Peace Project Water Use Plan

Peace River Mainstem Stage Discharge

Implementation Year 3

Reference: GMSWORKS-6

Mainstem Stage Discharge 2014 Study

Study Period: 2014 January 1 – 2014 December 31

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PEACE PROJECT WATER USE PLAN

GMSWORKS-6 Peace River Mainstem Stage Discharge 2014 Study

BC Hydro and Power Authority
6911 Southpoint Drive
Burnaby, BC

Final Report
2015 March 17

northwest hydraulic consultants

GMSWORKS-6
PEACE RIVER MAINSTEM STAGE DISCHARGE
- 2014 STUDY -

Prepared for

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DISCLAIMER

Executive Summary

GMSWORKS-6 was initiated by BC Hydro to fulfill the recommendations of the Peace River Water Use Plan (WUP) Committee to install hydrometric gauges, 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 objective started by the Physical Works Terms of Reference (ToR) is to establish stage discharge relationships at strategic points along the Peace River to allow correlation of side channel inundation with mainstem discharge. The work plan as defined by the ToR includes surveying transects and hydrometric gauge install at five locations, develop stage-discharge relationships for each gauge covering PCN discharges of 283 to 2,000 m^3/s, and conduct maintenance and data quality checks. Monitoring of stage and discharge was initially to continue for 10 years. After initial development of the study, its duration was limited to 5 years.

The GMSWORKS-6 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. The GMSWORKS-6 2013 study (NHC, 2014) outlines quality control measured used to finalise the stage and discharge time series from installation to December 31, 2012. It also presents gauge station maintenance, data quality checks, and additional field work completed from January 1 to December 31, 2013. Stage-discharge relations (i.e. rating curves) were successfully developed for each hydrometric gauge, allowing for continuous discharge estimates. 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).

As the 2014 study, this report outlines the gauge station maintenance, data quality checks, and additional field work completed from January 1 to December 31, 2014. Following is a list of field work conducted in 2014 to support the GMSWORKS-6 program:

- Equipment maintenance was conducted on September 3 and 4, 2014 including replacement of desiccant and breather tubes. Data were also retrieved from the temporary barologger and levelogger installed at Peace 3.
- Gauge maintenance was conducted on September 3 and 4, 2014 including discharge and physical water level measurements at each of the five BC Hydro gauges.

In addition to the fieldwork, the hydrometric data from the current year were uploaded to an Aquarius database and analysed to verify data quality and the stability of the stage-discharge rating curves; that is to detect instability of the gauge station or channel.

Through analysis of the 2014 data it was determined that all five rating curves appear stable with minimal error, and that 2014 data quality exceeds Grade A standards for Peace 29 and can be confirmed through additional water level measurements at Peace 9.

With conclusion of the 2014 study, the WUP commitment has been met (5 years of monitoring). However, if the gauges are to continue to be maintained in support of other GMSWORKS and GMSMON programs, then real-time sensor at Peace 3 and 25 should be replaced and for each site, each year (including 2015) a minimum of two water level measurements should be made, one discharge measurement should be taken, and general maintenance should be conducted (desiccant replaced and batteries, breather tubes, solar panels, and sensor anchoring checked). Additional site checks and water level measurements would reduce the potential extent of data loss.

Alternatively, if the GMSWORKS-6 program is to be terminated, than the equipment can be salvaged and used for other projects.

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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 has led to deposition of sediment and vegetation encroachment. Wetted area and connectivity of side channels has subsequently decreased; which negatively 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 started by the Physical Works Terms of Reference (ToR) is to establish stage discharge relationships at strategic points along the Peace River to allow correlation of side channel inundation with mainstem discharge. The objectives include the collection of data to increase knowledge of the magnitude, timing, and rate of change in flow as well as local hydraulic response as rapid changes in flow travel 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.

Rapid changes in flow are often referred to as ramping events. Such events result from operational changes in power production or spill flow. The rate of change in flow attenuates as the flow change translates downstream; primarily through dispersion and often to a lesser extent by dilution through lateral inflow. Rapid reduction of flow can result in stranding, isolating, or dewatering of fish (particularly in side channel habitat) – potentially leading to mortality from suffocation, predation, or freezing. Such effects can be seen for large distances downstream of projects, specifically if the duration of the ramping event is long and inflows are relatively small.

The work plan as defined by the ToR includes surveying transects and hydrometric gauge install at five locations, develop stage-discharge relationships for each gauge covering PCN discharges of 283 to 2,000 m^3/s, and conduct maintenance and data quality checks.

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 (**Figure 1**). 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 2014.

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 yet been published for 2014[1]; 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**.

[1] WSC Peace River at Hudson Hope 07EF001, data published to 2012 December 31
WSC Peace River above Pine River07FA004, data published to 2011 December 31
WSC Peace River at Hudson Hope 07FD002, data published to 2011 December 31

Hydrometric station nomenclature for the GMSWORKS-6 gauges is based on nearest Peace River cross-section; survey conducted by BC Hydro and Northwest Hydraulic Consultants Ltd. (NHC). Gauges are located near cross section 3, 9, 25, 29, and 35a. Location of each station is shown in **Figure 1**. Gauges stations were generally located relative to sizable tributaries allowing approximation of inflow during steady PCN discharges and the observation of any attenuation of ramping events from the additional inflow.

Table 1 Peace River gauges downstream of PCN to Taylor

Station Name	Station No.	Distance from PCN (km)	Notes (Generally on Location Selection Rational)
Peace River at Hudson's Hope	WSC 07EF001	7.644	• Referred to here as *WSC PR-Hudson*
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	• Referred to here as *WSC PR-Pine*

Peace Project WUP GMSWORKS-5 was the development of a hydraulic model of the Peace River from PCN to the Peace River confluence with the Pine River. The model was to support other Peace River mitigation projects that address side channel habitat; such as side channel habitat restoration (GMSWORKS-3), ramping rate strategies, and to estimate the degree of side channel inundation with increasing PCN discharge. Data from GMSWORKS-6 was used to support the development, calibration, and validation of the GMSWORKS-5 model.

1.4 Scope of 2014 work

A summary of tasks completed in 2014 under GMSWORKS-6 is provided in the following subsections.

1.4.1 2014 equipment maintenance

In order to ensure the ongoing functionality of the hydrometric stations, the following equipment maintenance was completed in 2014:

- Peace 3: Downloaded the temporary levelogger and barologger
- Peace 9: Replaced desiccant and breather tube
- Peace 25: Replaced desiccant and breather tube
- Peace 29: Replaced desiccant and breather tube
- Peace 35a: Replaced desiccant, and breather tube

1.4.2 2014 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 2014:

- Collection of a minimum of one flow measurement and one water surface level survey at each hydrometric station.
- Quality review of 2014 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.

1.4.3 Reporting

Reporting includes detailed descriptions of the gauge and equipment maintenance completed in 2014. 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 and gauge 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 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 2014 equipment maintenance

Annual station maintenance involved checking the components of each station to confirm the functionality of each site, repair and replacement of other equipment as required, and where applicable, downloading and re-launching of sensors and desiccant pack replacement. A list of maintenance work completed in 2014 is given in Table 2. During the 2014 site work, it was confirmed that the sensor at Peace 25 was dislodged and lost due to ice or other floating debris and would need replacement. It was also noted that the conduit to the sensor at Peace 9 was damaged in one location but the sensor was still functioning properly.

Table 2 Summary of equipment maintenance completed in 2014

Station Name	Date	Maintenance work completed
Peace 3	2014-Sept-03	• Downloaded and re-launched temporary levelogger and barologger
Peace 9	2014-Sept-03	• Replaced desiccant in enclosure
Peace 29	2014-Sept-03	• Replaced desiccant in enclosure
Peace 35a	2014-Sept-03	• Replaced desiccant in enclosure

2.2 2014 gauge maintenance

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.

One flow measurement and one water level measurement were collected at all gauges, except Peace 25, on September 3, 2014. No measurements were taken at Peace 25 as the gauge was no longer functional. Flow release from PCN was held constant by BC Hydro for the day to limit antecedent effects on the level-discharge measurements. A summary of gauge maintenance completed in 2014 is given in **Table 3**.

Table 3 Summary of gauge maintenance completed in 2014

Station Name	Date	Maintenance work completed in 2014
Peace 3	2014-Sept-03	• Flow measurement • Level check
Peace 9	2014-Sept-03	• Flow measurement • Level check
Peace 29	2014-Sept-03	• Flow measurement • Level check
Peace 35a	2014-Sept-03	• Flow measurement • Level check

Upon review of the gauge maintenance completed in 2014 and the subsequent data, it has been noted that Peace 29 still meets Grade A standards, while the other stations are considered Grade B. Peace 9, and 35a have been changed from Grade A to B due to anomalies in the discharge and stage records at some point in the record (this will be discussed further in Section 5); a minimum of one additional water level check is therefore required at each station to meet Grade A standards. Peace 3 had lost data for most of 2014 and was therefore not graded. The grade at Peace 25 was not evaluated as the gauge is no longer functional.

3 Data quality review

The 2014 quality review considered data from January 1 to December 31, 2014. The data is transferred real-time to BC Hydro via the GOES network and provided to NHC at years end. Interim data is periodically inspected throughout the year by NHC through remote download request for each station. However, only 2 weeks of data is available through this method.

Three consistent gaps were identified within Peace 9, 29, 35a data series (March 23-24, March 24-26 and August 5-8, 2014). Additional short duration gaps noted in the Peace 9 record. These gaps are attributed to logger communication error with the GOES network and data may be available through on-site logger downloads.

The 2014 quality review of the Peace River Mainstem hydrometric data involved comparing gauge stage data with physical water level measurements, assessing the level of agreement between 2014 flow measurements and the existing stage-discharge rating curves, and comparing discharge records with those from nearby gauges (including BC Hydro and WSC gauges). Gauge comparisons were done within NHC's Aquarius database allowing visual/graphical evaluation and corrections. A system wide flow balance was developed in 2013 and compared this year again, to assist in identifying periods of lower quality data.

Graphical gauge comparisons within NHC's Aquarius database included assessing high frequency (15 minute) and daily discharge hydrographs for each of the five BC Hydro gauges on a month by month basis. This allowed identification of inconsistencies in the relation between stations. Five day moving average hydrographs were also compared as daily hydrographs included large fluctuations.

The flow balance included calculating inflows between each of the five BC Hydro gauges on a high frequency time step, as well as between the five BC Hydro gauges and two mainstem WSC gauges (WSC PR-Hudson and WSC PR-Pine) on a daily time step. 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 inflow calculations. Preliminary WSC data were used in the 2014 flow balance, as final data were not yet available.

Flow balance results were compared with past flow balances and have been deemed acceptable for 2014's initial data review but additional examination should be completed when published WSC data becomes available.

3.1 Flow Balance

The 2014 flow balance involved calculating inflows between subsequent gauges to help verify and assess the confidence in adjacent data records. The flow balance as developed in 2013 can also be used to quantify inflows. The 2014 flow balance considered following reaches:

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

It should be noted that in the 2013 analysis, Peace 25 was compared to Peace 9 and to Peace 29. However, the Peace 25 gauge was dislodged by ice flows, or other debris, on January 13, 2014. The available 2014 data spans a period of two weeks and suggests that a shift occurred between

October 20, 2013 and January 1, 2014; the shift was not quantified. Due to the limited duration of available data and the unknown shift, Peace 25 was not included in the 2014 flow balance. Additionally, the 2014 flow balance compared Peace 29 to WSC PR-Pine instead of Peace 35a due to the large uncertainty noted in the 35a record; this is discussed further in Section 3.2.4

Gauge by gauge comparisons and inflows could only be calculated for periods with data overlap. Periods of missing data are identified in the attached tables for each gauge (**Table 7**, **Table 10**, **Table 13, Table 16** and **Table 19**). **Table 4** presents the percent of data coverage within the 2014 period for each of the BC Hydro and WSC gauges.

Table 4 BC Hydro and WSC gauge record length and percent data coverage for 2014

Station Name	Start Date	End Date	% Data coverage	Drainage Area (km^2)
WSC PR-Hudson	2014-Jan-01	2014-Dec-30	91	73,100
Peace 3	2014-Jan-01	2014-Mar-26	23	73,493
Peace 9	2014-Jan-01	2015-Jan-01	89	74,289
WSC Halfway	2014-Jan-01	2014-Oct-31	78	9,340
Peace 25	2014-Jan-01	2014-Jan-13*	3*	83,976
Peace 29	2014-Jan-01	2015-Jan-01	97	84,932
Peace 35a	2014-Jan-01	2015-Jan-01	97	95,174
WSC Moberly	2014-Jan-01	2014-Dec-30	99	1,520
WSC PR-Pine	2014-Jan-01	2014-Dec-30	94	87,200
Calculated Inflows				
Peace 3 – WSC PR-Hudson	2014-Jan-01	2014-Mar-26	23	393
Peace 9 – Peace 3	2014-Jan-01	2014-Mar-22	19	796
Peace 29 – Peace 9 – WSC Halfway	2014-Jan-01	2014-Oct-31	67	1,303
Peace 35 – Peace 29	2014-Jan-01	2014-Dec-31	97	242
WSC PR-Pine - Peace 29 - WSC Moberly	2014-Jan-01	2011-Dec-30	81	748

*gauge was dislodged on January 13, 2014

Variability in calculated inflows can be the result of ramping as well as tributary inflow. 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. The distance between gauges leads to varying lag times and flow dispersion/attenuation as ramping events translate downstream. It is not practical to consistently and accurately account for variations in lag time and dispersion or attenuation.

An average lag time was approximated and used to align timing of flow records despite the variance in lag time with discharge. Errors in applied lag times can lead to negative inflow between gauges, generally of short duration and/or small magnitude. The error associated with using an average lag time diminishes as the sample period increases, such as for daily flow records.

Throughout the reach there are a number of tributaries, two of which are gauged by WSC (Halfway River and Moberly River). Ungauged tributary inflow between Peace River hydrometric stations is generally less than 1% of the mainstem flow and is not expected to substantially influence the flow balance. Similar to the work done in 2013, ungauged tributary inflow was not explicitly calculated during this study. The following table (**Table 5**) provides an approximation of tributary inflow[2]. 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[2] ($l/s/km^2$)	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

3.2 2014 Data

Inflows were calculated on a daily and high frequency time step between January 1 and December 31, 2014. 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, a 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. Shifts were accounted for where possible and remaining periods of instability were removed.

[2] Inflow unit runoff based on KPL 2011

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

Peace 3 is 10.1 km downstream of the WSC PR-Hudson gauge with a 393 km^2 (0.5%) increase in contributing watershed area. Lynx Creek (288 km^2) [3] is the only major tributary between the two gauges. Due to limited data coverage at Peace 3, only 23% of the record could be used in this comparison, from January 1 to March 26, 2014. Daily hydrographs from WSC PR-Hudson and Peace 3 track well visually but the calculated discharge at Peace 3 was consistently lower than the discharge measured at Hudson, resulting in negative daily inflows throughout the record; the calculated daily inflows ranged from -79 to -8 m^3/s (-12 to -1% of Peace 3 flows **Figure 2**). Infrequent and short duration negative inflows were expected as a result of attenuation of flow changes between the gauges, but calculated inflow should be positive for the majority of the record. As comparison, in 2013, the calculated inflows ranged from -121 to 283 m^3/s with negative inflows calculated for 1.6% of the record.

The consistently negative inflows for the 2014 record may be a result of an imprecise offset applied to the stage record. Offsets are applied to each stage record to adjust sensor readings to geodetic water levels. The initial surveyed water level measurement, collected on August 11, 2013 when the temporary loggers were initially installed, was collected during a period of rapid stage change (0.8 cm/min), increasing the uncertainty in the offset. However, the negative inflows only exceeded 10% of the Peace 3 discharge for 2% of the record. Considering the contributing watershed increase within this reach is less than 1%, the uncertainty in this reach is within the expected tolerance for error.

3.2.2 Peace 3 to Peace 9 reach

Peace 9 is 12.6 km downstream of Peace 3 with a 796 km^2 (1%) increase in contributing watershed area. Farrell Creek (617 km^2)[3] is the only major tributary between the two gauges. Limited data coverage at Peace 3 constrains the assessment of inflows between the two gauges; data are available for both gauges for 19% of the time between January 1 and March 3, 2014 (**Table 4**). The daily and high frequency hydrographs from Peace 3 and Peace 9 track well, with rapid changes in flow attenuated between Peace 3 and Peace 9.

Calculated daily inflows between Peace 3 and Peace 9 ranged from -4 to 50.57 m^3/s (0 - 6% of Peace 9 flows, **Figure 3**) while calculated high frequency inflows ranged from -321 to 410 m^3/s (-23 to 30% of Peace 9 flows). Negative daily inflows were calculated 2.9% of the time throughout the record, with no occurrences of negative inflows exceeding 10% of the mainstem flow. Positive daily inflows did not exceed 6% of the river discharge. The uncertainty in this reach is within the expected tolerance for error.

The Peace 9 record shifted between October 20, 2013 and January 1, 2014 and returned to, or close to, the original position on April 23, 2014. The shift was approximated using the available data and an offset was applied to the stage record to account for it. The shift approximation and possible causes are discussed in Section 3.2.3

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

3.2.3 Peace 9 to Peace 29 reach

Peace 29 is 35.1 km downstream of Peace 9 with a 10,643 km^2 (13%) increase in contributing watershed area. Halfway River (9,389 km^2)[3] and Cache Creek (904 km^2)[3] are the only major tributaries between the two gauges. 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 (**Table 4**) constrains the assessment of inflows at this reach to 67% of the record. Overlapped hydrographs show flow attenuation between Peace 9 and 29, with lower and broader peaks observed at Peace 29.

As mentioned in Section 3.2.2, a shift was noted in the Peace 9 record between October 20, 2013 and January 1, 2014, which was then righted on April 23, 2014. The cause of this shift is unknown but it could possibly be attributed to sensor drift, ice cover or jams, ice in the breather tube, or sand in the sensor orifice. The magnitude of the shift was estimated to be 0.10 m through comparison of the stage and discharge records at Peace 9 and 29. An offset correction, of -0.10 m was therefore applied to the Peace 9 record from January 1 to April 23, 2014.

The calculated daily inflows between Peace 9 and 29, accounting for Halfway River, ranged from -157 to 227 m^3/s (-25 to 20% of the discharge at Peace 29 **Figure 4**). Negative values were seen 42% of the time, with negative values exceeding 10% of the mainstem discharge 6% of the time. Although the occurrence of large negative inflows (<-10%) is more frequent for this reach than others, they can be attributed to the added uncertainty in lag time and additional attenuation associated with the longer reach length between these two gauges.

3.2.4 Peace 29 to Peace 35a reach

Peace 35a is 16.5 km downstream of Peace 29 with a 242 km^2 (0.3%) 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 daily and high frequency hydrographs show attenuation of flow changes between Peace 29 and 35a, with lower and broader peaks at 35a, but large differences in the overall relationship between the gauges are noted throughout the record; this was further observed in the flow balance analysis for this reach.

Calculated daily inflows ranged from -193 to 144 m^3/s (-24 to 21% of the discharge at Peace 35a **Figure 5**), while high frequency inflows ranged from -216 to 274 m^3/s (-23 to 25% of the discharge at Peace 35a). Negative values were noted 55% of the time in the daily record, and 57% for the high frequency record. Considering the increase in contributing watershed area is only 0.3% for this reach of the Peace River, negative inflows are not expected to the magnitude observed (coupled with large positive inflows).

Further inspection of the inflow record for this reach (**Figure 5**) shows a distinct trend; inflows begin 2014 being notably negative but move to be more positive until July, where the inflows begin drifting towards negative values again. This movement of the inflow record suggests a continually shifting discharge record at Peace 29 or 35a; as this movement was not noted between Peace 29 and Peace 9, this has been attributed to Peace 35a. Without further inspection of the Peace 35a gauge, the cause of this shifting cannot be determined but it is likely the result of sensor drift. The Peace 35a record should be used with caution and has been prescribed an uncertainty +/- 25%.

3.2.5 Peace 29 to WSC PR-Pine reach

WSC PR-Pine is 27.7 km downstream of Peace 29 with a 2,268 km2 (3%) increase in contributing watershed area. Moberly River (1,851 km2), Wilder Creek (100 km2), and Tea Creek (32 km2) are the major tributaries between the gauges. There is a WSC gauge located on Moberly River approximately 31 km upstream of its confluence with the Peace River (1,520 km2).

Comparison of overlapped hydrographs show flow change attenuation between Peace 29 and WSC PR-Pine. An apparent shift took place on February 7, 2014 at WSC PR-Pine; before this time the record appears to be too low. During winter conditions, ice cover (and pressurised flow), ice jams, and or ice floes are frequent causes of problems at hydrometric stations. It has been assumed that the observed shift was the result of adverse conditions during the winter months, which were then righted in early February; therefore data before February 8, 2014 was not included in this comparison. The 2014 WSC PR-Pine discharge record is preliminary and the assumption noted above can be re-evaluated when finalized data becomes available.

The calculated daily inflows, accounting for inflows from Moberly River, range from -125 to 398 m3/s (-26 to 23% of the discharge at WSC PR-Pine **Figure 6**). Negative daily inflows were noted 21% of the time, exceeding 10% of the discharge in the mainstem 5% of the time. As was with the Peace 9 to Peace 29 reach, considerable negative inflows (<-10% of the mainstem) occurred with-in this reach more than other reaches but this has also been attributed to the extended reach length between Peace 29 and WSC PR-Pine. As a result, the uncertainty within this reach is within the expected level of error.

3.2.6 Summary of 2014 data review and flow balance

Analysis of the 2014 data record indicates the Peace 29 discharge series uncertainty is less than or equal to 5%. The Peace 9 discharge series uncertainty is expected to be less than or equal to 5% after April 23, 2014, however an additional physical water level measurement is required to confirm this. Before April 23, 2014 an offset correction was approximated using discharge and stage records downstream; it is expected that the uncertainty in this portion of the Peace 9 record is also less than or equal to 5% but it should be used with caution. Peace 35a appears to be experiencing significant and continual sensor drift. Multiple physical water level measurements should be used to confirm sensor position and drift. The sensor should also be physically inspected during low water level to ensure it is securely anchored. The Peace 3 discharge series requires the collection of additional data before its uncertainty can be determined. Peace 25 sensor was lost near the beginning of 2014 and no data has been collected at this location since then.

4 Station history and stage-discharge relationships

4.1 Peace 3

4.1.1 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 these loggers were downloaded on September 3, 2014, but the barologger's and levelogger's memories filled on April 26, 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 7.**

4.1.2 Data summary and rating curve development

The current Peace 3 stage time series extends from September 3, 2009 to March 27, 2014 (**Figure 8**), No data is available between March 27 and September 3, 2014 due to the loggers' memory being filled. The logger was redeployed on September 3, 2014 and the remaining 2014 data will be available after the next manual download. Gaps are detailed in **Table 7**. Data from August 11, 2013 to March 27, 2014 have been compared to one surveyed water level elevation.

Seventeen discharge measurements have been collected at Peace 3, covering a range of flow 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 445.085 m to 448.273 m (calculated as 284 to 3,184 m^3/s). The rating curve is shown in **Figure 9** 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 (2.3% root mean square of errors). The final stage-discharge relation for Peace 3 is as follows:

$$Q(S) = 238.050(S - 443.980)^{1.780}$$

The multiplier shown above is slightly different than the relation presented at the end of 2013, this is due to documentation error in the 2013 report. The above equation was used in both the 2013 and 2014 study.

The calculated discharge record using the above equation and the Peace 3 stage record is shown in **Figure 10**.

4.2 Peace 9

4.2.1 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.

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 at time of install prevented installation of the temporary levelogger at a site fully connected with all levels of Peace River Mainstem flows. On 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 next 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. Between October 20, 2013 and January 1, 2014 the stage record drifted by 0.1 m and then corrected on April 23, 2014; the cause of this record shift cannot be confirmed but it is possibly attributed to ice cover or ice jams, ice in the breather tube, sand in the sensor orifice, or sensor drift. The current sensor elevation was confirmed using surveyed water levels measured from September 3, 2014. Stage data between January 1 and April 23, 2014 have been corrected with a -0.1 m offset. 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 11**.

4.2.2 Data summary and rating curve development

The current Peace 9 stage time series extends from October 6, 2009 to December 31, 2014 with several data gaps (**Figure 12**). The data gaps in 2014 appear to be attributed to logger communication error with the GOES system. Gaps are detailed in **Table 10.**

Sixteen discharge measurements have been collected at Peace 9, covering a range of flow 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 436.178 m to 439.800 m (calculated as 324 to 3,299 m^3/s). The rating curve is shown in **Figure 13** 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 (2.1% root mean square of errors). The stage-discharge relation for Peace 9 has not changed in 2014 and 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 14**.

4.3 Peace 25

4.3.1 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. The transducer was replaced with an OTT August 11, 2013, and the battery and solar panel were replaced on August 12, 2013. Between October 20, 2013 and January 1, 2014, shifts in the data were noted. On January 13, 2014 the sensor was dislodged by ice flows or other floating debris. There are no available data for Peace 25 since that time. 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 15**.

4.3.2 Data summary and rating curve development

The current Peace 25 stage time series extends from September 23, 2009 to January 13, 2014 with three data gaps (**Figure 16**) including February 8, 2010 to February 25, 2010 (16 days of gauge instability), and July 3, 2012 to October 2, 2013 (456 days of logger malfunction). Gaps are detailed in **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 3,558 m^3/s). The rating curve is shown in **Figure 17** 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 25 has not changed in 2014 and is as follows:

$$Q(S) = 85.997(S - 422.430)^{2.270}$$

Calculated discharge record based on the above equation and the Peace 25 stage record is shown in **Figure 18**.

4.4 Peace 29

4.4.1 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. 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 19**.

4.4.2 Data summary and rating curve development

The current Peace 29 stage time series extends from September 23, 2009 to December 31, 2014 with six data gaps (**Figure 20**). The three data gaps in 2014 attributed to logger communication error with the GOES system as well as previous gaps, are detailed in **Table 16**.

Fifteen 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 3,044 m^3/s). The rating curve is shown in **Figure 21** 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 has not changed in 2014 and is as follows:

$$Q(S) = 40.722(S - 417.040)^{2.467}$$

The calculated discharge record and the Peace 29 stage record is shown in **Figure 22**.

4.5 Peace 35a

4.5.1 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. Between October 20, 2013 and January 1, 2014 the data experienced some drifting and continued to drift throughout the 2014 record. 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**); locations are shown in **Figure 23**.

4.5.2 Data summary and rating curve development

The current Peace 35a stage time series extends from September 21, 2009 to December 31, 2014, with six data gaps (**Figure 24**). Data gaps are detailed in **Table 19**.

Fifteen 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 25** 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 (3.0% root mean square of errors). The final stage-discharge relation for Peace 35a has not changed in 2014 and is as follows:

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

The calculated discharge record and the Peace 35a stage record is shown in **Figure 26**.

5 Summary and Recommendations

Through the analysis it was determined that all 5 rating curves appear stable with minimal error, and that 2014 data quality exceeds Grade A standards for Peace 29 and can be confirmed through additional water level measurements at Peace 9.

Initiation of GMSWORKS-6 led to the installation of 5 gauges on the Peace River Mainstem between PCN and the Pine River in early fall 2009. Initially, the stations were to be maintained for 10 years. The allocated budget did not 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 5 discharge measurements and 2 water level checks conducted annually until a stable rating curve can be developed. After which 1 discharge measurement and water level check is required per year as long as the station and channel remain stable. Due to the required level of effort associated with RISC Grade A standards to maintain the program, its duration was reduced from 10 to 5 years.

Between July 2009 and March 2010, 10 to 12 discharge measurements were taken at each gauge station and stage-discharge rating curves/relations 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 continued through 2014 (Year 5 of the program).

As part of the 2014 work, the detailed review and system wide flow balance initially completed in 2013 was extended using data from January 1 and December 31, 2014 from the five BC Hydro gauges. This analysis was used to identify instability and assess data quality. A manually downloaded levelogger is collecting data at Peace 3 and will require further physical water level measurements to improve confidence and quality of the data. Peace 25 sensor was lost early in 2014; potentially dislodged by ice or debris. Peace 35a appears to be experiencing continual sensor drift and the data has been prescribed an uncertainty of +/- 25%.

If the program is to continue through 2015, it is recommended that the sensors at Peace 3 and 25 are replaced, a minimum of two water level measurements are made at each site, one discharge measurement is made at each site, and general maintenance is conducted at each site (desiccant is replaced and batteries, breather tubes, solar panels, and sensor anchoring is checked). It is also recommended that the sensor at Peace 35a be tested for sensor drift and if confirmed, the sensor be replaced. Additional site checks and water level measurements at all sites would reduce the potential extent of data loss.

The hydraulic model (GMSWORKS-5), collected level and flow data (GMSWORKS-6), and previously identified side channel habitat (GMSWORKS-3) can be used to improve past evaluations of side channel inundation or isolation from mainstem flow and local response of flow ramping at various discharges on side channel habitats. Additional survey, model refinement, and potentially development of site specific 2D models will generally be needed to confirm specific side channel hydraulic 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 operational tests would be beneficial. Additional leveloggers temporarily installed at high value habitat sites should be considered to supplement data collection if such a test program is implemented.

6 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	0.00	N	Temporary levelogger installed
2014-Sept-03	Y	N/A	Y	Temporary levelogger and barologger downloaded and re-launched

Table 7 Summary of Peace 3 data gaps.

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
2013-May-04 14:15	2013-Aug-11 13:30	2375	99	Sensor failed

Note: 2010-June-16, the sensor was lowered to prevent further stranding

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
2014-Sept-03 11:00	445.400	417	-6.21	-27.6
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
2014-Sept-03	Y	0.03	Y	

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-28 19:25	1612	67.2	Logger memory full
2013-Oct-06 04:58	2013-Oct-07 15:13	34	1.4	Communication error
2013-Oct-07 16:58	2013-Oct-07 18:13	1	0.1	Communication error
2013-Oct-07 19:58	2013-Oct-08 00:13	4	0.2	Communication error
2013-Oct-08 12:58	2013-Oct-09 16:13	3	0.1	Communication error
2013-Oct-09 07:58	2013-Oct-09 19:13	11	0.5	Communication error
2013-Oct-10 16:58	2013-Oct-10 19:13	2	0.1	Communication error
2013-Oct-14 10:58	2013-Oct-14 12:13	1	0.1	Communication error

From time	To time	Hours affected	Days affected	Notes
2013-Oct-15 00:58	2013-Oct-15 03:13	2	0.1	Communication error
2013-Oct-15 04:58	2013-Oct-15 09:13	4	0.2	Communication error
2013-Oct-16 11:58	2013-Oct-16 13:13	1	0.1	Communication error
2013-Oct-17 16:58	2013-Oct-17 18:13	1	0.1	Communication error
2013-Oct-18 11:58	2013-Oct-18 13:13	1	0.1	Communication error
2013-Oct-18 18:58	2013-Oct-18 23:13	4	0.2	Communication error
2013-Oct-19 00:58	2013-Oct-19 06:13	5	0.2	Communication error
2013-Oct-19 07:58	2013-Oct-19 11:13	3	0.1	Communication error
2013-Oct-19 17:58	2013-Oct-19 21:13	3	0.1	Communication error
2013-Oct-20 09:58	2013-Oct-20 13:13	3	0.1	Communication error
2013-Oct-20 16:58	2014-Jan-01 00:00	1735	72.3	Data not yet received
2014-Jan-23 13:45	2014-Jan-23 23:00	9	0.4	Communication error
2014-Jan-24 00:45	2014-Jan-24 08:00	7	0.3	Communication error
2014-Feb-06 08:45	2014-Feb-06 12:00	3	0.1	Communication error
2014-Feb-25 08:45	2014-Feb-25 13:00	4	0.2	Communication error
2014-Mar-04 10:45	2014-Mar-04 13:00	2	0.1	Communication error
2014-Mar-06 07:45	2014-Mar-06 13:00	5	0.2	Communication error
2014-Mar-15 07:45	2014-Mar-15 12:00	4	0.2	Communication error
2014-Mar-16 15:45	2014-Mar-16 19:00	3	0.1	Communication error
2014-Mar-17 06:45	2014-Mar-17 12:00	5	0.2	Communication error
2014-Mar-18 08:45	2014-Mar-18 22:00	13	0.6	Communication error
2014-Mar-19 13:45	2014-Mar-20 03:00	13	0.6	Communication error
2014-Mar-23 10:45	2014-Mar-24 14:00	27	1.1	Communication error
2014-Mar-24 15:45	2014-Mar-26 16:00	48	2.0	Communication error
2014-Mar-27 07:45	2014-Mar-27 14:00	6	0.3	Communication error
2014-Mar-28 07:45	2014-Mar-28 13:00	5	0.2	Communication error
2014-Mar-30 07:45	2014-Mar-30 13:00	5	0.2	Communication error
2014-Apr-02 07:45	2014-Apr-02 11:00	3	0.1	Communication error
2014-Apr-05 18:45	2014-Apr-05 22:00	3	0.1	Communication error
2014-Apr-06 19:45	2014-Apr-06 22:00	2	0.1	Communication error
2014-Apr-10 23:45	2014-Apr-11 07:00	7	0.3	Communication error
2014-Apr-15 03:45	2014-Apr-15 08:00	4	0.2	Communication error
2014-Apr-15 10:45	2014-Apr-15 14:00	3	0.1	Communication error
2014-Apr-22 17:45	2014-Apr-23 06:00	12	0.5	Communication error
2014-Apr-23 07:45	2014-Apr-23 15:00	7	0.3	Communication error

From time	To time	Hours affected	Days affected	Notes
2014-Apr-26 18:45	2014-Apr-27 08:00	13	0.6	Communication error
2014-Aug-05 22:45	2014-Aug-10 21:00	118	4.9	Communication error
2014-Sept-24 18:45	2014-Sept-24 23:00	4	0.2	Communication error
2014-Sept-26 04:45	2014-Sept-26 08:00	3	0.1	Communication error
2014-Oct-13 13:45	2014-Oct-13 19:00	5	0.2	Communication error
2014-Nov-05 16:45	2014-Nov-05 19:00	2	0.1	Communication error

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
2014-Sept-03 15:00	436.447	434.476	3.5	14.7
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
2014-Sep-03	N	N/A	N	Confirmed sensor was dislodged

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
2013-Oct-20 16:58	2014-Jan-01 00:00	1735	72.3	Data not yet received

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
2014-Sept-03	Y	-0.03	Y	

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
2013-Oct-20 16:58	2014-Jan-01 00:00	1735	72.3	Data not yet received
2014-Mar-23 10:45	2014-Mar-24 14:00	27	1.1	Communication error
2014-Mar-24 15:45	2014-Mar-26 16:00	48	2.0	Communication error
2014-Aug-05 22:45	2014-Aug-10 21:00	118	4.9	Communication error

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
2014-Sep-03 15:31	419.619	424	0.5	2.1
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	
2014-Sep-03	Y	-0.08	Y	

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
2013-Oct-20 16:58	2014-Jan-01 00:00	1735	72.3	Data not yet received
2014-Mar-23 10:45	2014-Mar-24 14:00	27	1.1	Communication error
2014-Mar-24 15:45	2014-Mar-26 16:00	48	2.0	Communication error
2014-Aug-05 22:45	2014-Aug-10 21:00	118	4.9	Communication error

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
2014-Sep-03 16:32	412.010	448	1.54	6.81
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 (UTM Zone 10 NAD 83, based on RTK Survey Grade GPS)

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

Figure 1 Gauge location map with tributary watersheds.

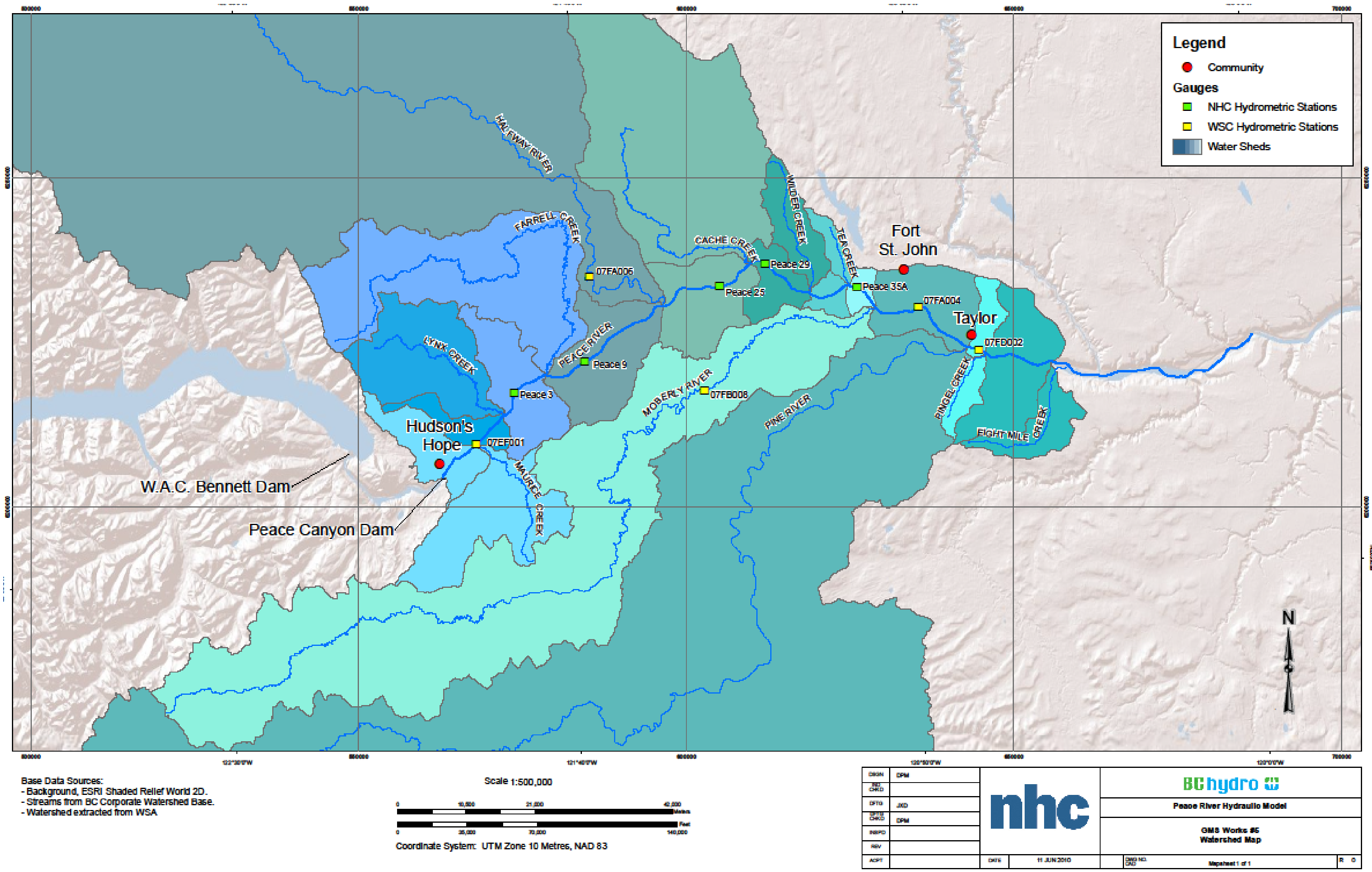

Figure 2 **Calculated daily inflows between WSC PR-Hudson and Peace 3 from October 1, 2009 to March 27, 2014 as a percent of WSC PR-Hudson and Peace 3 flows.**

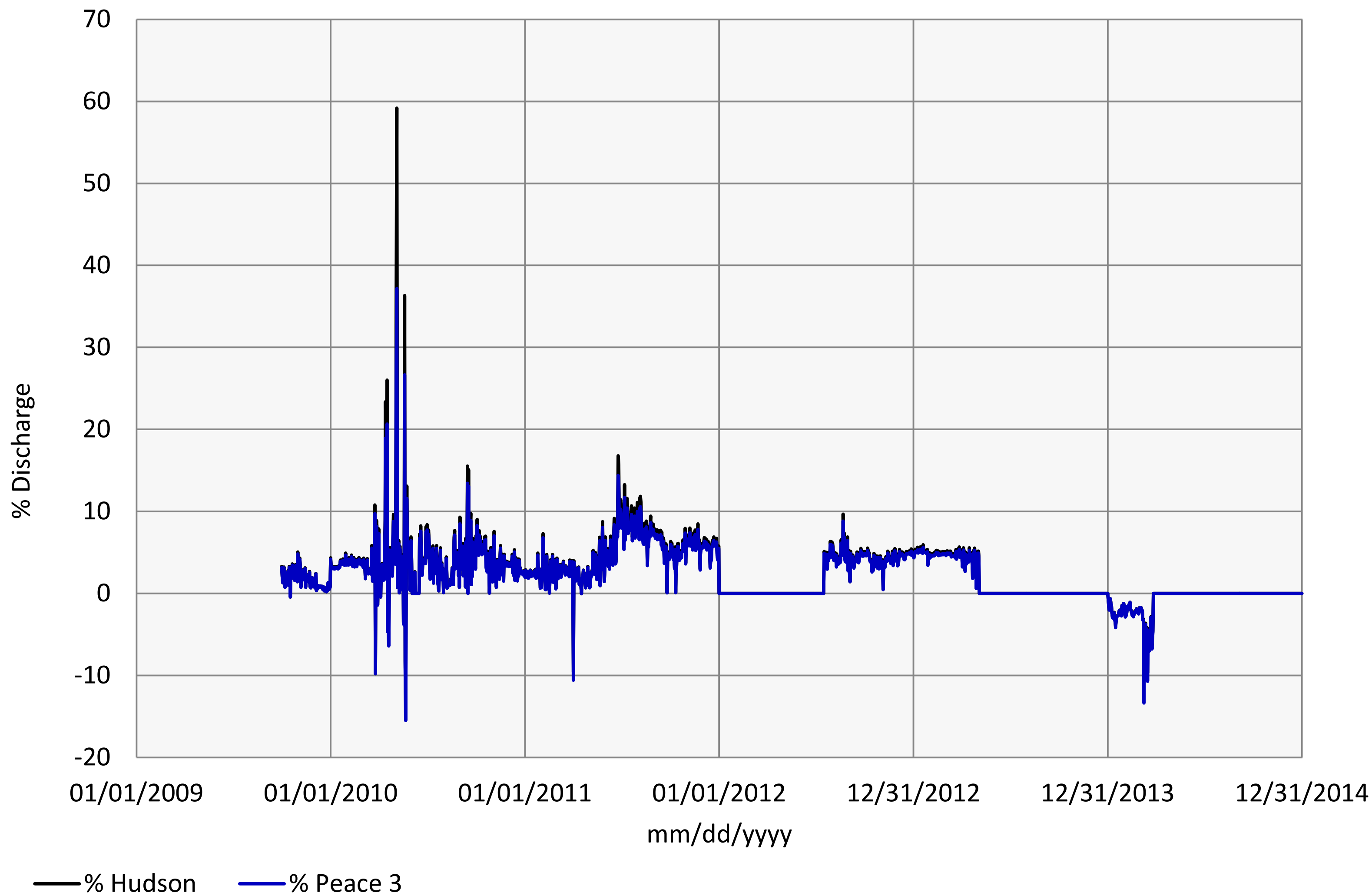

Figure 3 Calculated daily inflows between Peace 9 and Peace 3 from October 7, 2009 to March 22, 2014 as a percent of Peace 9 and Peace 3 flows.

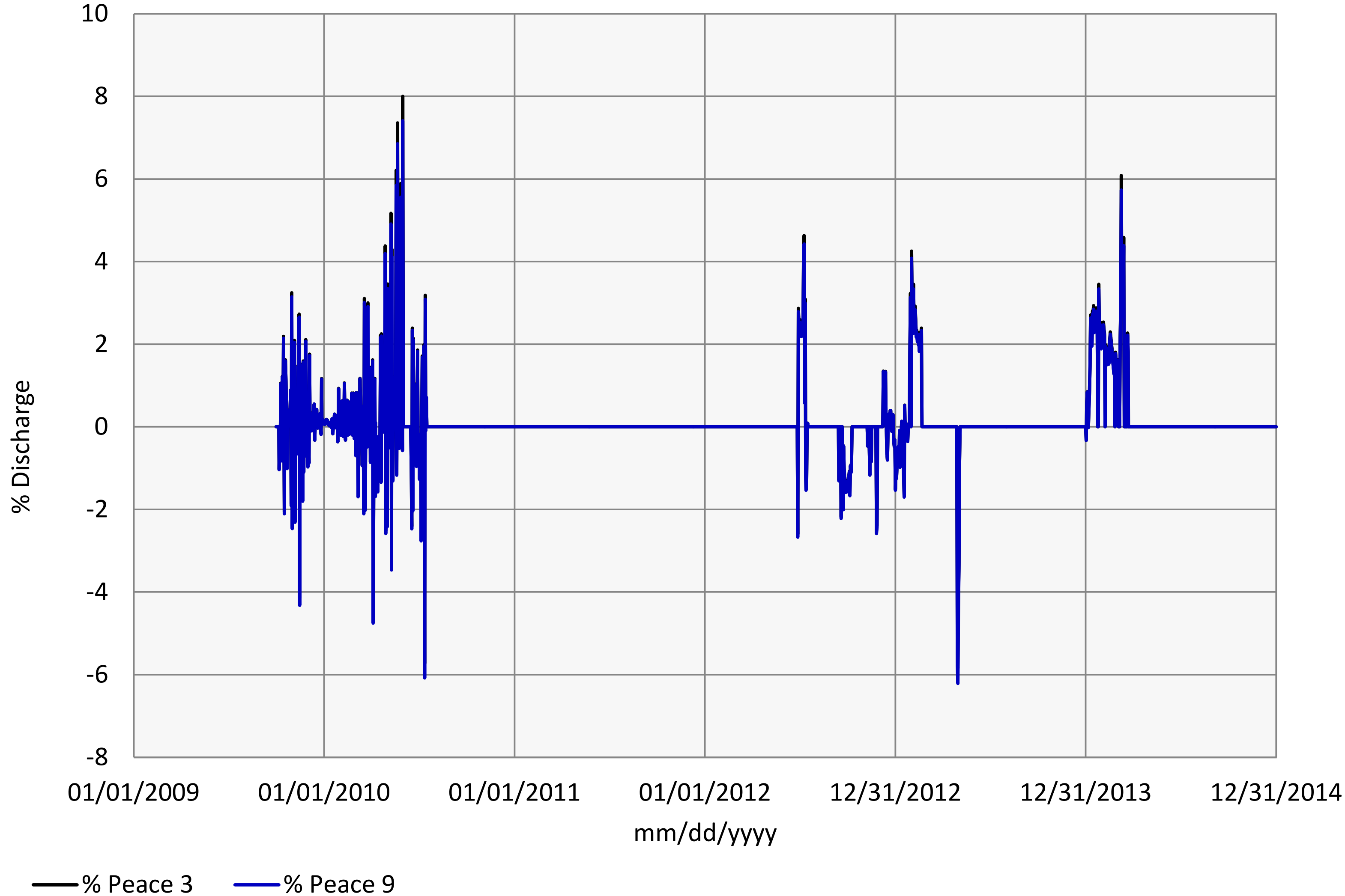

Figure 4 **Calculated daily inflows between Peace 29 and Peace 9 from October 7, 2009 to October 31, 2014 as percentage of Peace 29 and Peace 9, plus WSC Halfway River, flows.**

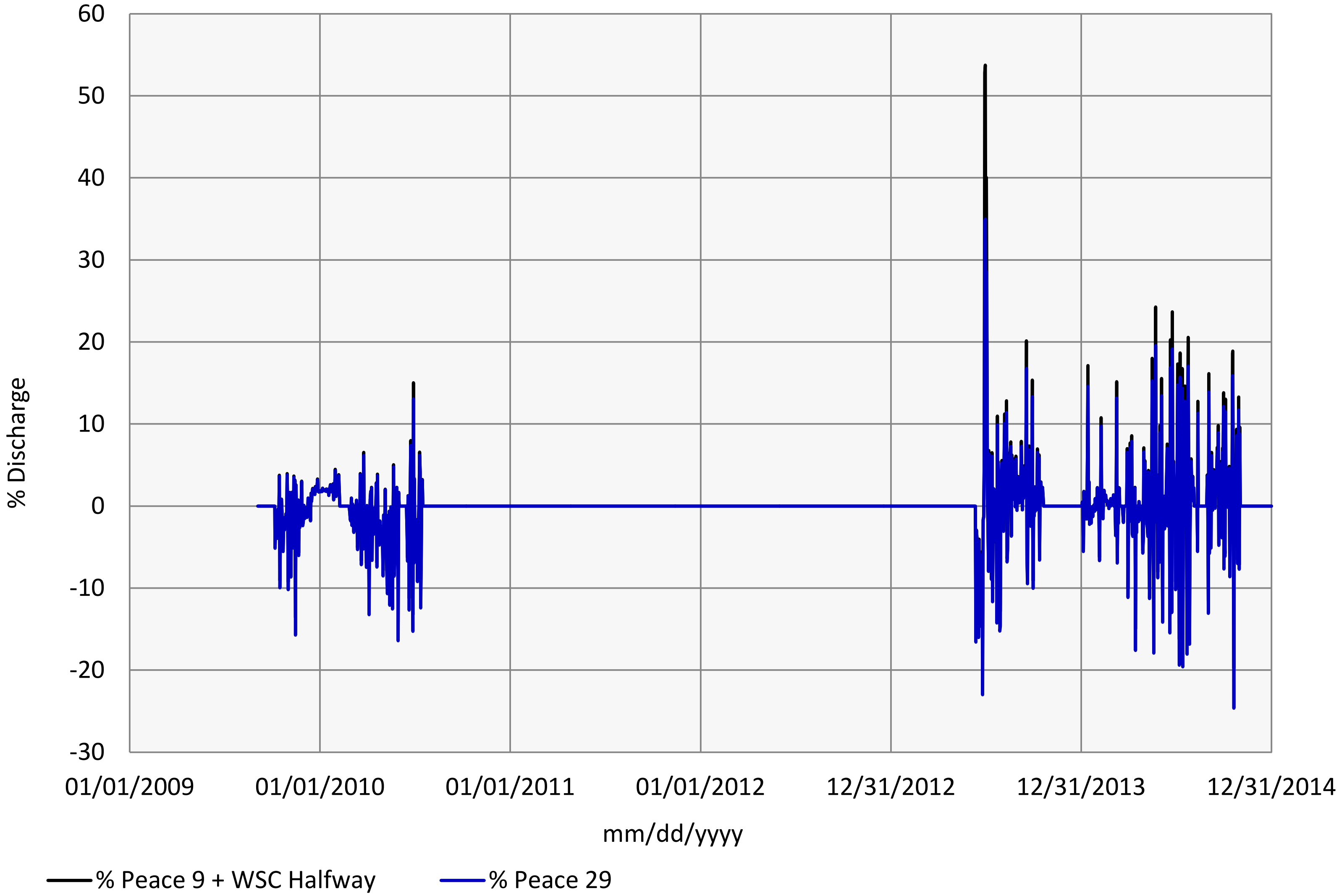

Figure 5 **Calculated daily inflows between Peace 35a and Peace 29 from September 24, 2009 to December 31, 2014 as percentages of Peace 35a and Peace 29 flows.**

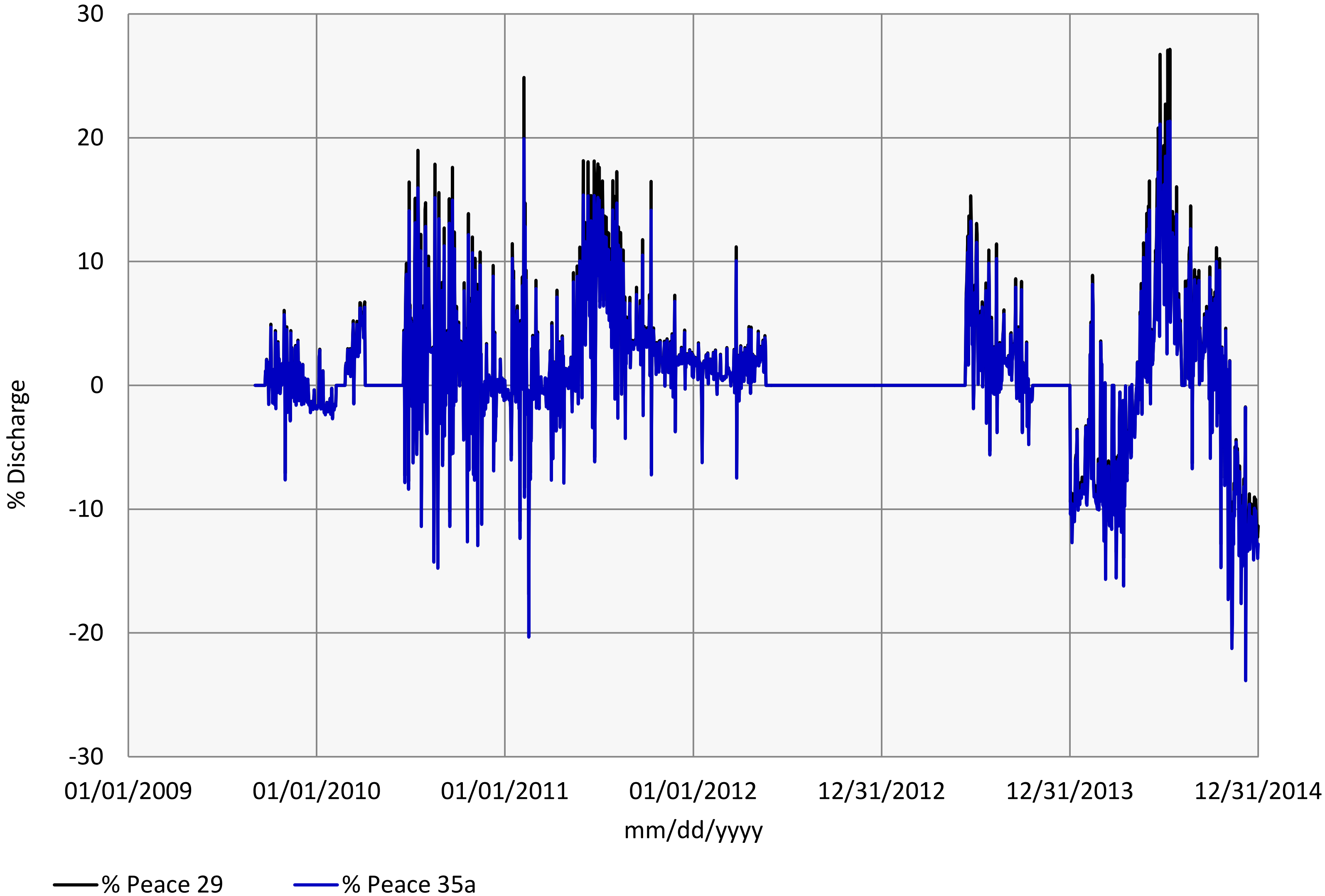

Figure 6 Calculated daily inflows between WSC Pine and Peace 29 from September 24, 2009 to December 30, 2014 as percentages of WSC Pine and Peace 29, plus WSC Moberly River, flows.

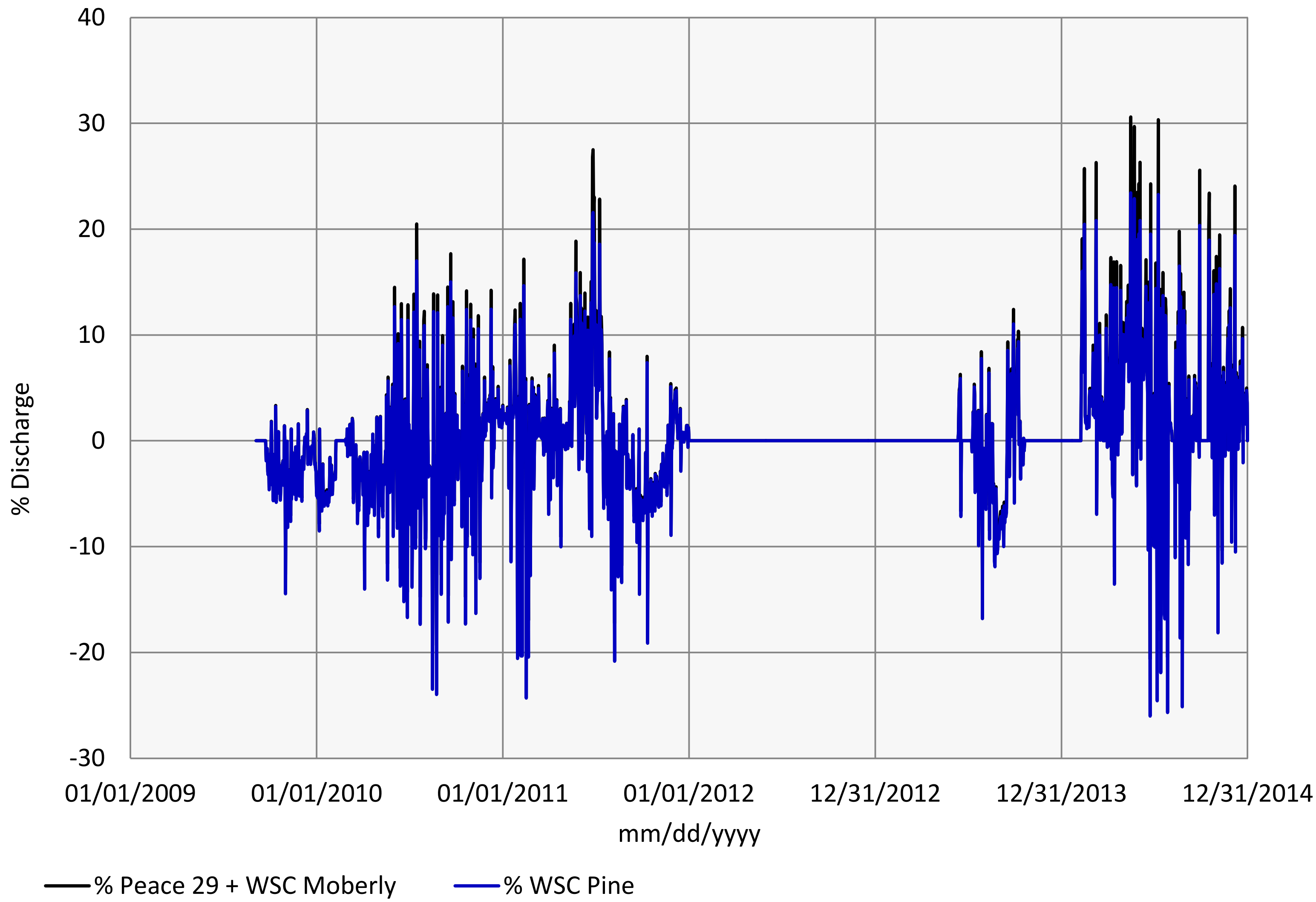

Figure 7 Peace 3 benchmark locations.

(from hydrometric station)		
	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 8 The 2014 stage record for Peace 3. The sampling interval is 5 minutes. Gaps in the stage record are detailed in Table 7.

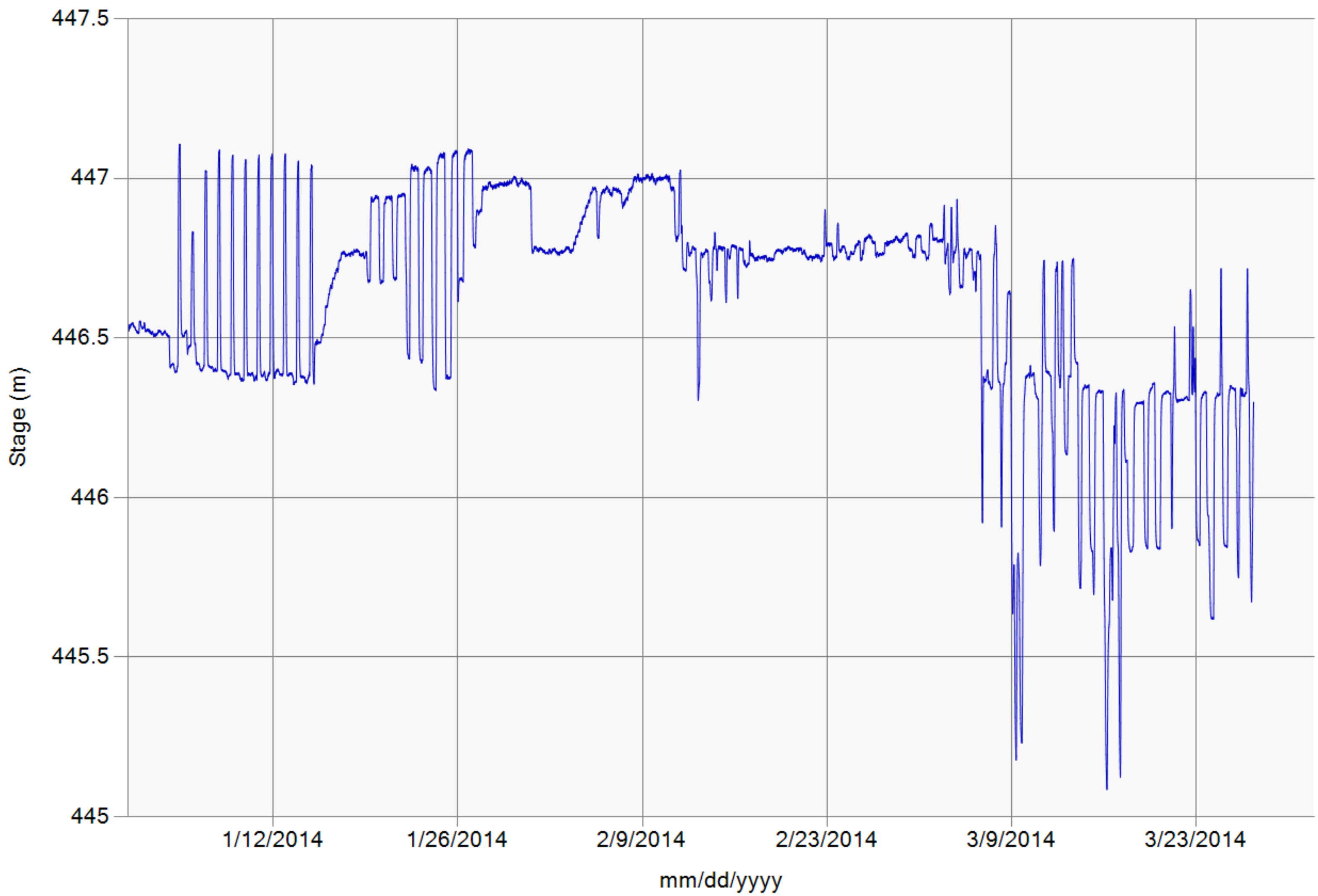

Figure 9 The rating curve for Peace 3. Within the gauged range, the rating curve shows excellent fit (2.3% root mean square of errors) meeting RISC grade A standards (Resources Information Standards Committee, 2009), represented by a green bar below the curve. Discharge values calculated using the extrapolated 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 445.159 m to 447.259 m; the current stage record ranges from 445.085 m to 448.273 m. The flow measurement collected in 2014 is shown in yellow.

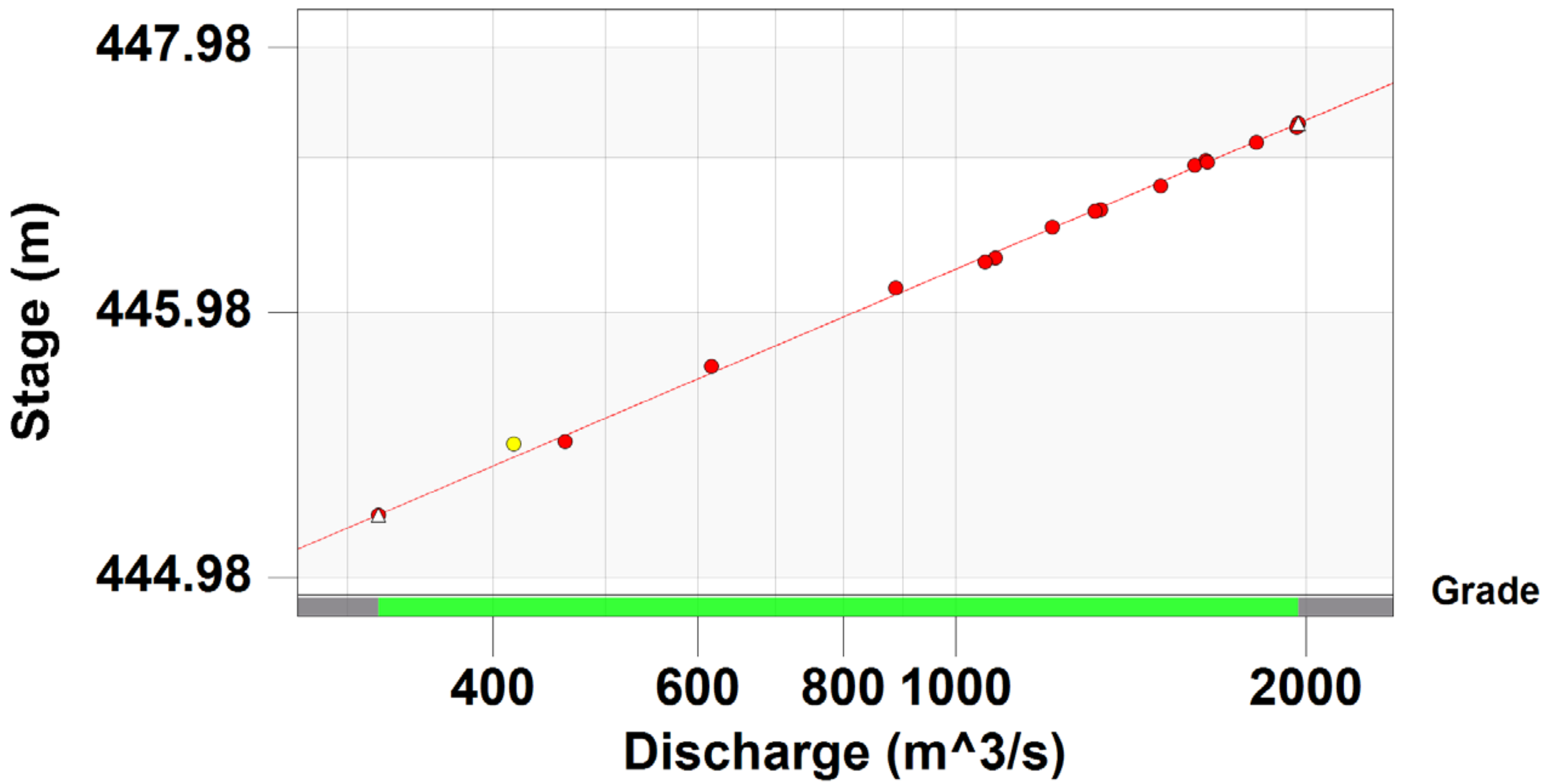

Figure 10 The 2014 discharge record for Peace 3. The sampling interval is 5 minutes. Gaps in the discharge record are given in Table 7.

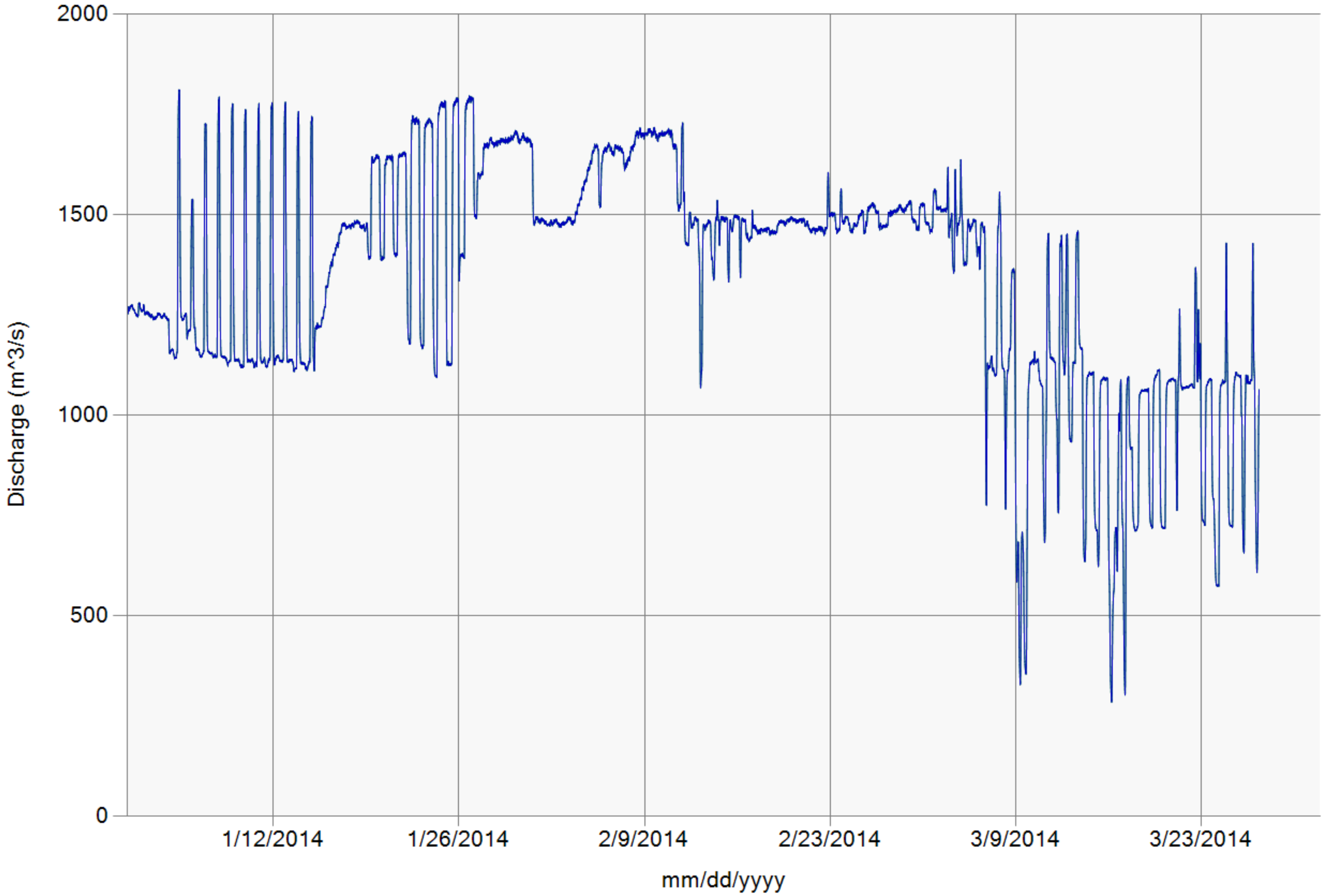

Figure 11 Peace 9 benchmark locations.

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

Figure 12 The 2014 stage record for Peace 9. The sampling interval is 15 minutes. Gaps in the stage record are given in Table 10.

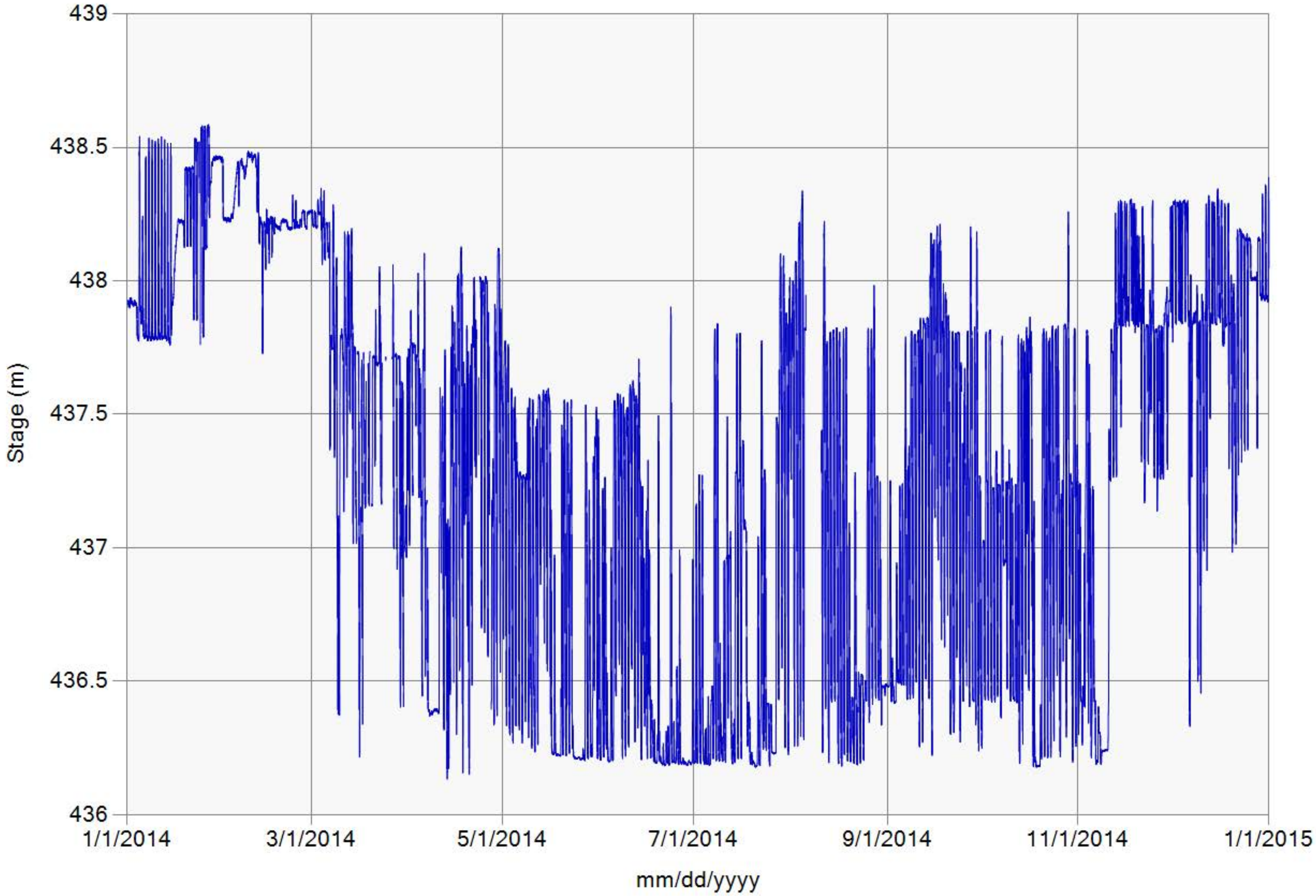

Figure 13 The rating curve for Peace 9. Within the gauged range, the rating curve shows excellent fit (2.1% root mean square of errors) meeting RISC grade A standards (Resources Information Standards Committee, 2009), represented by a green bar below the curve. Discharge values calculated using the extrapolated 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 436.163 m to 438.709 m; the current stage record ranges from 436.178 m to 439.800 m. The flow measurement collected in 2014 is shown in yellow.

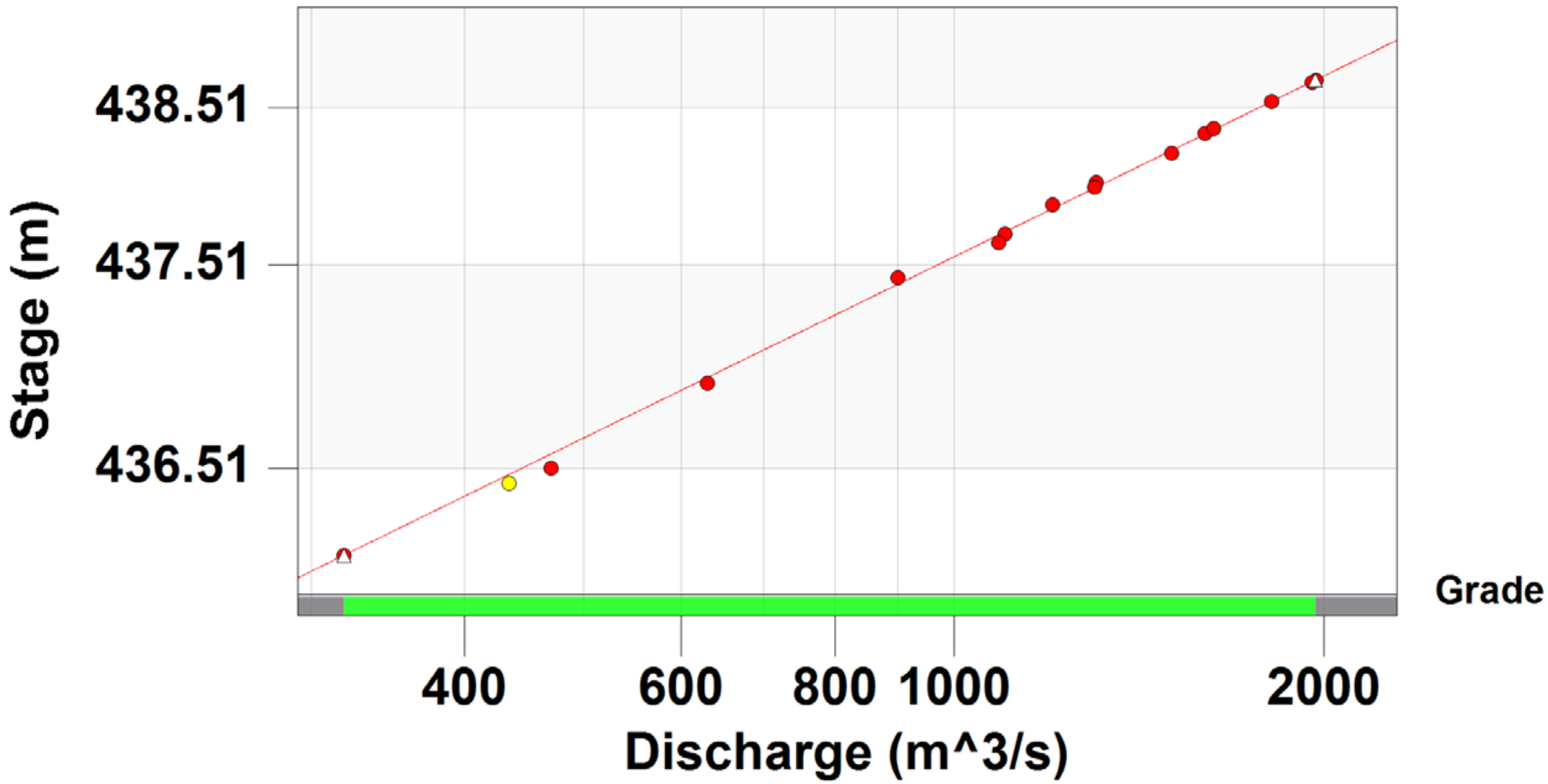

Figure 14 The 2014 discharge record for Peace 9. The sampling interval is 15 minutes. Gaps in the discharge record are given in Table 10.

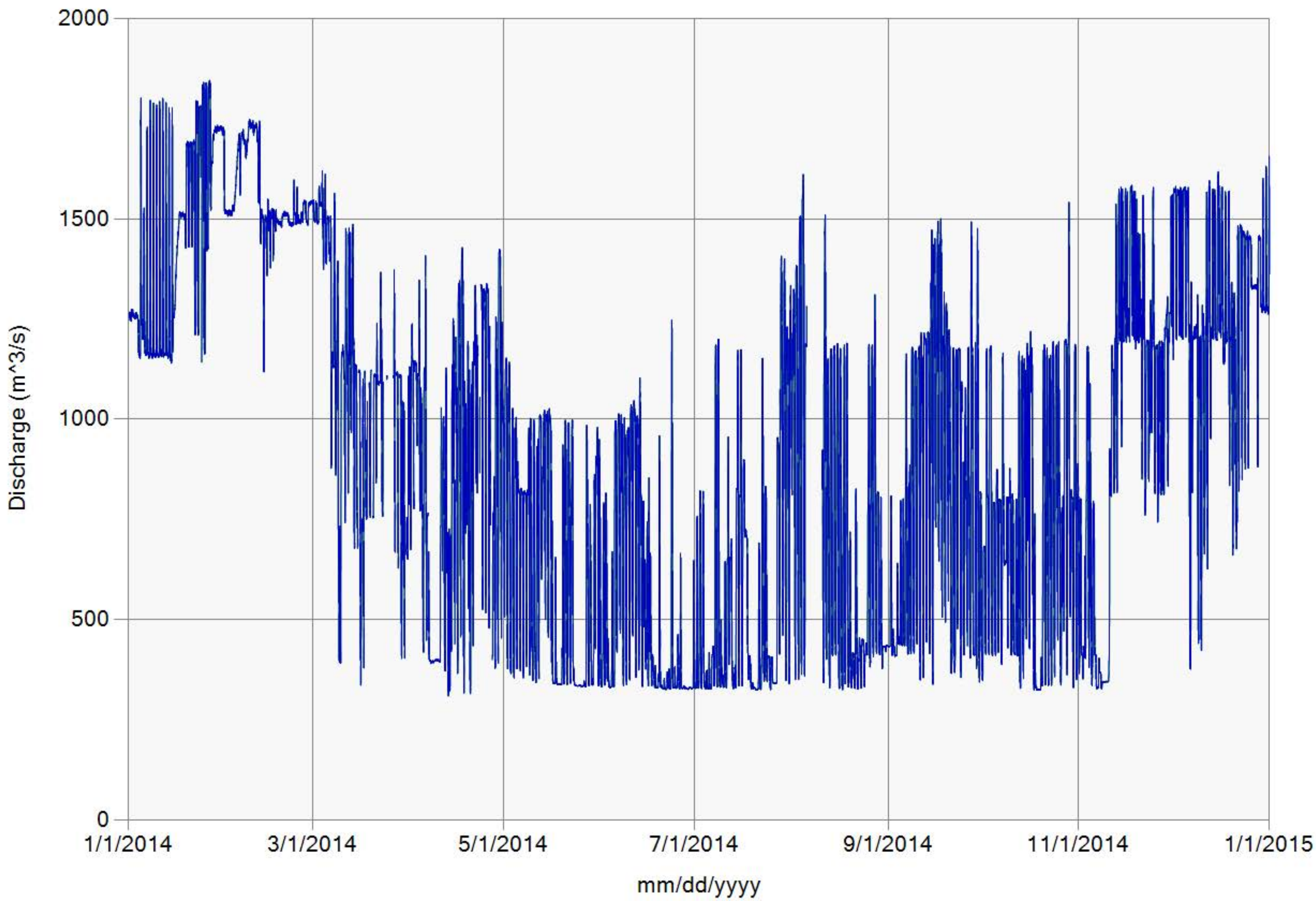

Figure 15 Peace 25 benchmark locations.

(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 16 The 2014 stage record for Peace 25. The sampling interval is 15 minutes. Gaps in the stage record are given in Table 13.

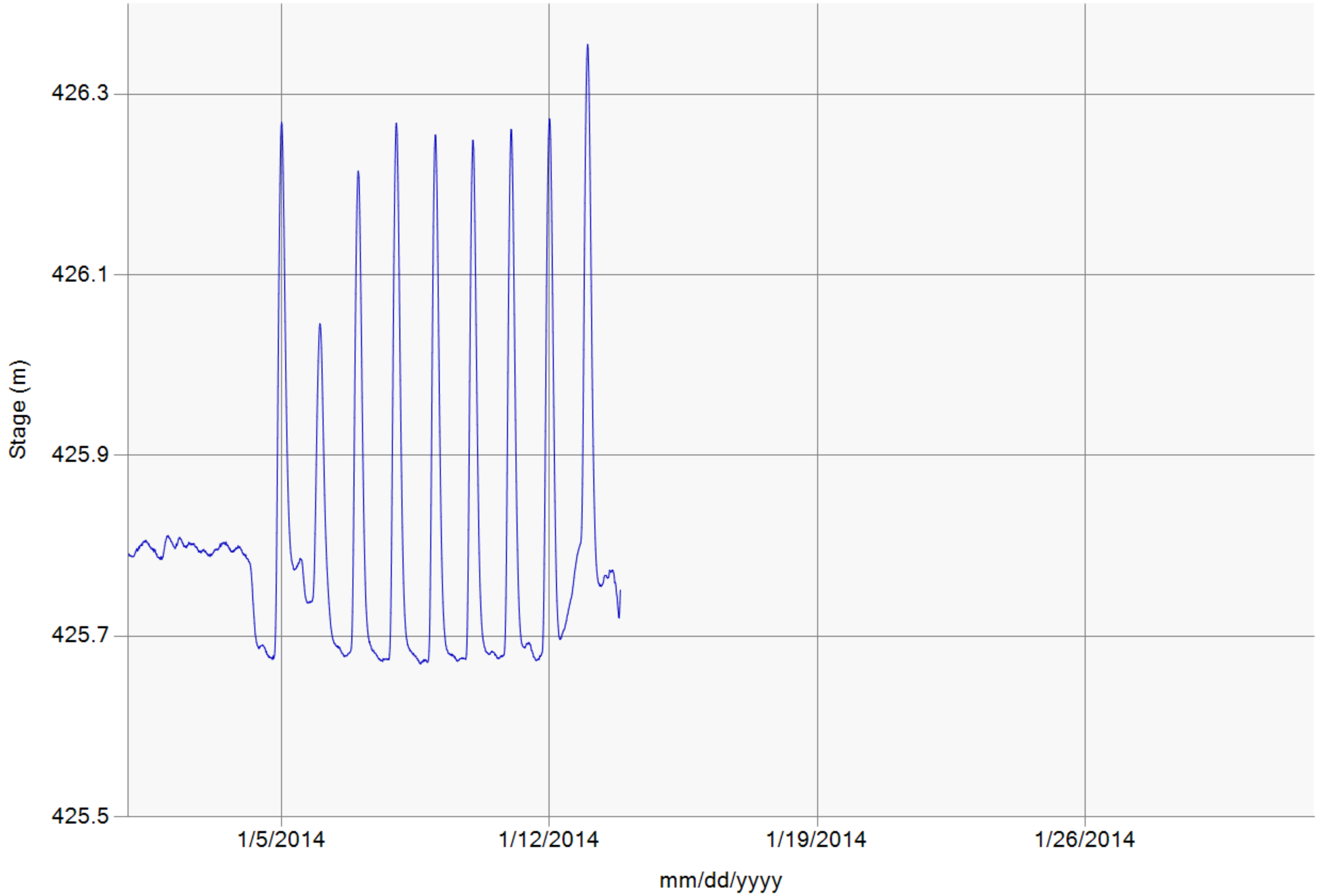

Figure 17 The rating curve for Peace 25. Within the gauged range, the rating curve shows excellent fit (1.8% root mean square of errors) meeting RISC grade A standards (Resources Information Standards Committee, 2009), represented by a green bar below the curve. Discharge values calculated using the 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. No flow measurements were collected in 2014.

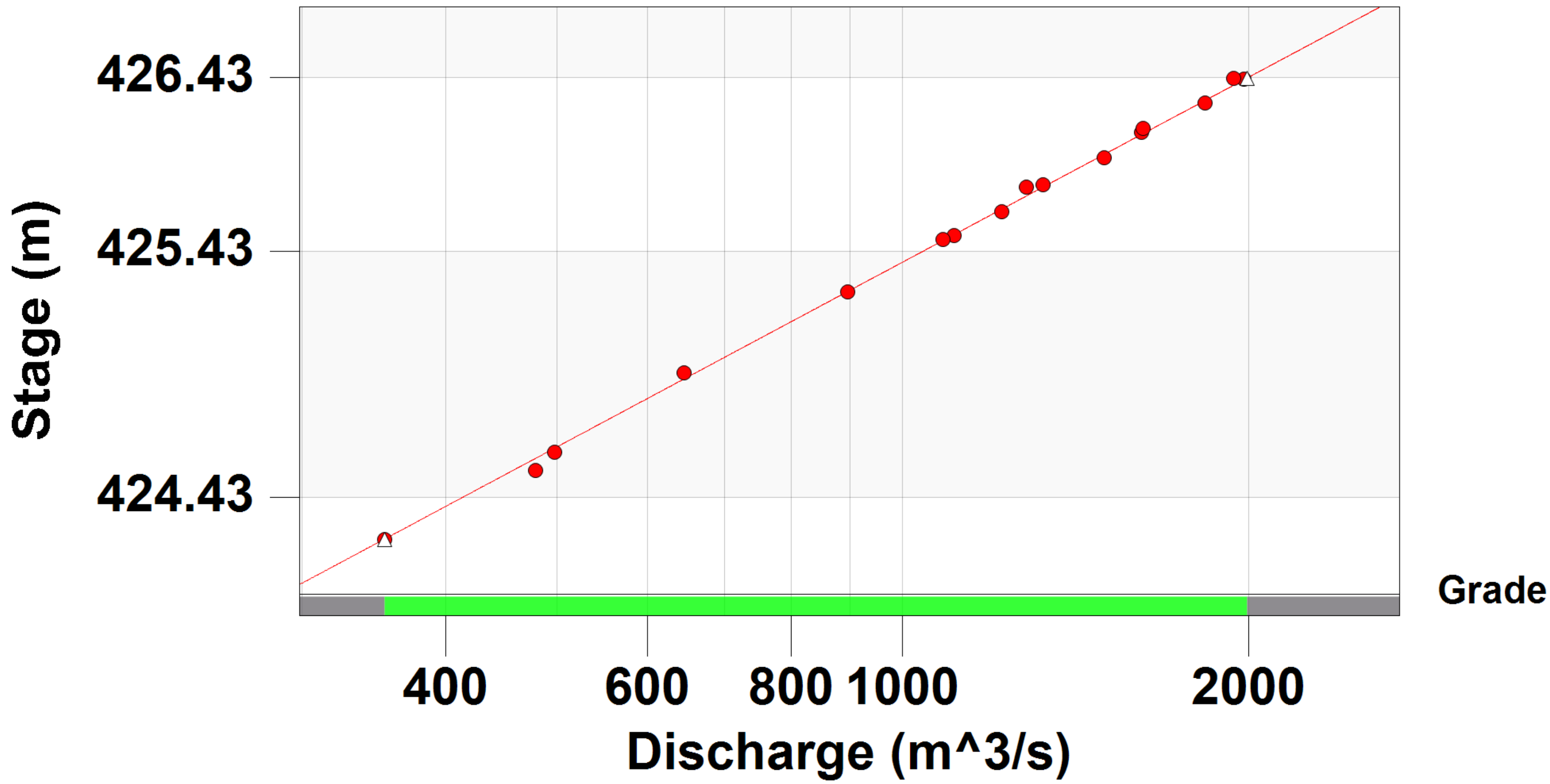

Figure 18 The 2014 discharge record for Peace 25. The sampling interval is 15 minutes. Gaps in the discharge record are detailed in Table 13.

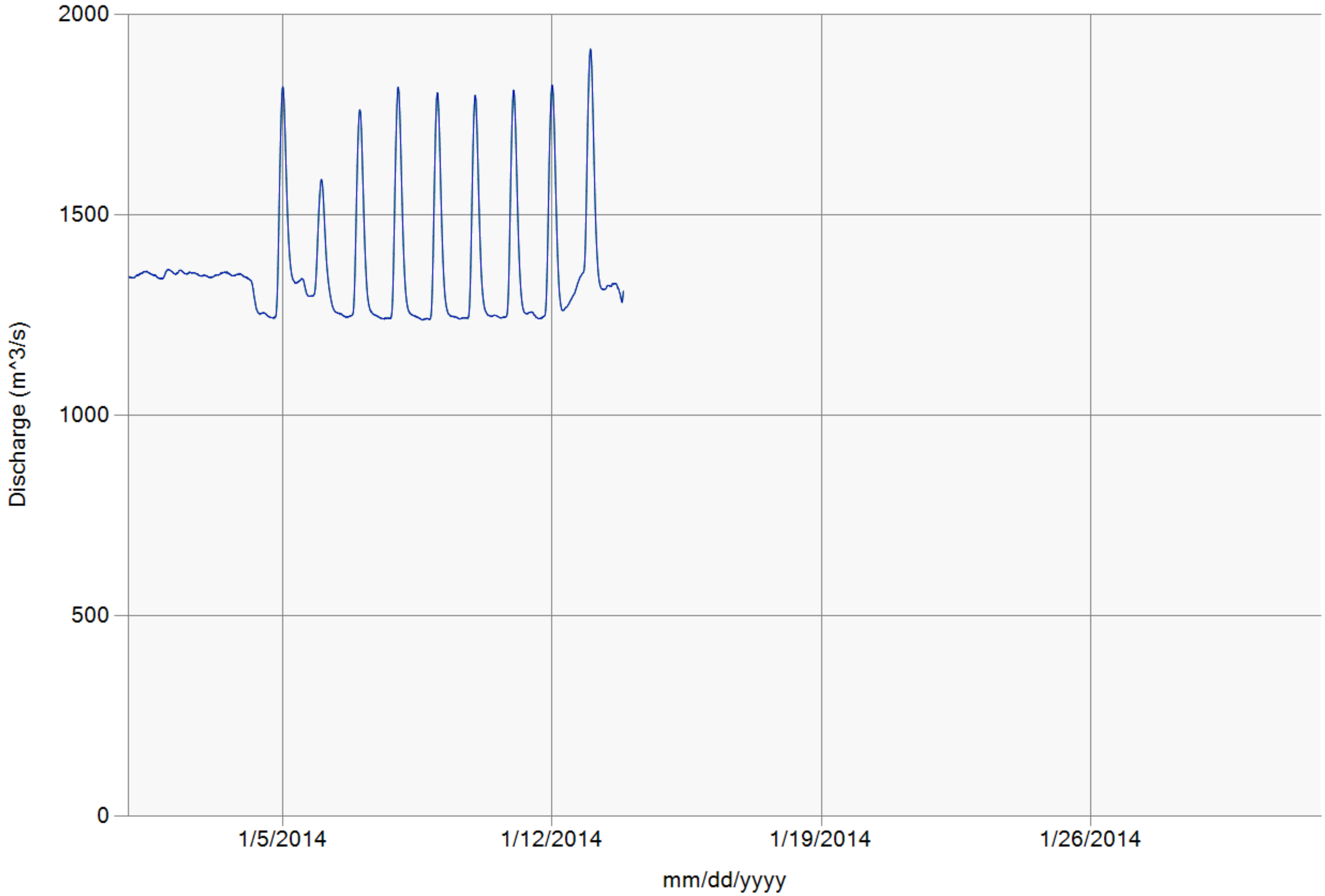

Figure 19 Peace 29 benchmark locations.

(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 20 The 2014 stage record for Peace 29. The sampling interval is 15 minutes. Gaps in the stage record are given in Table 16.

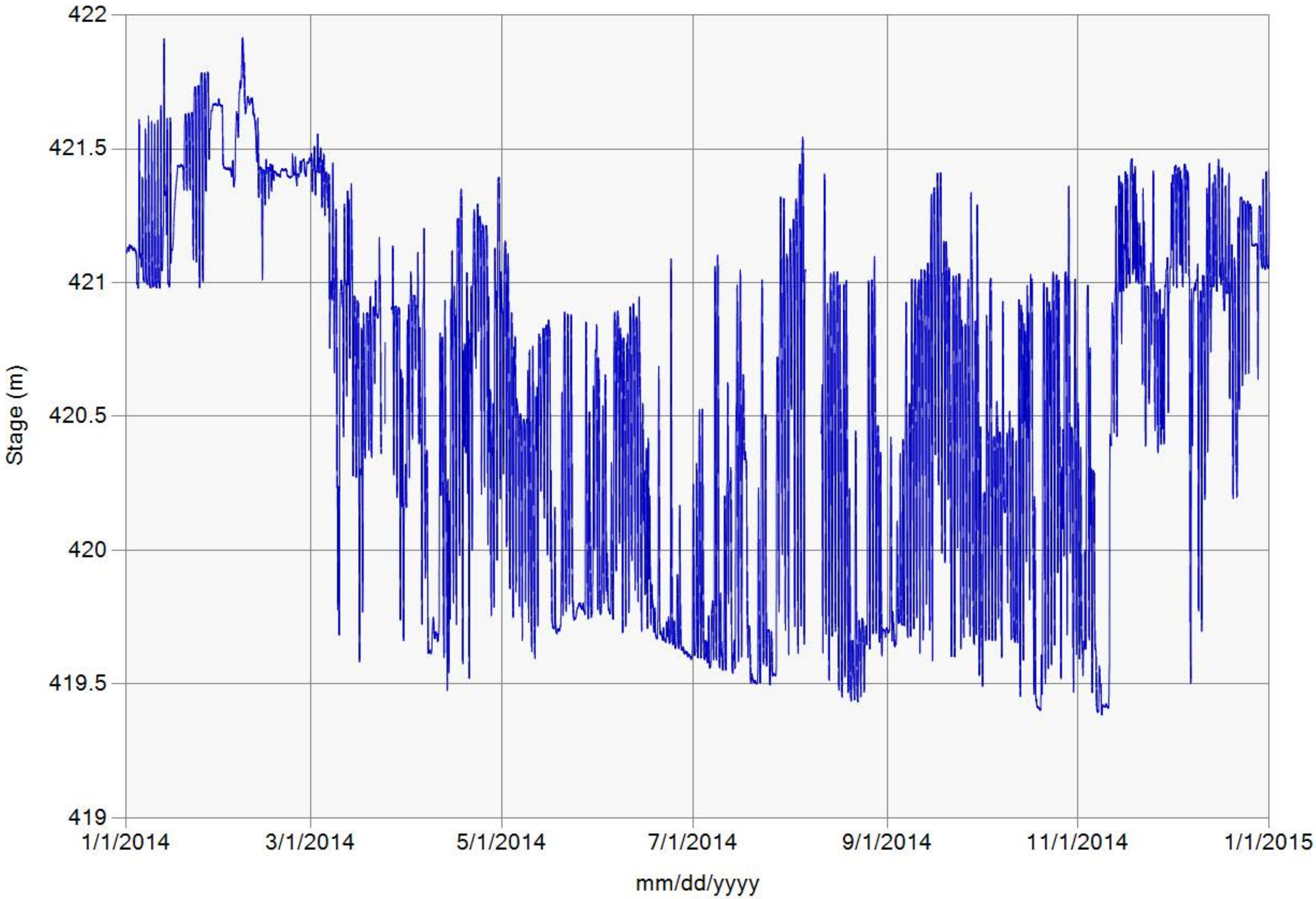

Figure 21 The rating curve for Peace 29. Within the gauged range, the rating curve shows excellent fit (1.3% root mean square of errors) meeting RISC grade A standards (Resources Information Standards Committee, 2009), represented by a green bar below the curve. Discharge values calculated using the 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. The flow measurement collected in 2014 is shown in yellow.

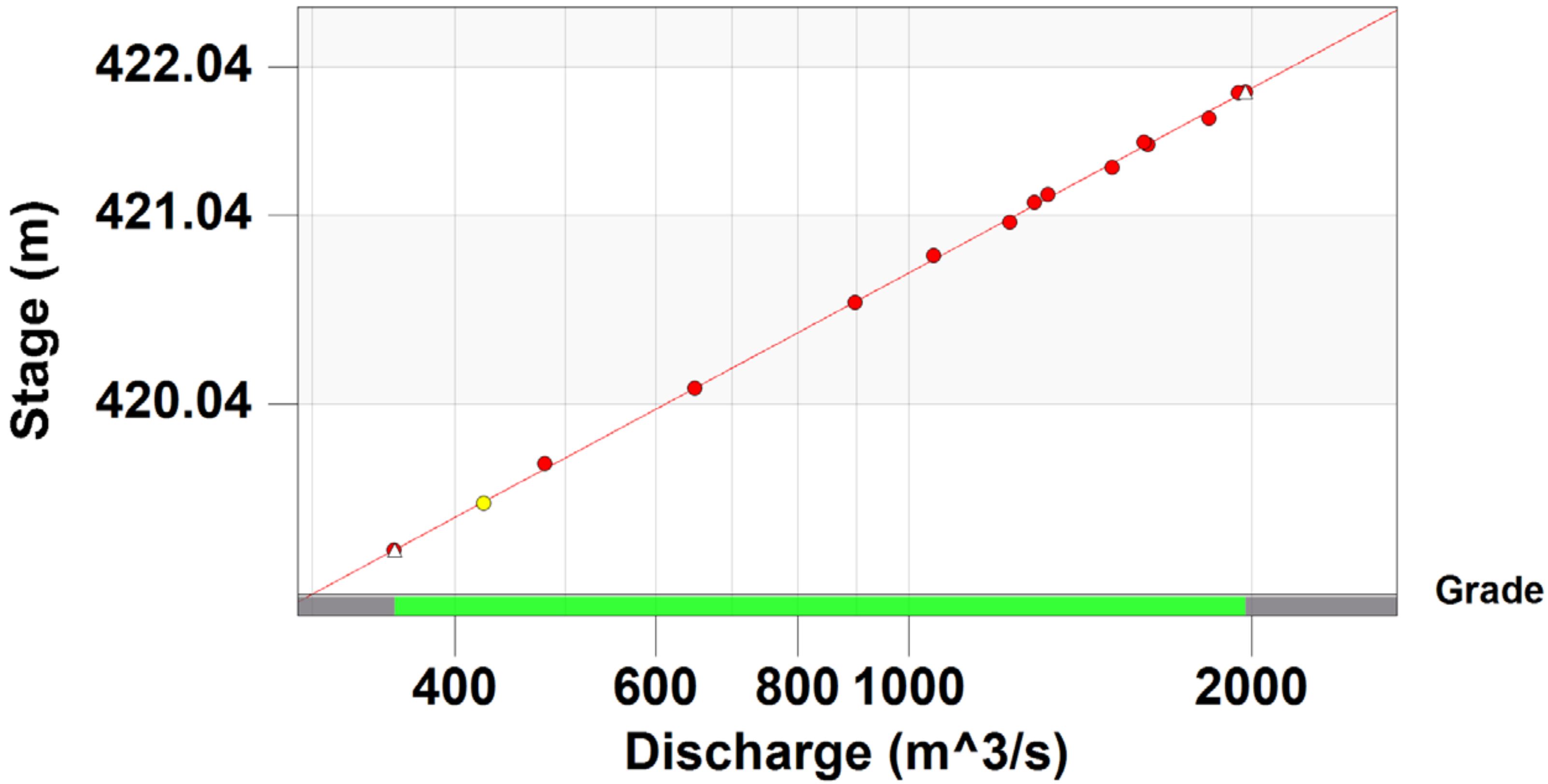

Figure 22 The 2014 discharge record for Peace 29. The sampling interval is 15 minutes. Gaps in the discharge record are detailed in Table 16.

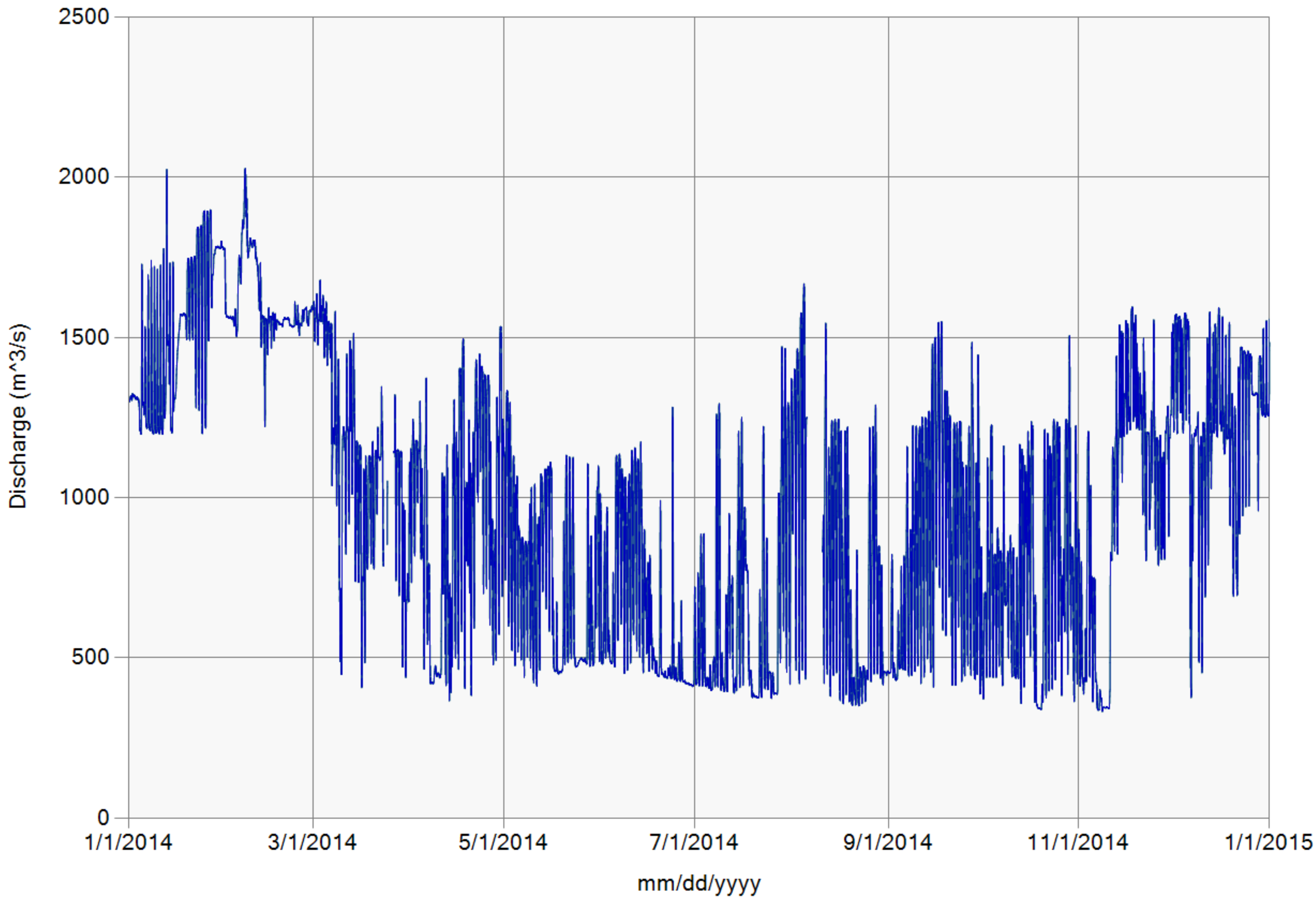

Figure 23 Peace 35a benchmark locations.

(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 24 The 2014 stage record for Peace 35a. The sampling interval is 15 minutes. Gaps in the stage record are given in Table 19.

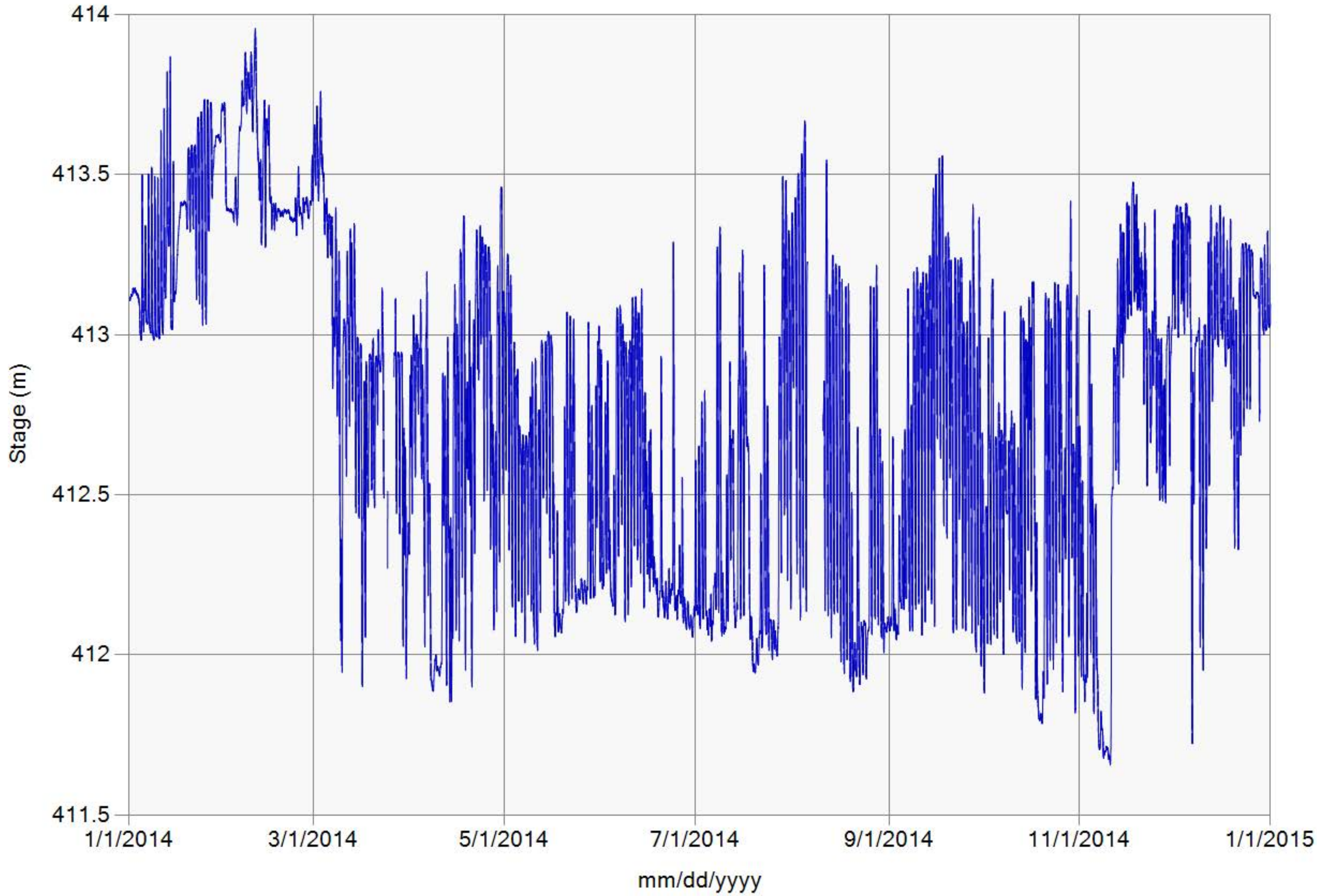

Figure 25 The rating curve for Peace 35a. Within the gauged range, the rating curve shows excellent fit (3.0% root mean square of errors) meeting RISC grade A standards (Resources Information Standards Committee, 2009), represented by a green bar below the curve. Discharge values calculated using the 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 411.869 m to 413.969 m; the current stage record ranges from 411.779 m to 415.123 m. The flow measurement collected in 2014 is shown in yellow.

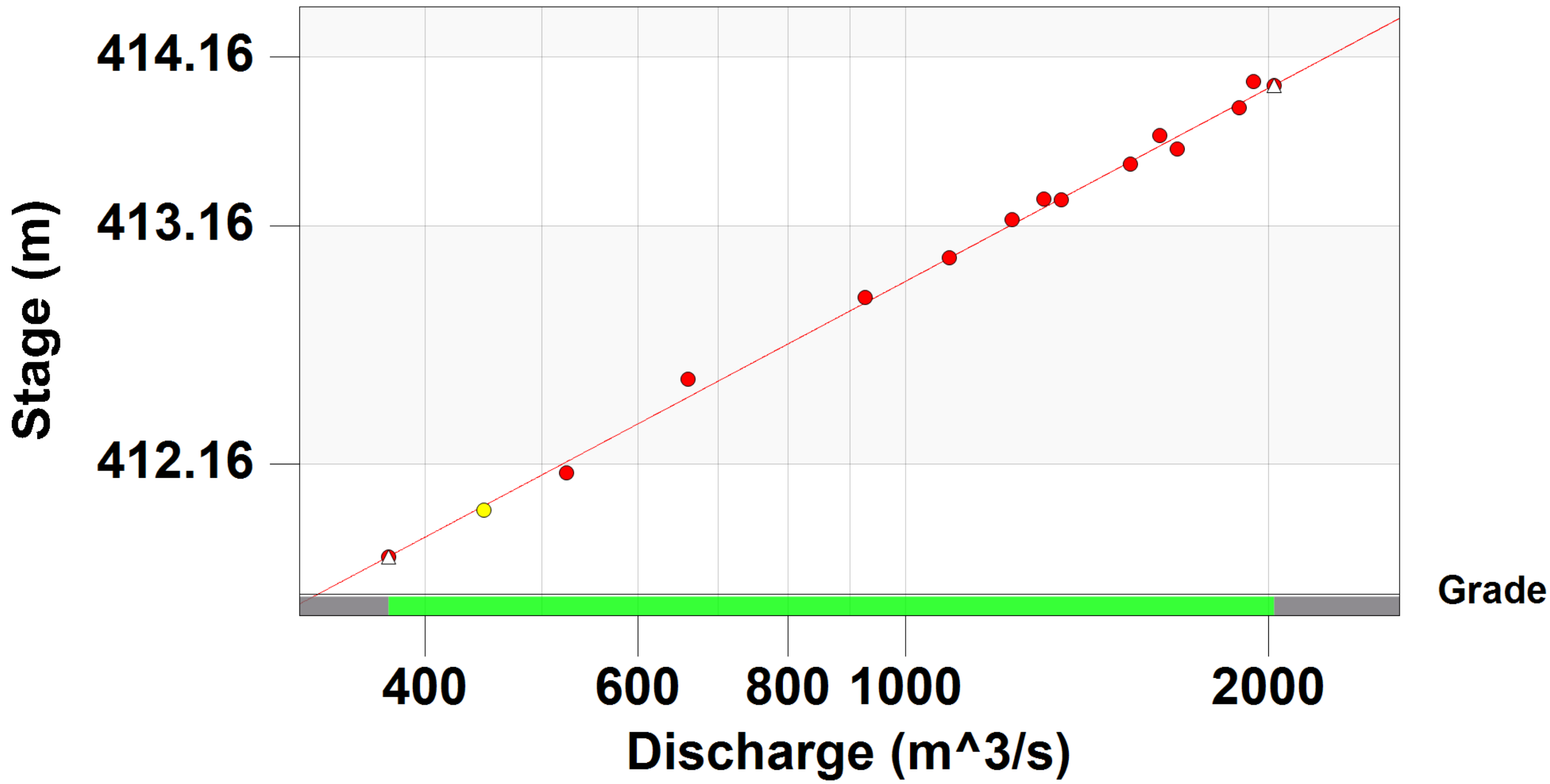

Figure 26 The 2014 discharge record for Peace 35a. The sampling interval is 15 minutes. Gaps in the discharge record are given in Table 19