0.2	Stranded
2012-Oct-29 01:25	2012-Oct-29 11:10	10	0.4	Stranded
2012-Oct-29 17:10	2012-Oct-29 21:50	5	0.2	Stranded
2012-Oct-30 01:20	2012-Oct-30 09:30	8	0.3	Stranded

From time	To time	Hours affected	Days affected	Notes
2012-Oct-31 00:45	2012-Oct-31 09:50	9	0.4	Stranded
2012-Oct-31 23:55	2012-Nov-01 09:10	9	0.4	Stranded
2012-Nov-02 02:35	2012-Nov-02 11:55	9	0.4	Stranded
2012-Nov-03 01:55	2012-Nov-04 20:35	43	1.8	Stranded
2012-Nov-05 00:10	2012-Nov-05 10:25	10	0.4	Stranded
2012-Nov-06 04:05	2012-Nov-06 08:55	5	0.2	Stranded
2012-Nov-07 03:40	2012-Nov-07 17:15	14	0.6	Stranded
2012-Nov-09 05:45	2012-Nov-09 07:05	1	0.1	Stranded
2012-Nov-10 20:45	2012-Nov-10 22:00	1	0.1	Stranded
2012-Nov-13 17:50	2012-Nov-13 18:35	1	0.0	Stranded
2012-Nov-16 04:45	2012-Nov-24 19:45	207	8.6	Stranded
2012-Nov-27 03:40	2012-Nov-27 08:20	5	0.2	Stranded
2012-Nov-28 02:40	2012-Nov-28 10:40	8	0.3	Stranded
2012-Nov-29 04:30	2012-Nov-29 10:15	6	0.2	Stranded
2012-Nov-30 04:05	2012-Nov-30 11:45	8	0.3	Stranded
2012-Dec-01 03:45	2012-Dec-01 18:05	14	0.6	Stranded
2012-Dec-02 04:40	2012-Dec-02 18:55	14	0.6	Stranded
2012-Dec-03 00:55	2012-Dec-03 08:25	8	0.3	Stranded
2012-Dec-04 03:10	2012-Dec-04 09:45	7	0.3	Stranded
2012-Dec-04 12:55	2012-Dec-04 20:20	7	0.3	Stranded
2012-Dec-05 02:55	2012-Dec-05 10:40	8	0.3	Stranded
2012-Dec-06 00:55	2012-Dec-06 10:35	10	0.4	Stranded
2012-Dec-07 00:55	2012-Dec-07 09:55	9	0.4	Stranded
2013-Jan-25 03:15	2013-Jan-25 11:30	8	0.3	Stranded
2013-Jan-26 04:30	2013-Jan-26 11:00	7	0.3	Stranded
2013-Jan-27 02:40	2013-Jan-27 10:35	8	0.3	Stranded
2013-Jan-30 05:00	2013-Jan-30 16:05	11	0.5	Stranded
2013-Feb-20 15:30	2013-Apr-27 12:45	1581	65.9	Logger memory full

Table 11 Summary of flow measurements used in developing the Peace 9 rating curve

Date/Time	Stage (m)	Discharge (m^3/s)	R Error (%)	R Error Value (m^3/s)
2009-Sep-13 11:09	436.163	319	0.1	0.2
2013-Apr-28 11:55	436.511	470	5.7	25.2
2009-Sep-20 10:55	436.894	630	2.3	14.0
2010-Mar-21 08:42	437.440	900	-2.6	-23.6
2009-Jul-30 11:34	437.639	1090	3.1	32.3
2009-Jul-29 15:11	437.688	1100	0.9	10.0
2010-Mar-20 08:44	437.866	1200	-1.4	-17.3
2011-Nov-20 12:28	437.977	1300	-0.3	-4.4
2010-Mar-07 09:24	438.007	1310	-1.9	-25.2
2010-Mar-06 10:07	438.200	1500	0.8	12.6
2010-Mar-05 10:07	438.329	1600	-0.2	-3.0
2011-Nov-21 11:03	438.364	1630	-0.6	-9.6
2010-Mar-04 10:45	438.553	1810	0.0	0.0
2011-Nov-22 10:57	438.690	1960	0.4	7.8
2010-Mar-19 09:45	438.709	1970	0.0	0.1

Table 12 Summary of Peace 25 site visits and gauge level checks

Date	Level Check	Offset (m)	Flow Measured	Maintenance/Repairs
2009-Jul-29	N/A	N/A	Y	
2009-Jul-30	N/A	N/A	Y	
2009-Sep-13	N/A	N/A	Y	
2009-Sep-20	N/A	N/A	Y	
2009-Sep-23	N/A	N/A	N	Sensor installed
2010-Mar-04	Y	-0.01	Y	Sensor shifted 0.13 m between February 8 and February 25, 2010
2010-Mar-05	Y	0.00	Y	
2010-Mar-06	Y	-0.02	Y	
2010-Mar-07	Y	0.03	Y	
2010-Mar-19	Y	0.00	Y	
2010-Mar-20	Y	-0.01	Y	
2010-Mar-21	Y	-0.02	Y	
2010-Jun-16	Y	0.00	N	Pressure transducer lowered by 0.658 m
2011-Nov-20	Y	0.02	Y	
2011-Nov-21	Y	0.01	Y	
2011-Nov-22	Y	0.01	Y	
2012-May-9	Y	0.06	N	
2013-Apr-28	Y	N/A	Y	Sensor and battery failed on June 3, 2012
2013-Jun-10	Y	N/A	N	
2013-Aug-11	Y	N/A	Y	Permanent OTT pressure transducer installed
2013-Aug-12	N	N/A	N	Replaced solar panel and battery
2013-Oct-02	N	N/A	N	Logger launched

Table 13 Summary of Peace 25 data gaps

From time	To time	Hours affected	Days affected	Notes
2010-Feb-08 23:55	2010-Feb-25 00:10	384	16.0	Logger shifting, stage data inaccurate
2012-Jul-03 12:13	2013-Oct-02 12:28	10944	456.0	Sensor malfunction

Table 14 Summary of flow measurements used in developing the Peace 25 rating curve

Date/Time	Stage (m)	Discharge (m^3/s)	R Error (%)	R Error Value (m^3/s)
2009-Sep-13 12:19	424.296	354	0.0	0.0
2013-Aug-11 15:13	424.521	479	4.5	20.6
2013-Apr-28 13:55	424.585	497	1.4	6.7
2009-Sep-20 12:25	424.886	645	-2.3	-15.4
2010-Mar-21 09:40	425.238	895	0.0	0.0
2009-Jul-30 12:49	425.489	1080	-0.3	-2.9
2009-Jul-29 13:35	425.510	1110	0.4	4.1
2010-Mar-20 09:48	425.633	1220	1.0	12.4
2011-Nov-20 13:54	425.767	1280	-3.3	-43.9
2010-Mar-07 12:10	425.779	1330	-0.7	-10.0
2010-Mar-06 11:21	425.931	1500	1.5	21.5
2010-Mar-05 11:16	426.085	1610	-0.9	-14.0
2011-Nov-21 12:20	426.106	1620	-1.9	-31.1
2010-Mar-04 12:01	426.266	1830	0.8	15.2
2011-Nov-22 12:26	426.425	1940	-2.6	-51.3
2010-Mar-19 11:00	426.416	1980	0.0	0.0

Table 15 Summary of Peace 29 site visits and gauge level checks

Date	Level Check	Offset (m)	Flow Measured	Maintenance/Repairs
2009-Jul-29	N/A	N/A	Y	
2009-Sep-13	N/A	N/A	Y	
2009-Sep-20	N/A	N/A	Y	
2009-Sep-23	N/A	N/A	N	Sensor installed
2010-Mar-04	Y	-0.02	Y	Sensor shifted 0.05 m between February 8 and February 25, 2010
2010-Mar-05	Y	0.00	Y	
2010-Mar-06	Y	0.00	Y	
2010-Mar-07	Y	0.05	Y	
2010-Mar-19	Y	0.00	Y	
2010-Mar-20	Y	-0.01	Y	
2010-Mar-21	Y	-0.01	Y	
2010-Jun-17	Y	0.00	N	Pressure transducer lowered by 0.390 m
2011-Nov-20	Y	0.03	Y	
2011-Nov-21	Y	0.03	Y	
2011-Nov-22	Y	0.05	Y	
2012-May-9	Y	-0.16	N	
2013-Apr-28	Y	N/A	Y	
2013-Jun-10	Y	N/A	N	Battery failed on May 21, 2012
2013-Jun-11	Y	-0.01	N	Replaced battery

Table 16 Summary of Peace 29 data gaps

From time	To time	Hours affected	Days affected	Notes
2010-Feb-08 23:55	2010-Feb-25 00:10	384	16.0	Logger shifting, stage data inaccurate
2012-May-21 20:45	2013-Jun-11 08:28	9252	385.5	Battery failure

Table 17 Summary of flow measurements used in developing the Peace 29 rating curve

Date/Time	Stage (m)	Discharge (m^3/s)	R Error (%)	R Error Value (m^3/s)
2009-Sep-13 13:06	419.443	354	0.0	-0.1
2013-Apr-28 15:05	419.781	480	-2.1	-10.1
2009-Sep-20 15:46	420.112	649	0.0	-0.1
2010-Mar-21 10:18	420.543	897	0.0	-0.4
2009-Jul-29 12:31	420.800	1050	-1.7	-17.6
2010-Mar-20 10:30	420.994	1230	1.4	17.2
2011-Nov-20 15:12	421.116	1290	-1.2	-15.3
2010-Mar-07 12:15	421.167	1330	-1.5	-19.6
2010-Mar-06 12:16	421.340	1510	1.4	21.0
2011-Nov-21 13:33	421.506	1610	-1.6	-26.7
2010-Mar-05 12:39	421.492	1620	0.0	-0.1
2010-Mar-04 12:50	421.673	1830	2.5	45.4
2011-Nov-22 13:28	421.856	1950	-1.1	-22.0
2010-Mar-19 11:45	421.860	1970	0.0	0.0

Table 18 Summary of Peace 35a site visits and gauge level checks

Date	Level Check	Offset (m)	Flow Measured	Maintenance/Repairs
2009-Jul-29	N/A	N/A	Y	
2009-Sep-13	N/A	N/A	Y	
2009-Sep-20	N/A	N/A	Y	
2009-Sep-21	N/A	N/A	N	Sensor installed
2010-Mar-04	Y	0.01	Y	
2010-Mar-05	Y	-0.04	Y	
2010-Mar-06	Y	0.01	Y	
2010-Mar-07	Y	0.01	Y	
2010-Mar-19	Y	-0.02	Y	
2010-Mar-20	Y	0.00	Y	
2010-Mar-21	Y	0.00	Y	
2010-Jun-18	Y	0.00	N	Sensor shifted 0.342 m between April 5 and June 18, 2010 Pressure transducer lowered by 0.658 m
2011-Nov-20	Y	0.06	Y	
2011-Nov-21	Y	0.05	Y	
2011-Nov-22	Y	0.08	Y	
2012-May-9	Y	-0.06	N	
2013-Apr-27	N	N/A	N	Battery failed on August 4, 2012 Replaced solar panel and battery
2013-Apr-28	Y	0.06	Y	
2013-Jun-11	Y	-0.02	N	

Table 19 Summary of Peace 35a data gaps.

From time	To time	Hours affected	Days affected	Notes
2010-Apr-05 13:25	2010-Jun-18 11:10	1774	73.9	Logger shifting, stage data inaccurate
2012-Aug-04 02:45	2013-Apr-27 11:15	6393	266.4	Battery failure

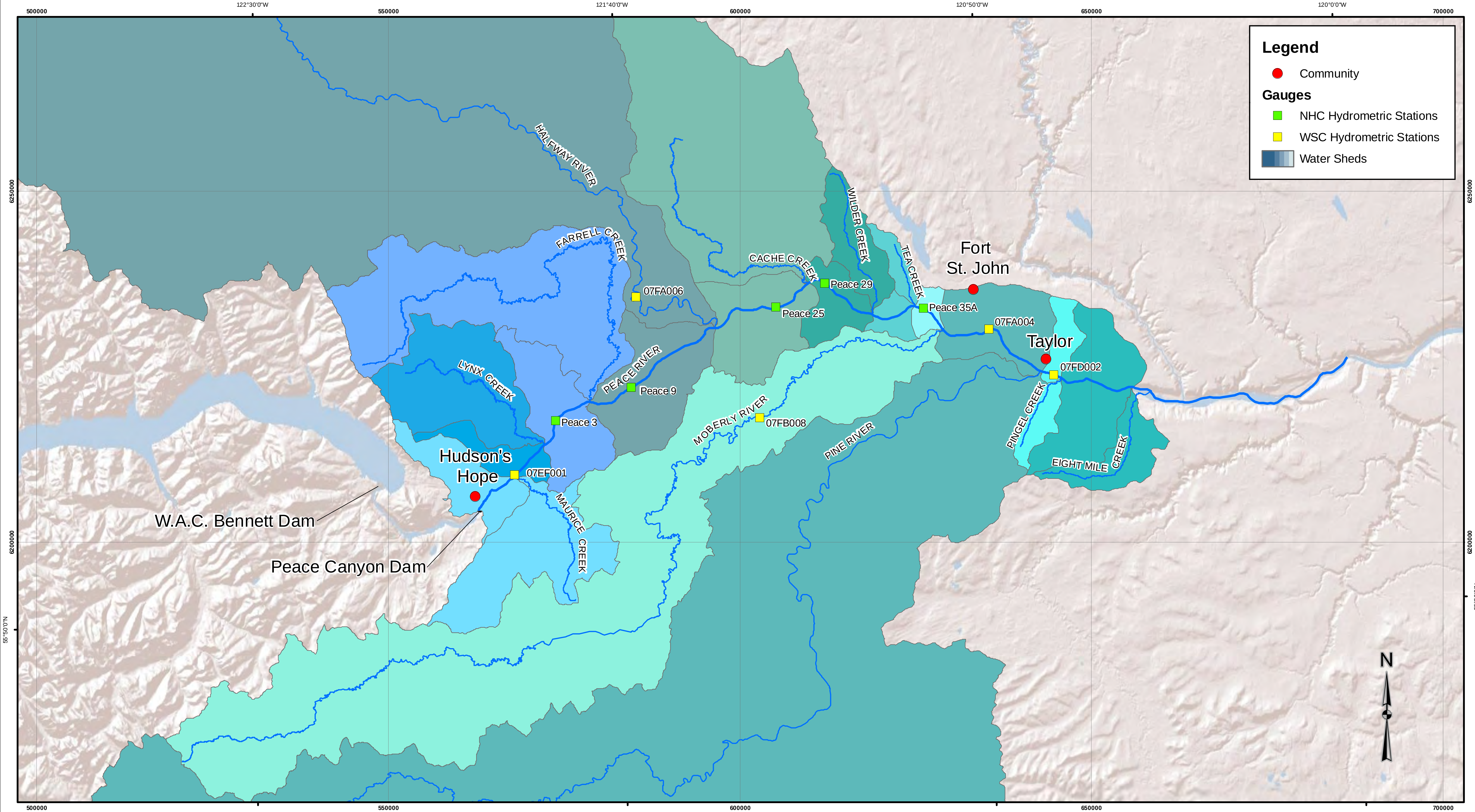
Table 20 Summary of flow measurements used in developing the Peace 35a rating curve

Date/Time	Stage (m)	Discharge (m^3/s)	R Error (%)	R Error Value (m^3/s)
2009-Sep-13 14:29	411.869	373	0.0	0.1
2013-Apr-28 16:09	412.132	524	3.9	19.5
2009-Sep-20 17:25	412.471	661	-6.2	-43.5
2010-Mar-21 11:20	412.815	926	-1.9	-17.9
2009-Jul-29 10:53	413.003	1090	-0.3	-3.3
2010-Mar-20 11:22	413.193	1230	-1.9	-23.7
2011-Nov-20 16:16	413.300	1300	-3.2	-42.3
2010-Mar-07 13:30	413.294	1350	0.6	8.0
2010-Mar-06 13:21	413.491	1540	0.9	13.4
2011-Nov-21 14:25	413.657	1620	-3.7	-63.0
2010-Mar-05 14:09	413.576	1680	4.7	75.3
2010-Mar-04 14:21	413.826	1890	1.5	28.5
2011-Nov-22 13:21	413.995	1940	-5.1	-105.0
2010-Mar-19 12:45	413.969	2020	0.0	0.0

Table 21 Summary of benchmarks

Benchmark	Description	Elevation	Northing	Easting
Peace 3				
rebar 3 hm	Iron pin located approximately 9.1 m south of shelter	448.134	6217426.83	573569.49
via rebar	Iron pin located approximately 5.2 m upstream of shelter	451.024	6217440.14	573554.24
nhc new rebar1	Top of 15mm diameter rebar, 5 metres downstream shelter	450.954	6217445.65	573559.56
via stn bolt	Bolt set horizontally in the shelter support post.	450.482	6217440.01	573559.02
nhc new rebar2	Rebar	448.431	6217414.20	573551.92
nhc 3b	Rebar	447.030	6217359.41	573508.26
nhc 3a	Opposite side of river	447.020	6217187.98	573915.49
Peace 9				
base 9 hm	Iron pin (rebar) located approximately 3.0 m east of shelter	439.529	6222085.84	584465.44
nhc new rebar	Top of 15mm diameter rebar, 10 metres upstream of shelter	440.884	6222085.80	584460.23
89h5971	Upstream on left bank	444.160	6220446.52	582263.98
BM2	Lag bolt driven into a conifer tree, 3.0 m north of shelter	442.667	6222093.03	584464.24
Peace 25				
rebar 25 hm	Iron pin located approximately 14.6 m southeast of shelter	426.466	6233513.03	605076.77
rebar 25b	Rebar	426.210	6233539.02	605131.14
via stn bolt	Bolt set horizontally in the shelter support post	427.988	6233526.40	605069.86
nhc new rebar	Top of 15mm diameter rebar, 5 metres upstream of shelter	428.643	6233530.73	605065.06
new bolt	Top of horizontal bolt (threads) in 5cm square channel (post), 4 m downstream of shelter	428.297	6233529.35	605073.75
Peace 29				
rebar29b	Rebar	421.730	6236922.76	612129.82
hm rebar	Iron pin located approximately 9.1 m south of the shelter	421.890	6236944.83	612093.22
mid hill	Rebar on bank	424.371	6236948.36	612096.82
up hill	Rebar on bank	425.333	6236950.30	612097.94
conc pad x	'x' in the downstream concrete footing	425.779	6236951.33	612098.99
via stn bolt	Bolt set horizontally in the shelter support post	426.055	6236951.57	612098.31
bolt on square pipe	Top of horizontal bolt (threads) in 5cm square channel, 3.5 m north of shelter	425.885	6236955.41	612099.41
BM4	Top of lag bolt in 36cm dia conifer, 30 m downstream of shelter.	426.235	6236935.54	612123.68
Peace 35a				
hm rebar	Iron pin located approximately 8.5 meters southeast of shelter	415.758	6233383.52	626327.07
via stn bolt	Bolt set horizontally in DCP shelter support post	417.190	6233391.85	626327.70
nhc new rebar	Top of 15mm diameter rebar, 2 metres upstream of shelter	416.443	6233391.48	626325.91
bolt in channel	Top of horizontal bolt (threads) in 5cm square channel, 5 m up-stream of shelter	415.656	6233388.31	626321.60

Figures not included in the text



Base Data Sources:
- Background, ESRI Shaded Relief World 2D.
- Streams from BC Corporate Watershed Base.
- Watershed extracted from WSA

Scale 1:500,000

0 10,500 21,000 42,000 Meters

0 35,000 70,000 140,000 Feet

Coordinate System: UTM Zone 10 Metres, NAD 83

DSGN	DPM	nhc	BC hydro
IND CHKD			Peace River Mainstream Stage-Discharge
DFTG	JXD		
DFTG CHKD	DPM		GMSWorks 6 Watershed Map
INSPD			
REV			
ACPT		DATE 11 JUN 2010	DWG NO. CAD Mapsheet 1 of 1 R 0

Figure 1

Figure 2 **Calculated daily inflows between WSC Hudson and Peace 3 from October 1, 2009 to December 31, 2012 as a percent of WSC Hudson and Peace 3 flows.**

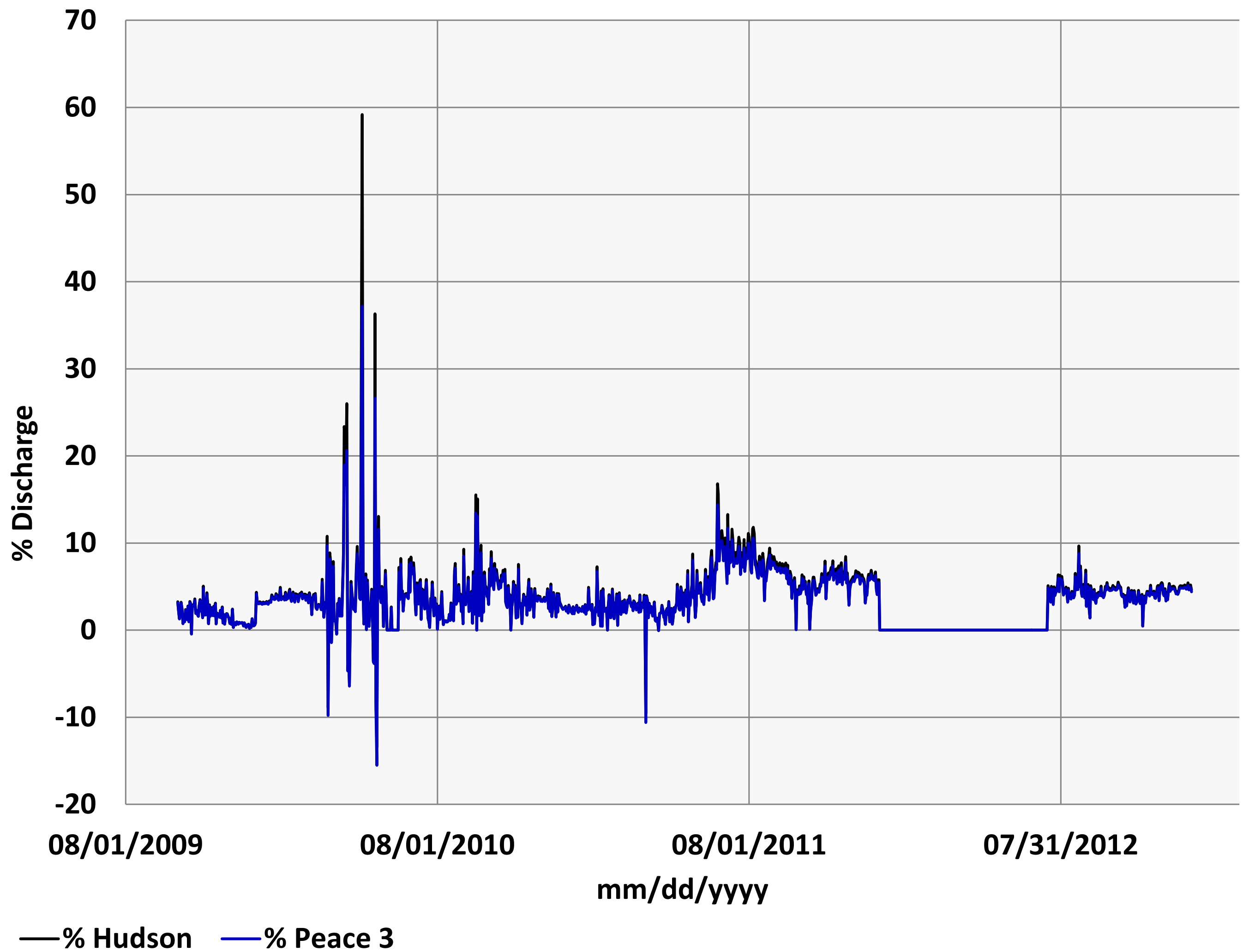


Figure 3 Calculated daily inflows between Peace 3 and Peace 9 from October 1, 2009 to December 31, 2012 as a percent of Peace 3 and Peace 9 flows.

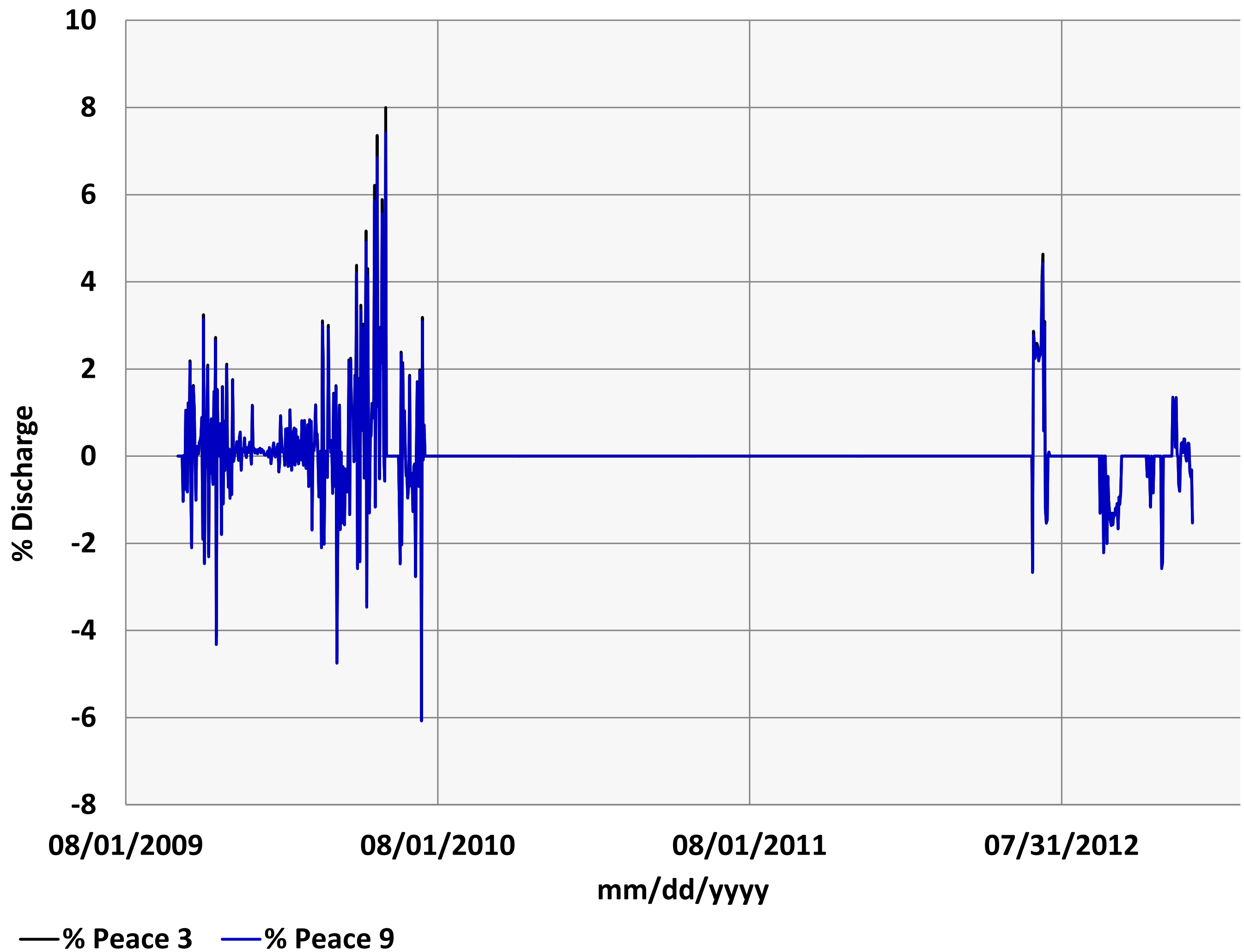


Figure 4 **Calculated daily inflows between Peace 9 and Peace 25 minus WSC Halfway flows from October 1, 2009 to December 31, 2012 as a percent of Peace 9 plus WSC Halfway and Peace 25 flows.**

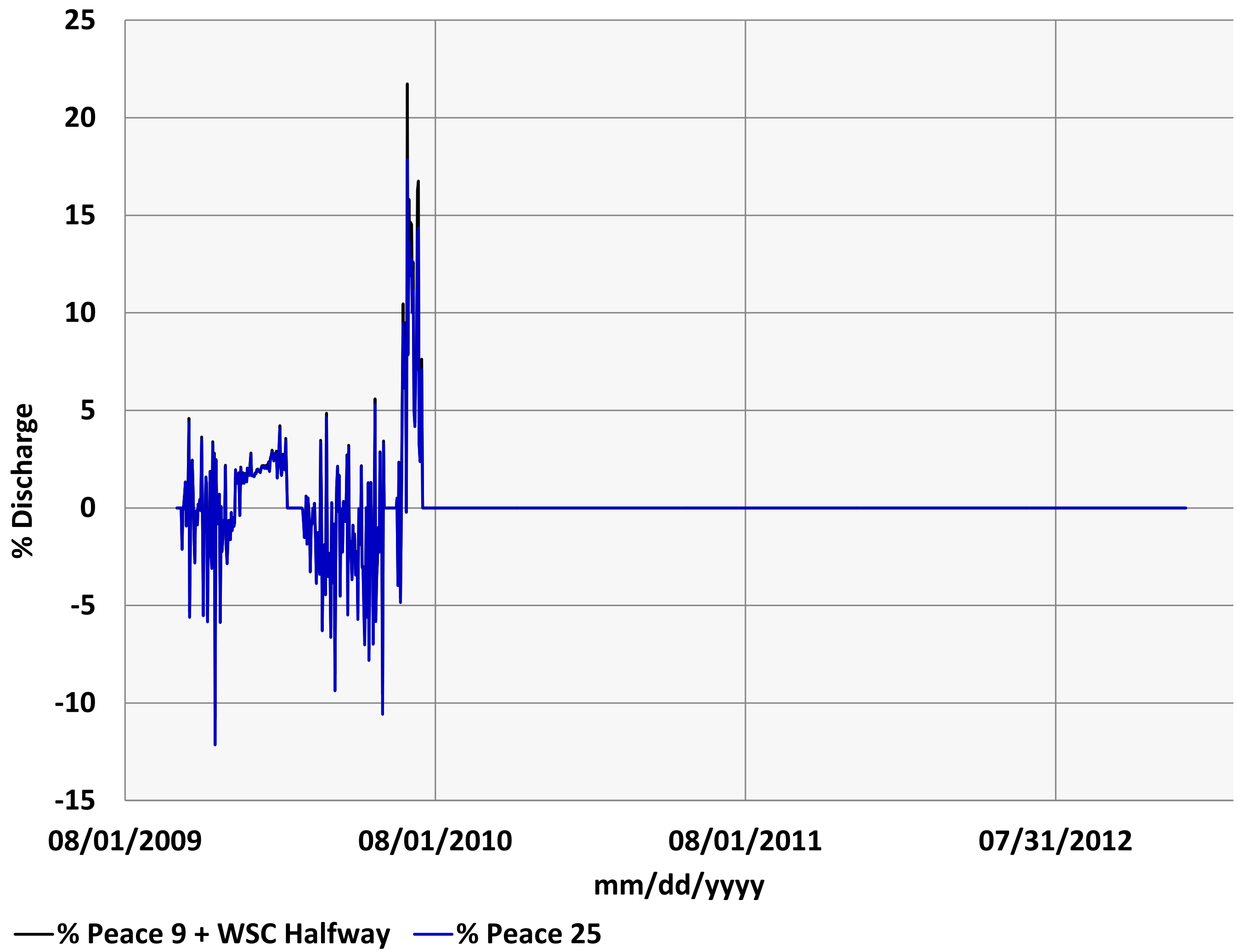


Figure 5 **Calculated daily inflows between Peace 25 and Peace 29 from October 1, 2009 to December 31, 2012 as a percent of Peace 25 and Peace 29 flows**

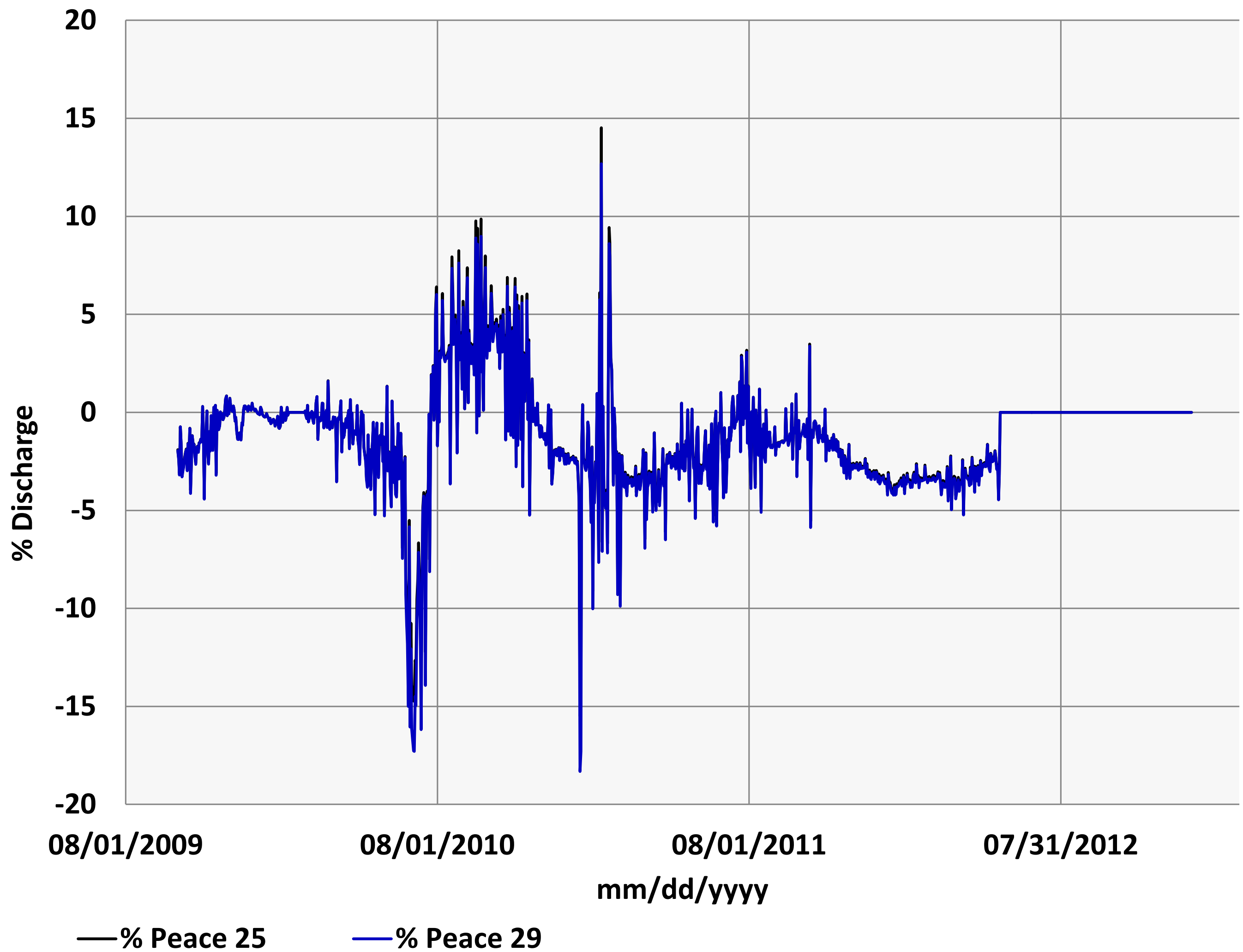


Figure 6 **Calculated daily inflows between Peace 29 and Peace 35a from October 1, 2009 to December 31, 2012 as a percent of Peace 29 and Peace 35a flows**

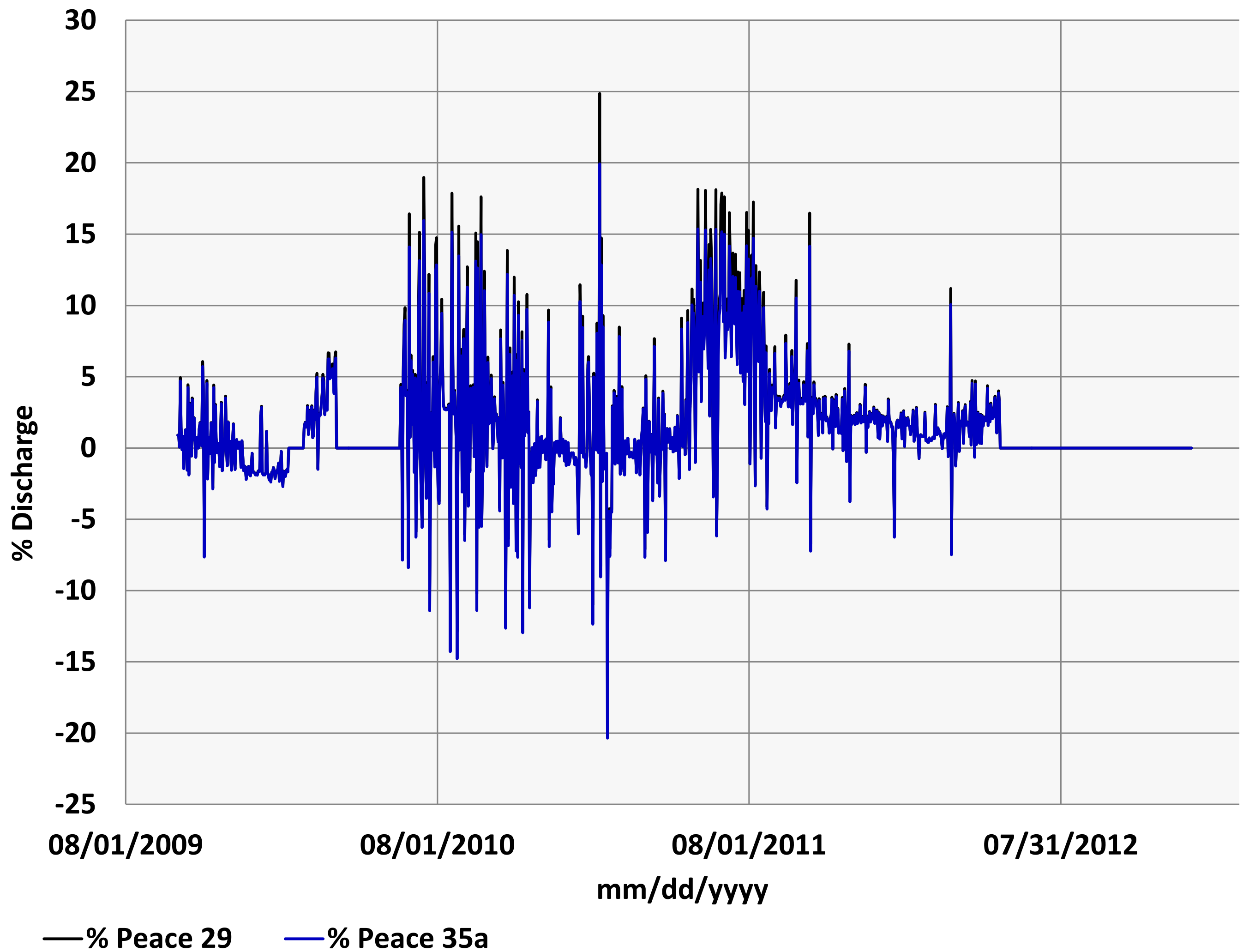


Figure 7 Calculated daily inflows between Peace 35a and WSC Pine minus WSC Moberly flows from October 1, 2009 to December 31, 2012 as a percent of Peace 35a plus WSC Moberly and WSC Pine flows.

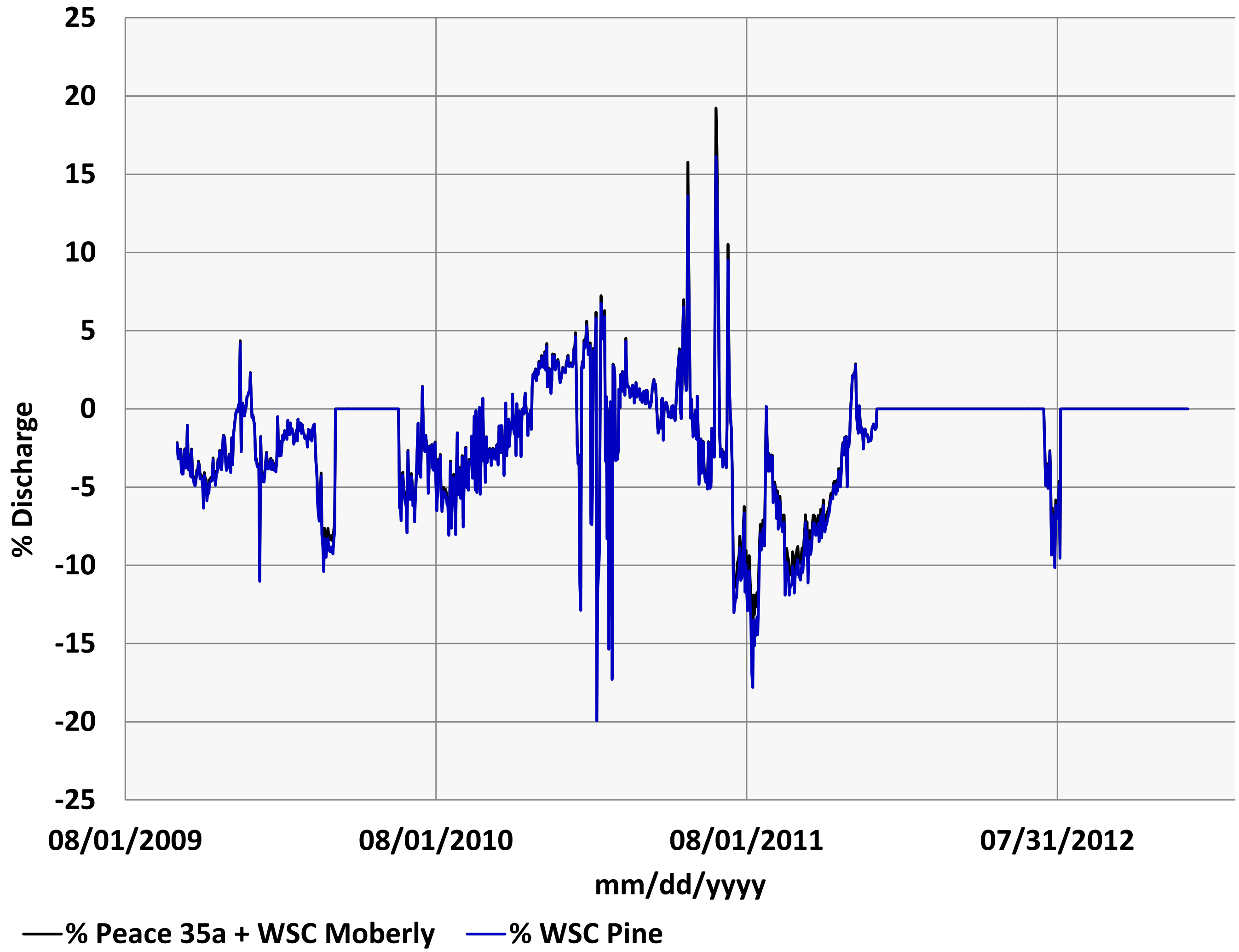


Figure 8 Peace 3 benchmark locations.

(from hydrometric station)	~~~v	~~~v
	distance	bearing
rebar 3 hm	16.83419	141.5
bm via rebar	4.774409	271.6
bm nhc new rebar1	5.672532	5.5
bm nhc new rebar2	26.76729	195.4
nhc 3b	95.24629	212.2
transducer	46.33757	124.7

Figure 9 The stage record for Peace 3. The sampling interval is 15 minutes. Gaps in the stage record are given in Table 7.

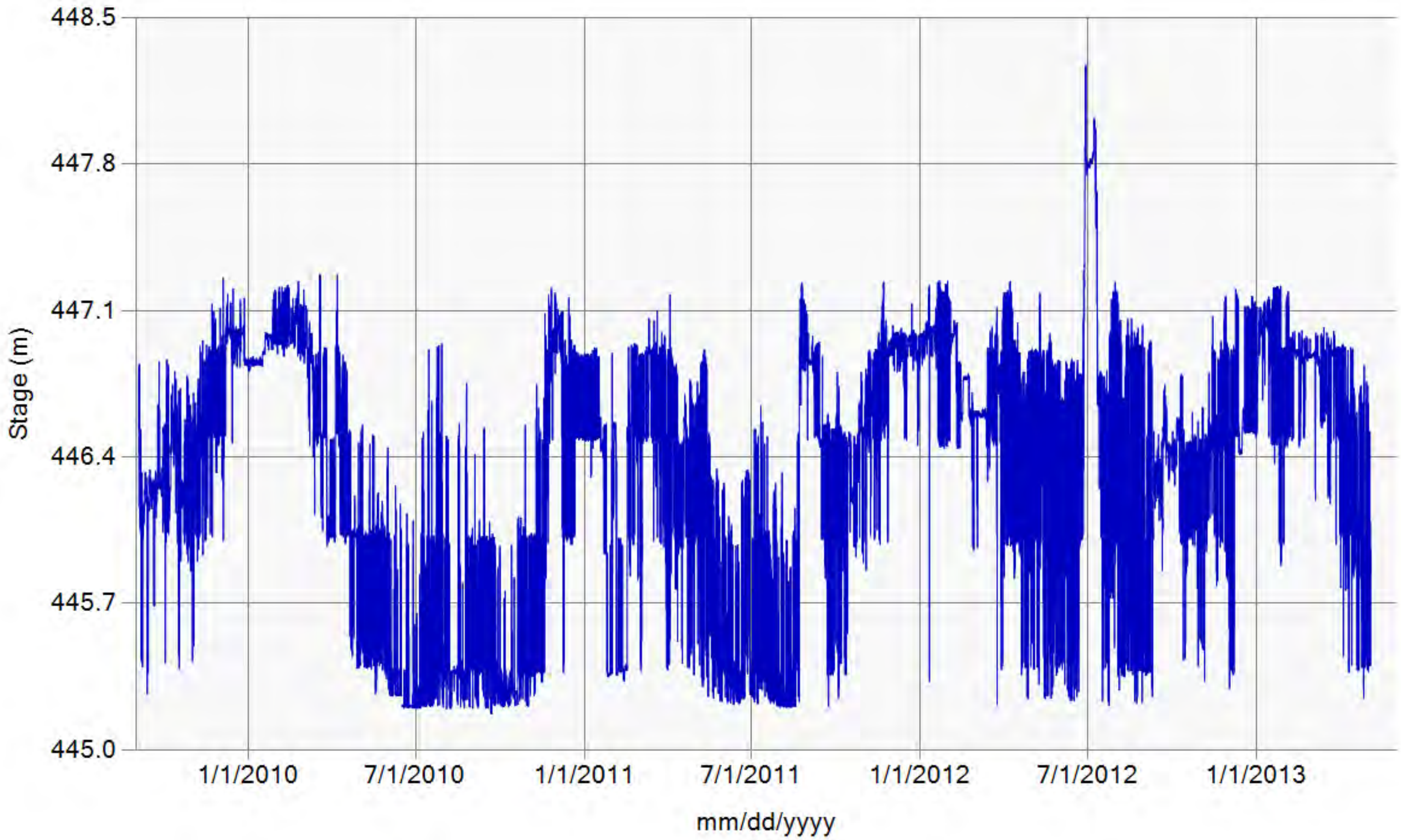


Figure 10 **The rating curve for Peace 3. Within the gauged range, the rating curve shows excellent fit (1.8% root mean square of errors) meeting RISC grade A standards (Resources Information Standards Committee, 2009), represented by a green bar below the curve. Discharge values calculated using the extrapolated portion of the rating curve (outside the highest and lowest gauged flow) are RISC Grade E, represented by grey bars below the curve. Gauged stages range from 445.159 m to 447.259 m; the current stage record ranges from 445.173 m to 448.273 m. Flow measurements collected in 2013 are shown in yellow.**

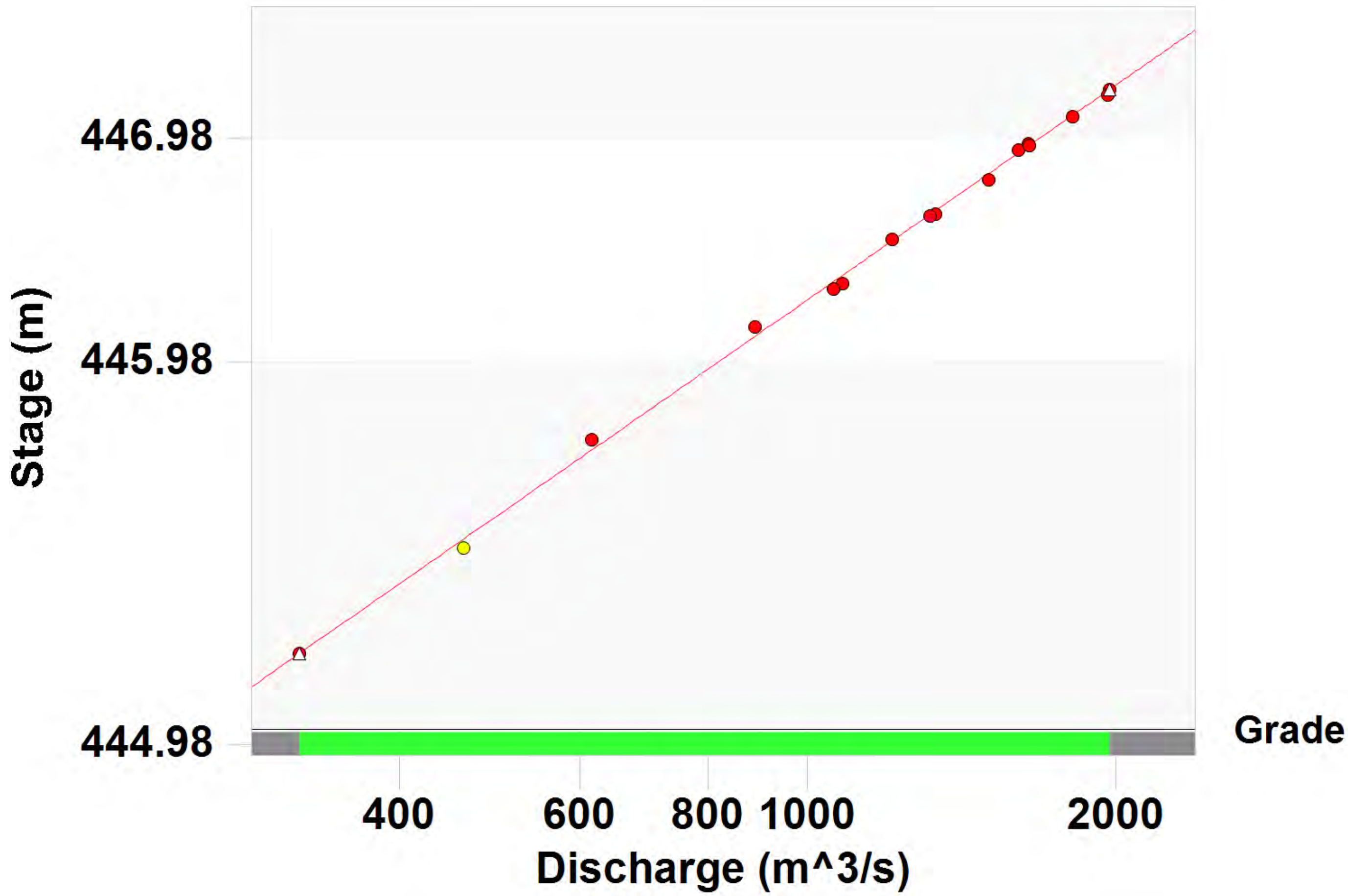


Figure 11 The discharge record for Peace 3. The sampling interval is 15 minutes. Gaps in the discharge record are given in Table 7.

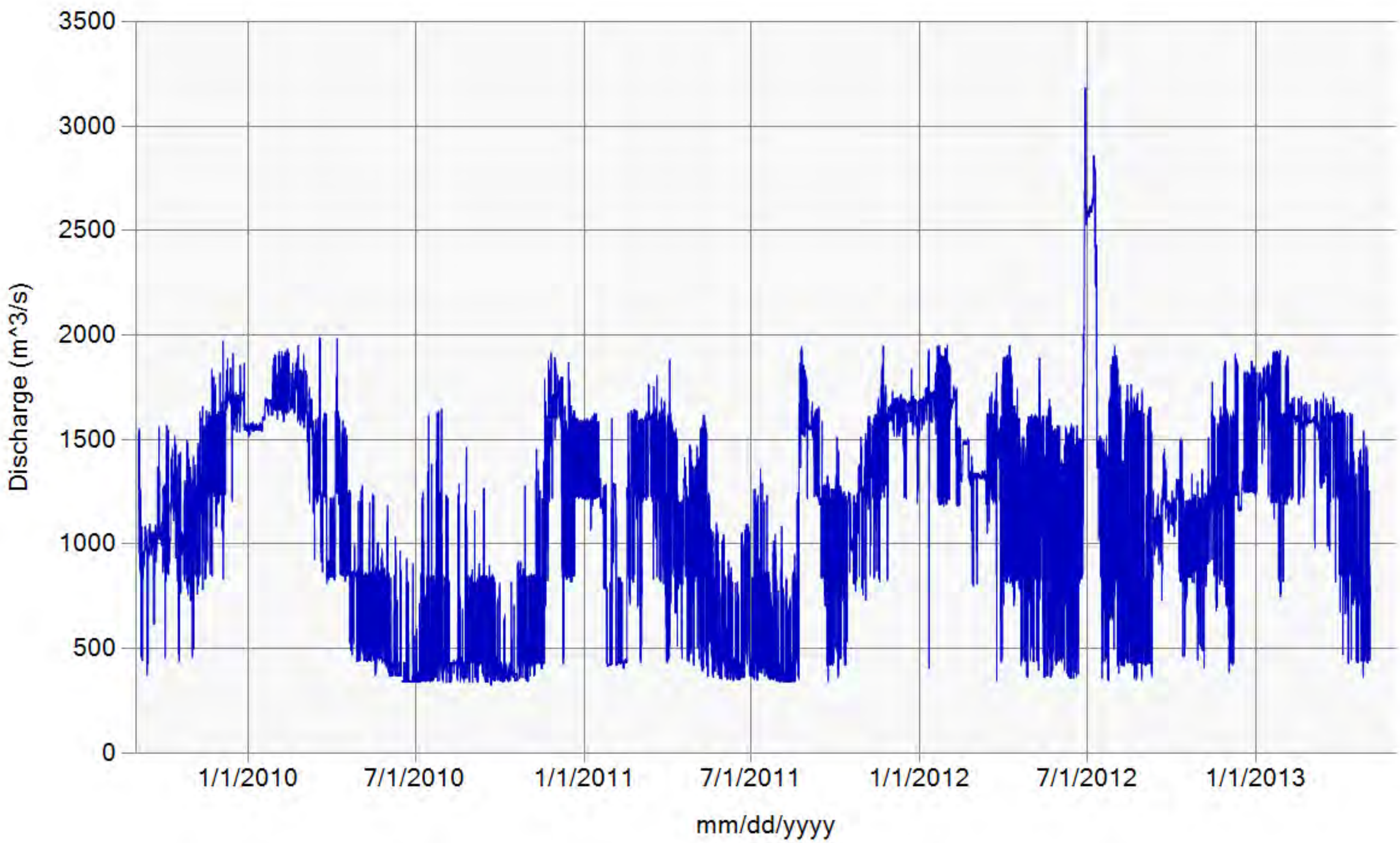


Figure 12 Peace 9 benchmark locations.

(from HM rebar, BM1)	~~~v	~~~v
	distance	bearing
nhc new rebar	5.211169	269.5
transducer9	36.65265	132.0
BM2	?	?
stn location	?	?

Figure 13 The stage record for Peace 9. The sampling interval of the Keller and OTT PT are 15 minutes and the sampling interval of the temporary levelogger is 5 minutes. Gaps in the stage record are given in Table 10.

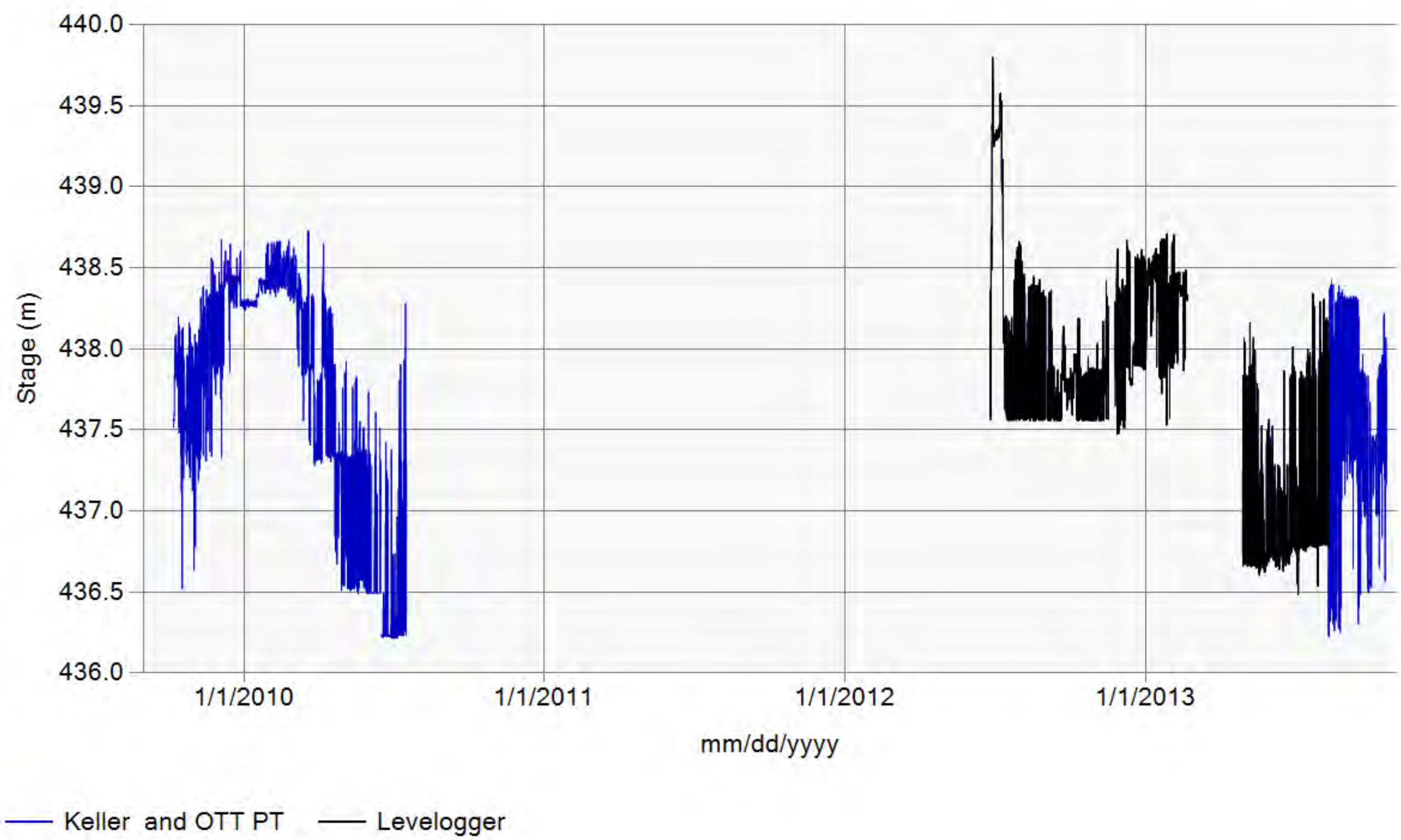


Figure 14 **The rating curve for Peace 9. Within the gauged range, the rating curve shows excellent fit (2.0% root mean square of errors) meeting RISC grade A standards (Resources Information Standards Committee, 2009), represented by a green bar below the curve. Discharge values calculated using the extrapolated portion of the rating curve (outside the highest and lowest gauged flow) are RISC Grade E, represented by grey bars below the curve. Gauged stages range from 436.163 m to 438.709 m; the current stage record ranges from 436.214 m to 439.800 m. Flow measurements collected in 2013 are shown in yellow.**

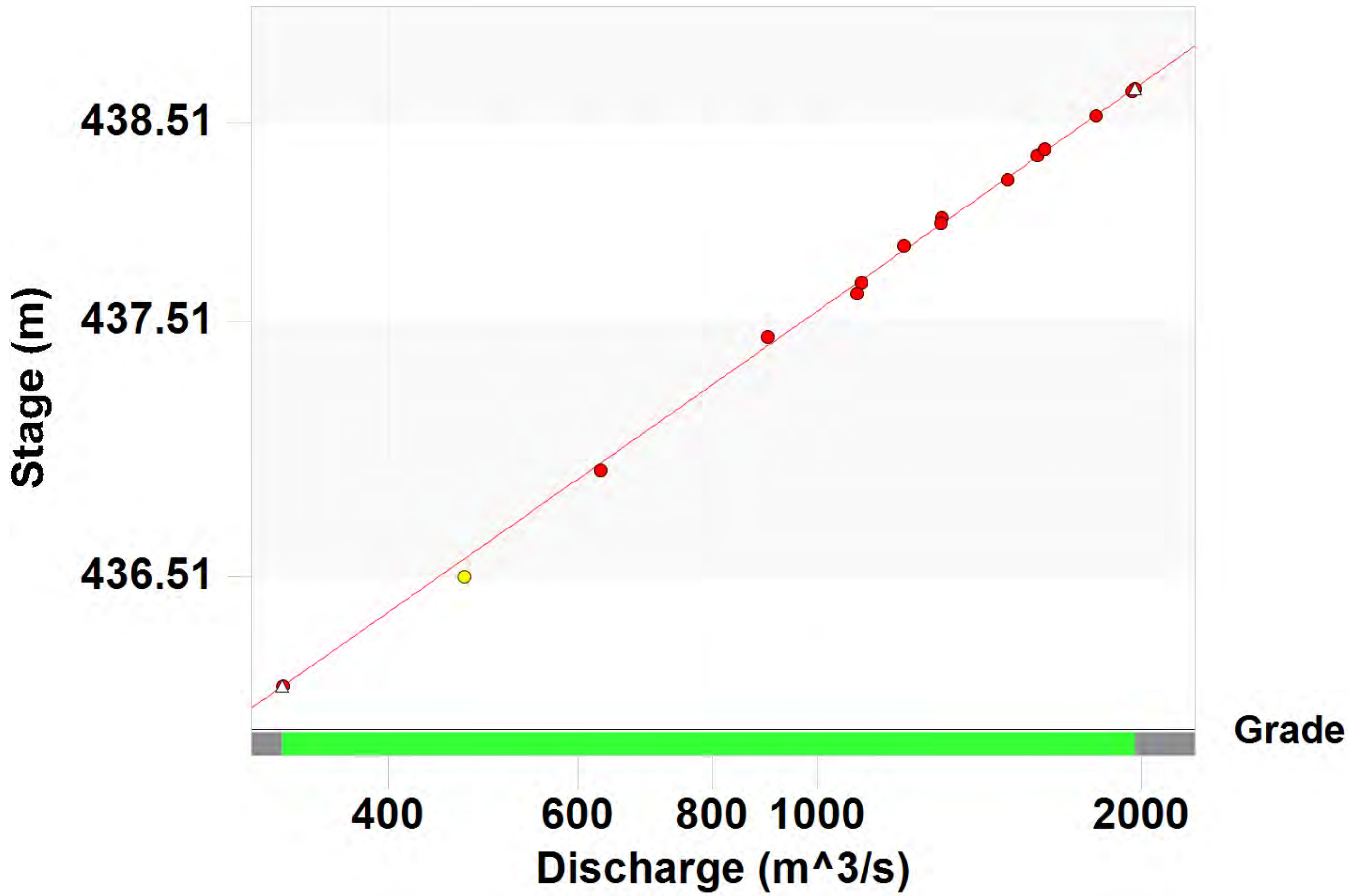


Figure 15 The discharge record for Peace 9. The sampling interval of the Keller and OTT PT are 15 minutes and the sampling interval of the temporary levelogger is 5 minutes. Gaps in the discharge record are given in Table 10.

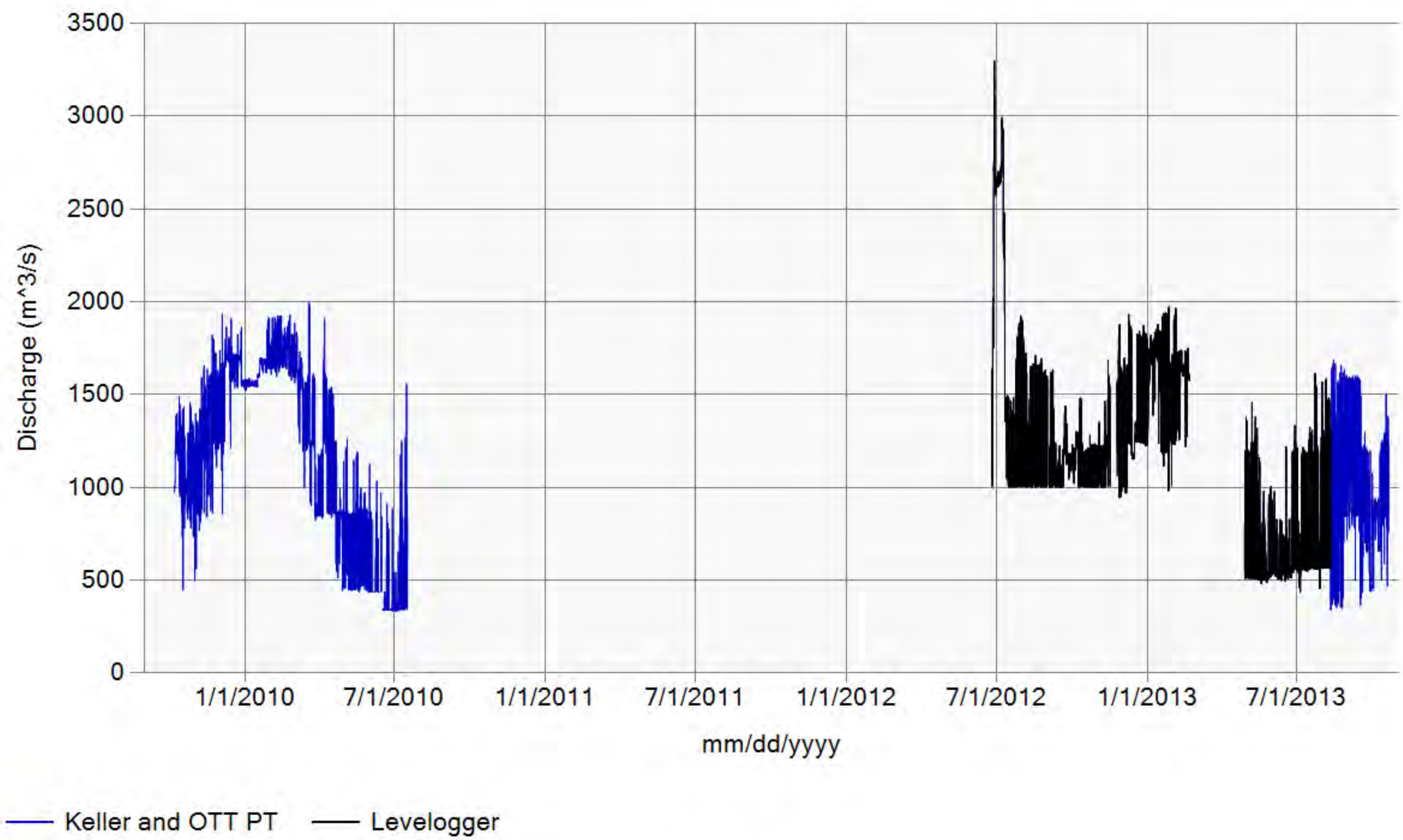


Figure 16 Peace 25 benchmark locations.

(from hydrometric station)	~~~v	~~~v
	distance	bearing
rebar 25 hm	15.0528	152.7
rebar 25b	62.5602	78.4
nhc new rebar	6.46205	312.0
new transducer	56.3813	162.8
new bolt	4.87864	52.9

Figure 17 The stage record for Peace 25. The sampling interval is 15 minutes. Gaps in the stage record are given in Table 13.

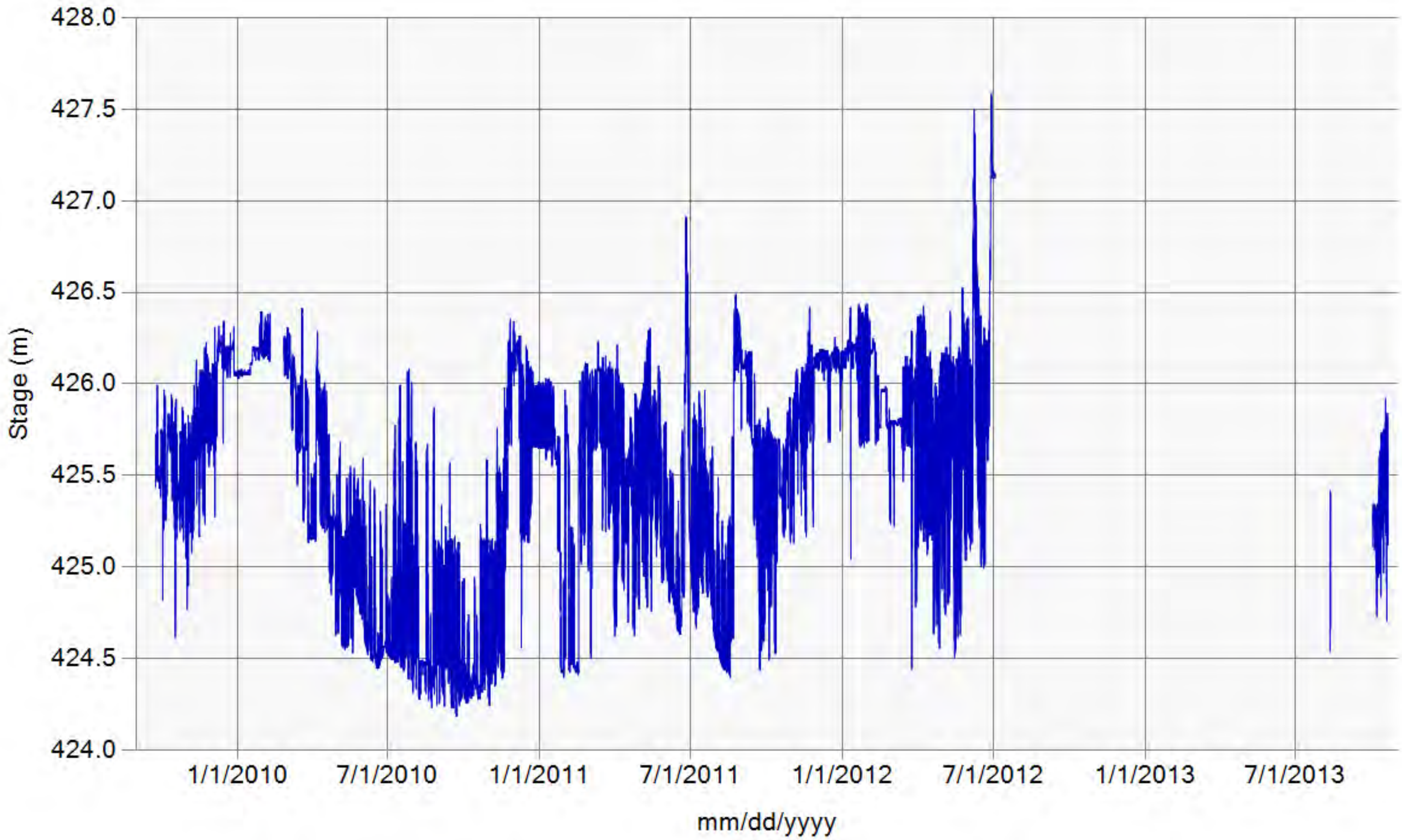


Figure 18 **The rating curve for Peace 25. Within the gauged range, the rating curve shows excellent fit (1.8% root mean square of errors) meeting RISC grade A standards (Resources Information Standards Committee, 2009), represented by a green bar below the curve. Discharge values calculated using the extrapolated portion of the rating curve (outside the highest and lowest gauged flow) are RISC Grade E, represented by grey bars below the curve. Gauged stages range from 424.296 m to 426.416 m; the current stage record ranges from 424.184 m to 427.588 m. Flow measurements collected in 2013 are shown in yellow.**

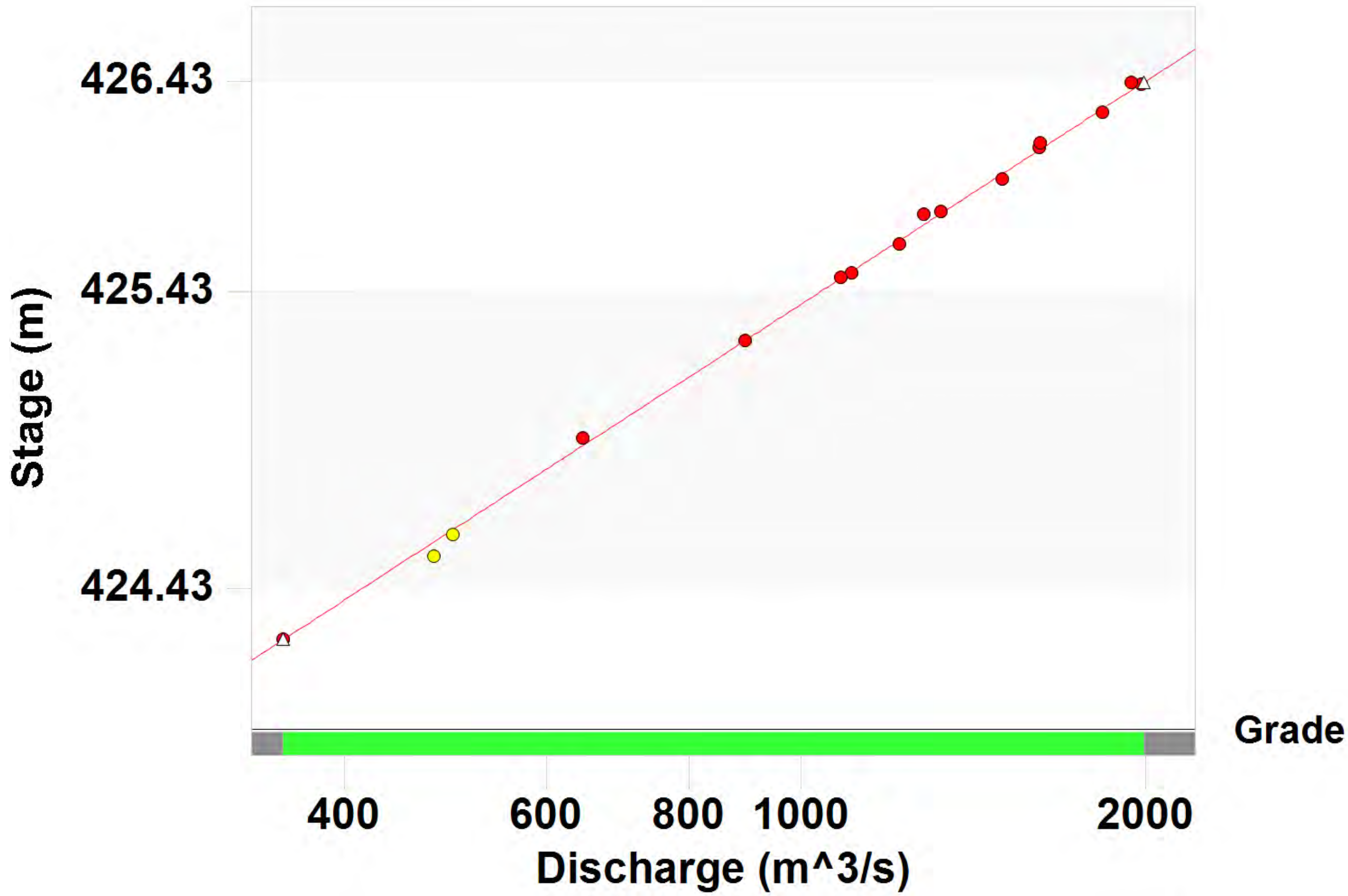


Figure 19 The discharge record for Peace 25. The sampling interval is 15 minutes. Gaps in the discharge record are given in Table 13.

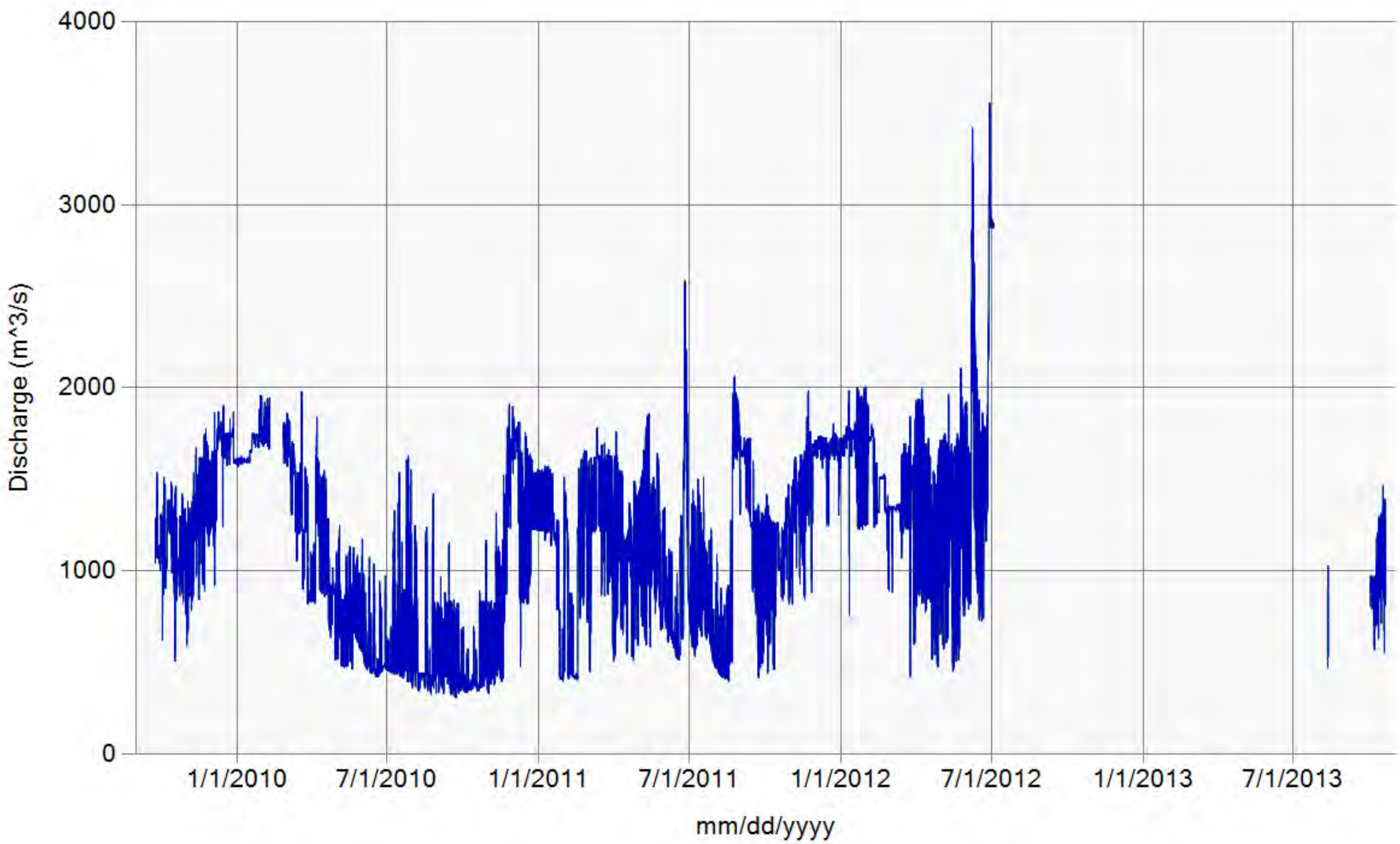


Figure 20 Peace 29 benchmark locations.

(from hydrometric station)	~~~v	~~~v
	distance	bearing
rebar29b	42.699	132.4
hm rebar	8.44803	217.0
mid hill	3.54544	204.8
up hill	1.32155	195.9
conc pad x	0.72866	109.2
bolt on square pipe	3.98829	16.1
transducer	18.9142	211.4
BM4 (approximate location!)	30.0163	122.3

Figure 21 The stage record for Peace 29. The sampling interval is 15 minutes. Gaps in the stage record are given in Table 16.

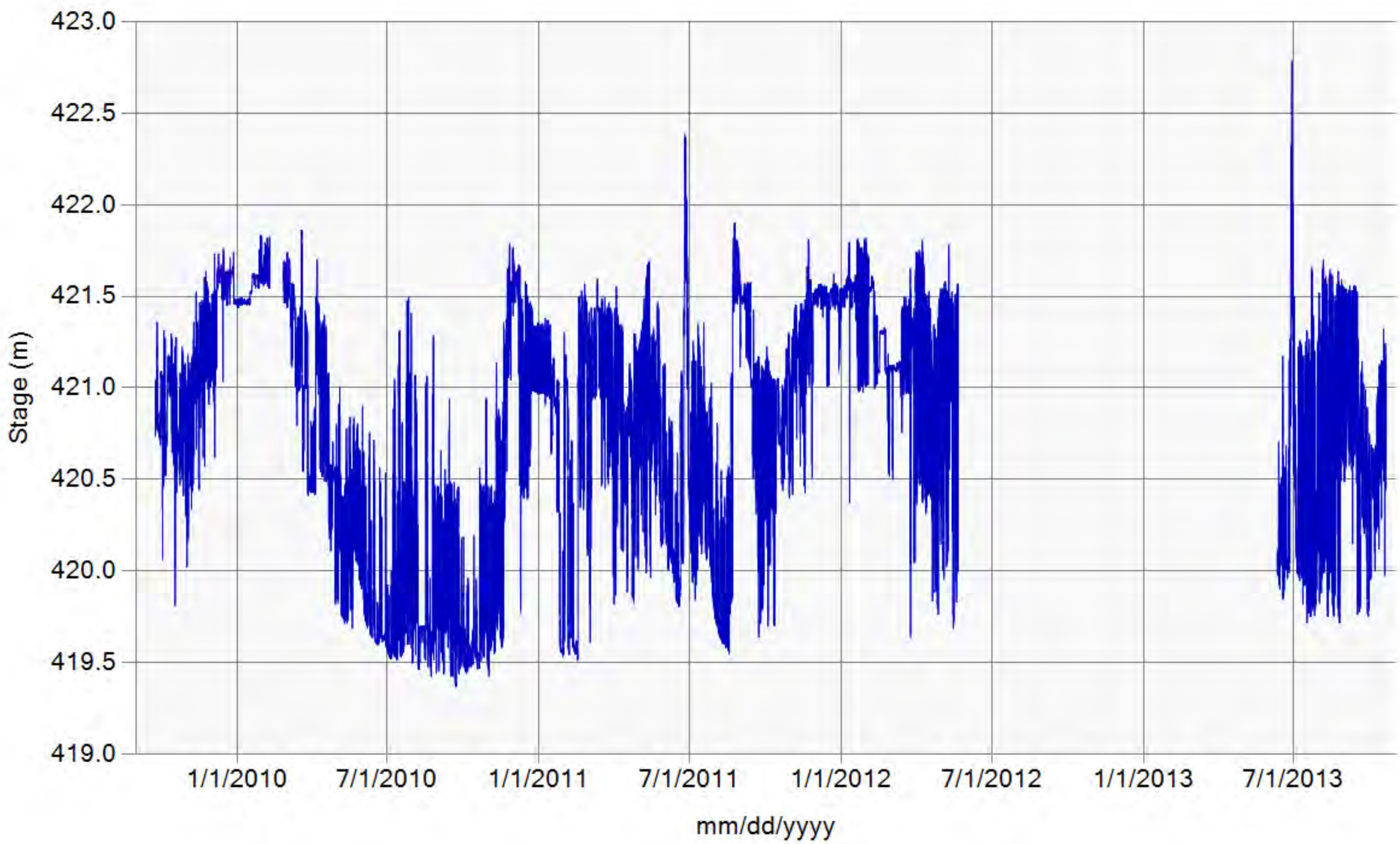


Figure 22 The rating curve for Peace 29. Within the gauged range, the rating curve shows excellent fit (1.3% root mean square of errors) meeting RISC grade A standards (Resources Information Standards Committee, 2009), represented by a green bar below the curve. Discharge values calculated using the extrapolated portion of the rating curve (outside the highest and lowest gauged flow) are RISC Grade E, represented by grey bars below the curve. Gauged stages range from 419.443 m to 421.860 m; the current stage record ranges from 419.367 m to 422.787 m. Flow measurements collected in 2013 are shown in yellow.

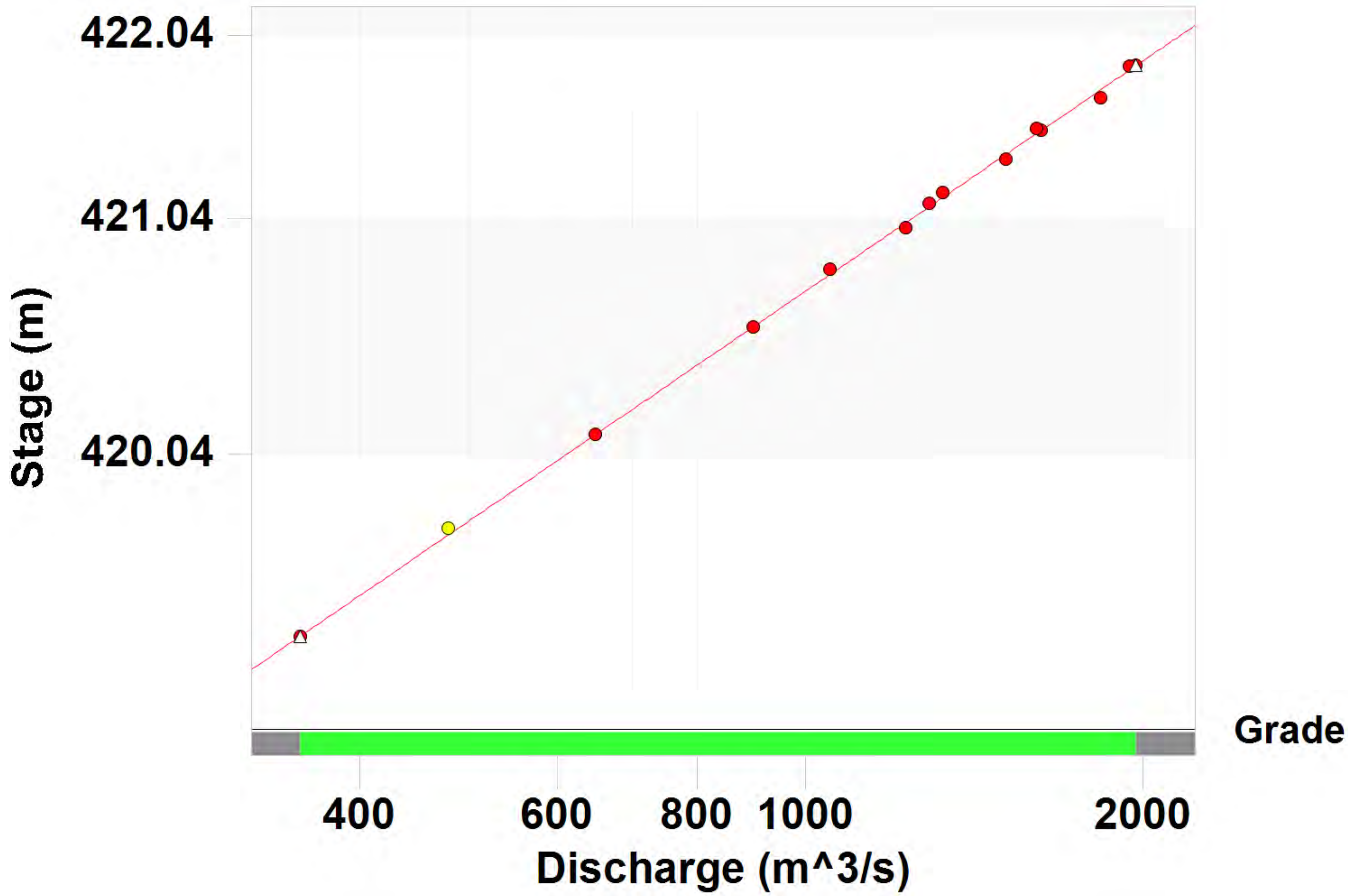


Figure 23 The discharge record for Peace 29. The sampling interval is 15 minutes. Gaps in the discharge record are given in Table 16.

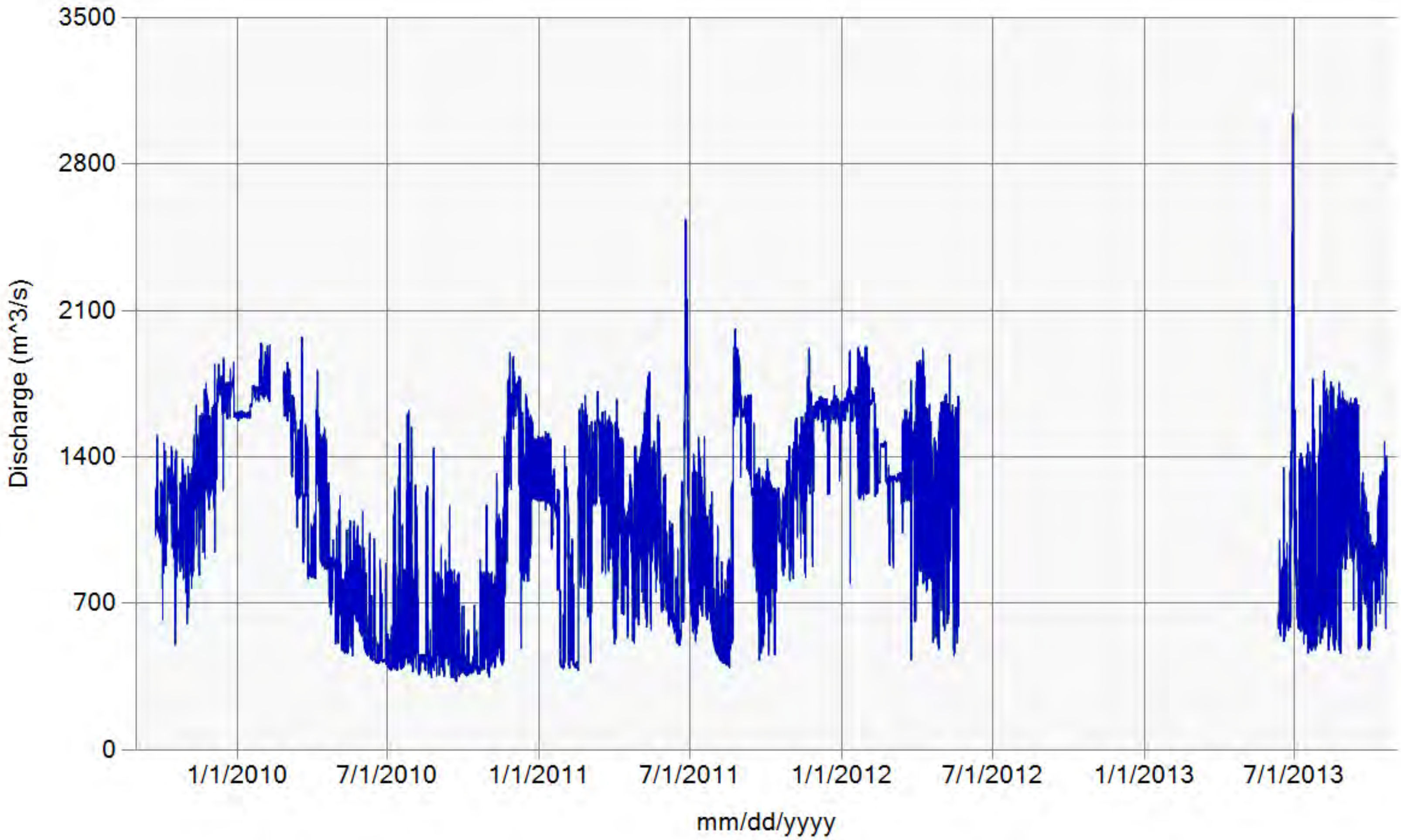


Figure 24 Peace 35a benchmark locations.

(from hydrometric station)	~~~v	~~~v
	distance	bearing
hm rebar	8.352492	184.3
transducer	24.13123	197.6
nhc new rebar	1.828533	258.3
bolt in channel	7.04651	239.9

Figure 25 The stage record for Peace 35a. The sampling interval is 15 minutes. Gaps in the stage record are given in Table 19.

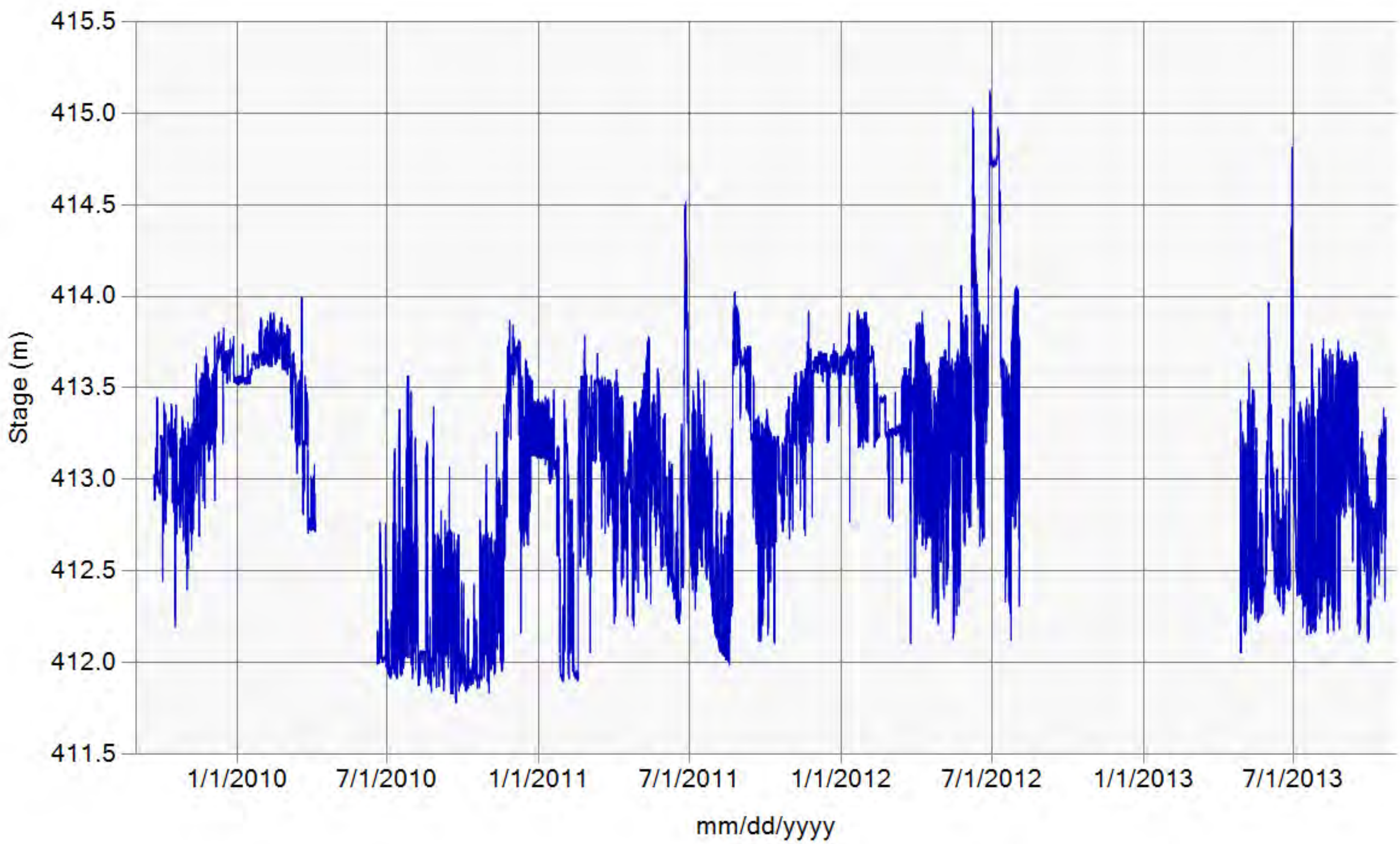


Figure 26 The rating curve for Peace 35a. Within the gauged range, the rating curve shows excellent fit (3.1% root mean square of errors) meeting RISC grade A standards (Resources Information Standards Committee, 2009), represented by a green bar below the curve. Discharge values calculated using the extrapolated portion of the rating curve (outside the highest and lowest gauged flow) are RISC Grade E, represented by grey bars below the curve. Gauged stages range from 411.869 m to 413.969 m; the current stage record ranges from 411.779 m to 415.123 m. Flow measurements collected in 2013 are shown in yellow.

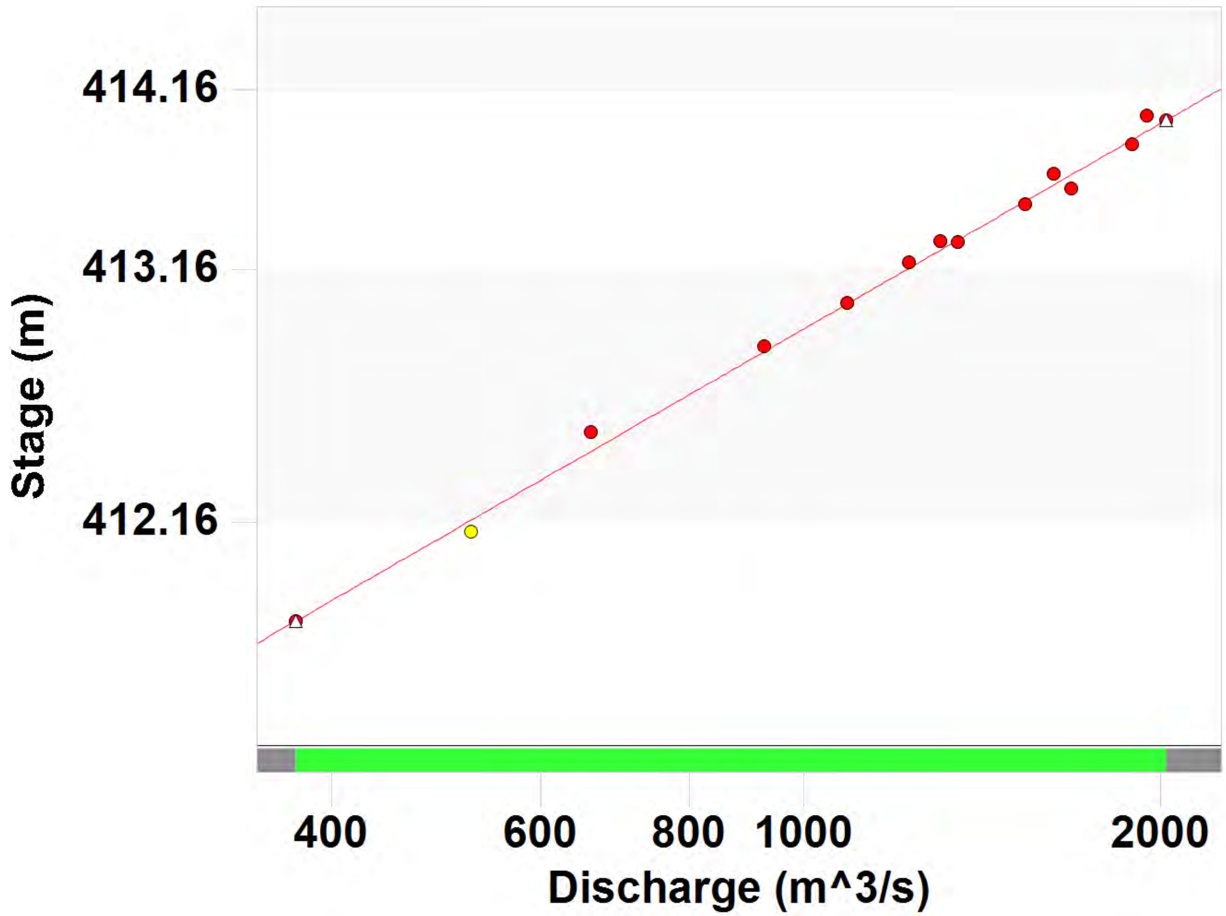


Figure 27 The discharge record for Peace 35a. The sampling interval is 15 minutes. Gaps in the discharge record are given in Table 19.