Peace Project Water Use Plan

Peace River Hydraulic Model

Reference: GMSWORKS-5

2011 Status Update

Study Period: August 2011 to December 2011

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PEACE PROJECT WATER USE PLAN
PEACE RIVER HYDRAULIC MODEL
2011 STATUS UPDATE
(GMSWorks #5)

BC hydro

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1 INTRODUCTION

1.1 CONTRACTS

The Peace River Water Use Plan (WUP) Committee recommended BC Hydro (BCH) monitor water levels and develop and maintain stage-discharge relations for the Peace River mainstem downstream of the G.M. Shrum power station. In response to these recommendations, BCH retained Northwest Hydraulic Consultants (NHC) in May 2009 to provide engineering services for GMSWorks#5 Numerical Hydraulic Model and GMSWorks#6 Mainstem Stage Discharge. This was accomplished through contract Q9-9144 that had a start date of May 15, 2009, an end date of March 13, 2009. Reports for each portion of the original contract (GMSWorks #5 and #6) were provided June 2010. Additional work within the contract to investigate large spills flow hydrology (GMSMon#9) was since initiated and presently on standby until a flood spill is expected.

August 9, 2011 BCH provided NHC authorization to update the numerical model (GMSWorks #5) in 2011 and 2012 with hydrometric data collected during those years utilizing the contract's remaining available funds.

1.2 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 Lake – 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 PCN and GMS.

1.3 BACKGROUND

October 2009, NHC along with VIASAT Data Systems Inc. (VIASAT) installed five hydrometric stations downstream of GMS on the Peace River under GMSWorks#6 (NHC, 2010c). Hydrometric stations were installed for long term flow monitoring to assist in the ongoing operation of GMS and PCN facilities, to fulfill WUP monitoring recommendations, and to provide data for calibration and validation of a numerical model. NHC developed a numerical model from survey sections collected by NHC under GMSWorks#6 and existing LiDAR data. The model was developed in conjunction with the hydrometric station installation with the objective of providing a tool to assess hydraulic impacts – i.e. magnitude, timing, and variability of flow and water level – at downstream side channel and mainstem habitats from dam operation (NHC, 2010b).

Hydrometric station installation and monitoring were completed following Grade A standards as set by the BC Ministry of Environment (MOE) Resources Information Standards Committee (RISC) published hydrometric standards (RISC, 2009). Monitoring and maintenance of the stations ceased upon completion of the 2009-2010 installation work (June 2010). RISC Grade A standard suggests a minimum of five discharge and level measurements for each gauge per year until gauge consistency – i.e. reach stability – is confirmed; thereafter one flow measurement and two level measurements or more are considered acceptable. No flow or level measurements were conducted following the initial development of the rating curve. Therefore a number of flow measurements (i.e. a minimum of five) are required at each station to confirm stability of the gauge site and the validity of the existing rating curves.

Table 2 provides the location of each of the Peace River gauges installed as well as the three Water Survey of Canada (WSC) gauges downstream of GMS; stationing is provided in kilometres downstream from the GMS.

Table 1 Peace River hydrometric stations downstream of GMS

Gauge Reference	Stationing (km)
WSC 07FA004 Peace River above Pine River	7.644
PEACE 3 (NHC)	17.768
PEACE 9 (NHC)	30.318
PEACE 25 (NHC)	55.722
PEACE 29 (NHC)	64.419
PEACE 35A (NHC)	80.913
WSC 07FD002 Peace River near Taylor	92.123
WSC 07FD010 Peace River above Alces River	104.180

Station locations were selected based on channel stability, hydraulic control, and proximity to other hydrometric gauges, tributaries, and side channel complexes that have the potential of providing aquatic habitat as defined in GMSWorks#3 (NHC, 2010a). Peace 3 is located on the left (North) river bank approximately 4 km downstream of Lynx Creek. Peace 9 is located on the left river bank 6.8 km downstream of Farrell Creek. Peace 25 is located on the left river bank 10.1 km downstream of Halfway River. Peace 29 is located on the left river bank 2.8 km downstream of Cache Creek. Peace 35A is located on the left river bank 8.1 km downstream of Wilder Creek.

1.4 SCOPE

The objectives of the current project are:

1. Use flow data from the Peace River hydrometric gauges (BCH and WSC) to check model validation and calibration

2. Use flow data from the Peace River hydrometric gauges (BCH and WSC) to refine inflow estimates from Peace River tributaries along the study reach

Both objectives require using data from the recently installed Peace River gauges. As presented in the previous section, the gauges were installed following RISC Grade A standard. Following the standard would suggest that a minimum of five discharge measurements be taken each year until the sites are confirmed stable. At the onset of this current project no flow measurements had been made in 2011, it was therefore recommended that flow measurements be taken in 2011 and 2012 to confirm the stability of the gauge sites and maintain Grade A standard prior to using the 2011 and 2012 data with the numerical model. **Table 3** presents the scope proposed for the current project.

Table 2 Current project scope

2011
Collect flow measurements at the gauges • Purpose: to validate the 2011 flow data (i.e. update level-to-discharge rating curve) • Schedule to occur in early fall dependent on availability of BCH to regulate flows
Update the numerical model with the 2011 gauge data • Run the model for a number of flows within the range of 2011 validated flows • Identify issues for model calibration
2012
Collect flow measurements at the gauges • Purpose: to validate the 2011 & 2012 flow data (i.e. update level-to-discharge rating curve) • Schedule to occur in spring or summer dependent on availability of BCH to regulate flows
Potentially survey river sections and/or collect additional flow measurements where 2011 & 2012 flow measurements suggest significant changes in the rating curve.
Update the numerical model with the 2012 gauge data • Run the model for a number of flows within the range of 2011 & 2012 validated flows • Identify and attempt to correct issues of model calibration • Develop a flow balance model for seasonal tributary inflows
Adjust model outputs presented in 2010 for any changes in the model (i.e. ramping response, water level profiles for range of discharges and resulting expected inundation or activation of previously identified habitat sites (GMSWorks#3).

It was agreed within BCH to target flow releases of 1300, 1600, and 1950 m^3/s from the PCN power station for November 20, 21, and 22 of 2011. The releases were scheduled to commence at 1800 hours the previous day and end at 1200 hours of the scheduled day to allow a steady discharge for the duration of each flow measurement as the measurements progressed downstream. The regulated flows were not conducted earlier as two of the units were out of service prior to November 20th, and nine of ten units are required to release the larger flows. Flow releases of 300, 600, and 950 m^3/s are to be scheduled for May or June.

This report describes the data collection and processing that has taken place in 2011.

2 2011 Flow Measurement

2.1 Hydrology

Despite the cold weather (high of -25°C) BCH was able to regulate the flows as stated and NHC was able to collect water level and flow measurements for each of the flows. Discharge from PCN and hence GMS typically varies daily. BCH was able to provide steady flows for 1300, 1600, and 1900 m^3/s. The steady flow allows measurement of water level and discharge independent of antecedent flow conditions; that is the water level was not rising or falling.

The following figure presents the typical discharge from PCN as recorded from the Water Survey of Canada gauge *Peace River above Pine River* (WSC 07FA004).

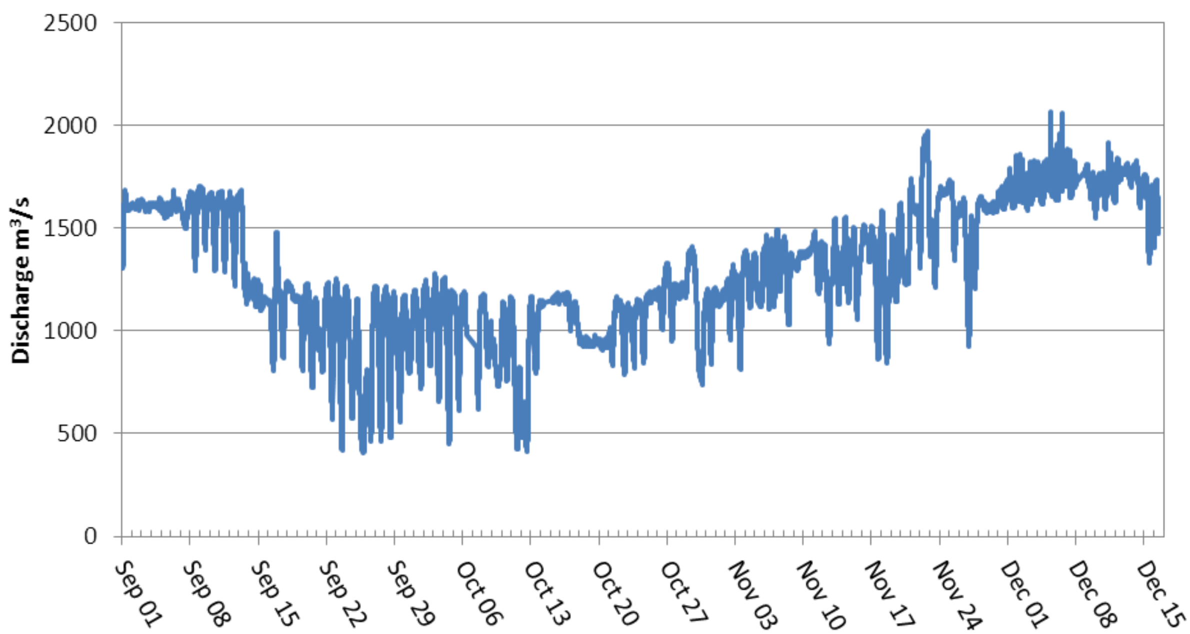

Figure 1 Peace River discharge autumn 2011 (WSC 07FA004)

As shown by **Figure 1**, it would be difficult if not impossible to obtain measurements of flow and water level at steady flow conditions without BCH coordination. BCH therefore, maintained consistent flow for an extended period to allow collection of steady flow measurements, as shown in the following figure (**Figure 2**) of gauged discharge.

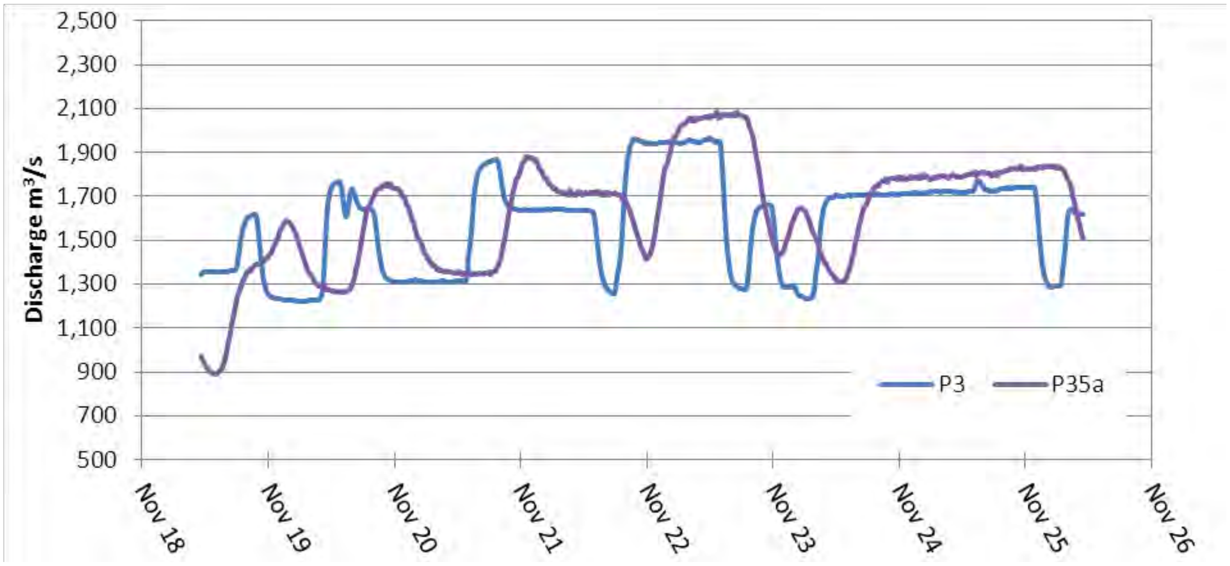

Figure 2 Peace River flow during 2011 discharge measurements

2.2 COLLECTION METHODOLOGY

Flow was measured with an Acoustic Doppler Current Profiler (ADCP, Teledyne RDI's River Ray 600 kHz). The ADCP was mounted to a multi-hull raft, which was attached to the end of a pole extended off the front of a jet boat (**Photo 1** and **Photo 2**). This setup prevents the pitch and roll experienced by the jet boat from directly affecting the ADCP. Specifications of the ADCP can be found at http://www.rdinstruments.com/riverray.aspx. At each site a minimum of two discharge measurements were taken. The largest error between measurements was 3%. If error was to exceed 3%, additional measurements would have been made.

At each site river stage (water level) was surveyed relative to multiple benchmarks using a survey level before and after each set of discharge measurements at a given site. If the stage change was greater than 2 cm between the pair of measurements, the discharge measurements and water level survey were repeated; as a change greater than 2 cm can produces substantial uncertainty in the discharge estimate for wide and shallow river channels such as the study reach of the Peace River.

Transects conducted with the ADCP generally lasted between five and ten minutes, depending on channel width and flow conditions with an average gauging time of 45 minutes per site excluding setup and survey times. Travel between these sites takes as long as 1 hour with a total one-way travel time between all sites of 3 hours, assuming minimal delays due to flow conditions or equipment. The travel time constrains the amount of effort that can be expended at each site during any particular flow.

The Manual of British Columbia Hydrometric Standards (RISC, 2009) outlines data collection guidelines as follows:

- Grade A standards are to have five or more flow measurements a year or at least once a year when the rating curve is established and stable. Two or more level checks are recommended per year, or at least once a year when the reference gauge benchmarks are stable.

- Grade A discharge rating accuracy must be less than 7%

- Discharge measurements within 7% of a rating curve can be used to define that curve

Photo 3 provides an image of a typical hydrometric station. This photograph was taken while collecting a water level survey during the November 2011 field work.

2.3 DATA PROCESSING

Water levels were translated to geodetic datum (metres above mean sea level) based on the surveyed local benchmarks and discharge measurements were plotted on the previously developed 10-point rating curves. **Figure 3** through **Figure 7** provide these rating curves plotted with the 2011 discharge measurements for each site.

Rating curves relate locally referenced river stage to discharge at a particular river location. This relation is dependent on several channel characteristics, including: lateral and longitudinal channel geometries, reach slope, and bed roughness. As previously presented by NHC (2010c) the relation between river stage and discharge for the Peace River hydrometric stations is best expressed by a Power Law function of the form (Maidment, 1993):

$$Q = C\,(H + A)^{B} \qquad \text{Equation 1}$$

where Q = discharge
H = stage, and
C, A, and B are constants dependent on channel characteristics.

'H + A' represents the depth of water above the point of zero flow, while C reflects the channel width, and B is dependent on channel geometry. This relation can consequently change as a result of a change in channel characteristics, which most commonly occurs from scour or sediment deposition during or following peak flow events. As shown in **Figure 3** through **Figure 7**, values of the B coefficient generally increase in the downstream direction reflecting a shift from steep sided channel banks to less defined channel banks. Coefficient C on the other hand, generally decreases with distance downstream reflecting a shift to wider channel and reduced bed slope.

Due to the difficulty associated with submerging a pressure transducer to the deepest part of a river channel (the depth that represents zero discharge), a constant offset is applied to the stage within the rating curve equation. This is represented by coefficient A in Equation 1, and is seen as a visual shift in the rating curve to higher stage values. Adding this value to the rating curve equation also improves the fit of the power law function.

The 2011 measurements are generally within the confidence bounds for the rating curves (+/- 5%) as shown in **Table 4**. Exceptions are the high flow measurement at Peace 35A and the moderate flow measurements at Peace 25, with only the high flow at Peace 35A being outside of RISC standards (2009).

Table 3 November 2011 measurements in comparison to existing rating curves at Peace River hydrometric stations

Gauge Reference	Measured WSEL (m)	Measured Stage (m)	Measured Flow (m^3/s)	Predicted Flow (m^3/s)	Difference
PEACE 3	446.587	1.338	1317	1309	-0.6%
	446.943	1.694	1640	1649	0.5%
	447.225	1.976	1962	1945	-0.9%
PEACE 9	437.977	1.518	1302	1322	1.5%
	438.364	1.905	1626	1646	1.2%
	438.69	2.231	1958	1947	-0.6%
PEACE 25	425.767	1.161	1280	1210	-5.4%
	426.106	1.500	1615	1521	-5.8%
	426.425	1.819	1932	1849	-4.3%
PEACE 29	421.116	0.837	1289	1310	1.6%
	421.506	1.227	1607	1644	2.3%
	421.856	1.577	1925	1982	2.9%
PEACE 35A	413.300	1.574	1302	1342	3.1%
	413.657	1.931	1624	1703	4.9%
	413.995	2.269	1944	2094	7.7%

3 2011 Model Verification

The existing 1D hydrodynamic model was run with steady flow conditions to represent the flows during the November data collection. The results of these model runs are presented in the **Table 5**.

Table 4 Comparison of modelled and measured water level for November 2011 measurements at Peace River hydrometric stations

Gauge Reference	PCN Flow (m^3/s)	Measured WSEL (m)	Modelled WSEL (m)	Difference (m)
PEACE 3	1300	446.59	446.31	-0.28
	1600	446.94	446.64	-0.31
	1900	447.23	446.93	-0.30
PEACE 9	1300	437.98	438.10	0.12
	1600	438.36	438.48	0.12
	1900	438.69	438.82	0.13
PEACE 25	1300	425.77	425.62	-0.15
	1600	426.11	425.97	-0.14
	1900	426.43	426.29	-0.14
PEACE 29	1300	421.12	421.49	0.38
	1600	421.51	421.86	0.35
	1900	421.86	422.20	0.34
PEACE 35A	1300	413.30	413.31	0.01
	1600	413.66	413.68	0.02
	1900	414.00	414.01	0.02

The acceptable range of error between the modelled and the measured water level is dependent on the particular application of the model. Additional assessment of the model with 2011 and 2012 flow record is scheduled for 2012, in which attempts will be made to further define expected model accuracy.

4 DISCUSSION

4.1 TRANSDUCER ELEVATION

In order to use the rating curves to convert gauged level data to flow data it is necessary to know the elevation of the hydrometric station pressure transducers. **Table 6** presents the elevation of the transducers. The rating curves were initially developed using the surveyed elevation of the pressure transducers (second column of **Table 6)**. Post installation the gauged stage could be and was compared with the surveyed water levels. This comparison enabled a more accurate estimate of the elevation of the sensor and any internal sensor offsets (third column of **Table 6)**.

Table 5 Peace River hydrometric stations transducer elevation

Gauge Reference	Surveyed Elev. Sept 2010 (m)	Corrected Elev. Pre June 2010 (m)	Current Elev. (m)
PEACE 3	445.249	445.235	444.885
PEACE 9	436.459	436.452	435.591
PEACE 25	424.606	424.474	423.962
PEACE 29	419.411	419.415	419.064
PEACE 35A	411.726	411.697	411.424

Due to high water levels at the time of installation (September, 2009) transducers could not be permanently anchored to the river bed. Subsequently, the transducers were reinstalled (June 16, 2010) and hence the addition of the last column of **Table 6**. Any gauge level data prior to June 2010 can be converted into the rating curve stage by adding the difference between the middle two columns (of **Table 6**). Any data after June 2010 can be converted into the rating curve stage by adding the difference between second and the last column (of **Table 6**). These differences are presented in **Table 7**.

Table 6 Conversion of Peace River hydrometric station stage to rating curve stage

Gauge Reference	Pre June 2010 (m)	Post June 2010 (m)
PEACE 3	-0.014	-0.364
PEACE 9	-0.007	-0.868
PEACE 25	-0.132	-0.644
PEACE 29	+0.004	-0.347
PEACE 35A	-0.029	-0.302

Peace 9 gauge station is not working due to damage from bullet holes through the data logger. Therefore, no recent data was available to correct the current transducer elevation. The current elevation for Peace 9 and the conversion from station stage to rating curve stage is based on the surveyed elevation of the transducer and is potentially 5 to 10 cm too high.

4.2 Observed Transducer Shift at Peace 25

Past review of the stage and discharge hydrographs for each site conducted by NHC May 2010, revealed a vertical rating curve shift had occurred at Peace 25 over the period February 9-24, 2010. The rating curve appears to have stabilized since that particular high flow period. The stage-discharge relationship presented in this document is for the period after February 24, 2010. The shift in the rating curve at Peace 25 is estimated to be 0.13 metres downwards due to local scour at the sensor.

It was also noted that many of the initial site benchmarks shifted due to freeze-thaw action and soil upheaval. NHC installed new benchmarks in June 2010 by supplementing the steel rods installed by others with steel tubing hammered roughly 3 metres into the ground.

5 Conclusions & Recommendations

5.1 Flow Measurements and Rating Curve Confirmation

The rating curves developed under the year 1 report (NHC, 2010c) appear to have remained valid. Additional flow monitoring is scheduled for spring of 2012 to cover lower flows – the portion of the rating curve most likely to adjust with time. If the rating curve remains valid for these low flows the sites are likely to be considered stable and future site work kept to a minimum; that is:

- annual field verification of meter
- one or more annual flow measurements
- two or more level checks of the gauge per year

If the rating curve and channel section cannot be confirmed to be stable then a minimum of five flow measurements is recommended each year (RISC, 2009).

5.2 Local Benchmarks

The initial benchmarks appeared to show instability over the first winter (2009-2010). NHC supplemented the original benchmarks with the addition of steel tubing driven approximately 3 m into the ground (June 2010). The survey of benchmarks conducted in November (2011) generally showed little differential movement between the accessible benchmarks. It is recommended that future surveying of the benchmarks at each site be conducted when free of snow cover (not all benchmarks were able to be found November 2011) during next field work to confirm minimal differential movement. If uncertainty persists in the benchmark elevations, then the benchmarks should be resurveyed with tie-in to geodetic datum.

While many benchmarks exist along the banks of the Peace River from previous survey work the accuracy of many of these benchmarks were discovered (NHC, 2010c) to not be sufficient to meet the Canadian Hydrographic Standards (CHS) (Canadian Hydrographic Service, 2008). Mass movements and localized erosion has also altered the location or condition of many of the high accuracy Geodetic Survey of Canada benchmarks in the area and caution should be used if these are to be relied on in future work. The distance between hydrometric stations, lack of frequent boat launches along the Peace River, and limited range of survey grade RTK GPS prevents geodetic tie-in of benchmarks during flow measurements. It is expected such an exercise would require an additional two days of field work.

5.3 Peace 9 Station Repair

A number of the sites have been subjected to target practice with bullet holes in a number of solar panels (**Photo 4**). The data logger at Peace 9 suffered damage as a result (**Photo 5**) and requires repair. Presently no data is being collected by this station. It will be repaired during the next scheduled field work (i.e. flow measurement – spring 2012).

5.4 Future Work

Work scheduled for 2012 includes:

- Repair of Peace 9 scheduled for spring 2012
- Flow measurement at each of the sites during low flow (300, 600, and possibly 950 m^3/s) scheduled for spring 2012. Stability of the gauges, local channel, and hence the existing rating curves will be confirmed to assess future data collection requirements.
- 2011 and 2012 level records (from the gauges) will be obtained from BCH and used to further confirm the validity of the numerical model.
- The numerical model was originally developed with tributary inflows based on average flows historically recorded from;
    - WSC 07FB008 Moberly River near Fort Saint John
    - WSC 07FA006 Halfway River near Farrell Creek
    - WSC 07FA004 Peace River above Pine River
    - WSC 07FD002 Peace River near Taylor

  The data collected at the Peace 3 to Peach 35a gauges will be used to develop a flow balance model and subsequently redefine estimated seasonal tributary inflows for the primary tributaries within the modelled reach.
- Using the gauge records and the hydraulic model, evaluation of duration, variability, and timing of water levels expected to provide access to the highest ranking side channel habitat sites identified in GMSWorks#3 (NHC, 2010a) can be evaluated. This work would supplement any detail design for improving hydraulic connectivity and habitat value at these sites.

It may be desirable to extend the study downstream; that is the numerical model, gauging, and identification of high value side channel habitat. This would allow the identification of opportunities for compensation or restoration work downstream of Taylor and provide baseline data and tools for the assessment and design of any works.

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FIGURES

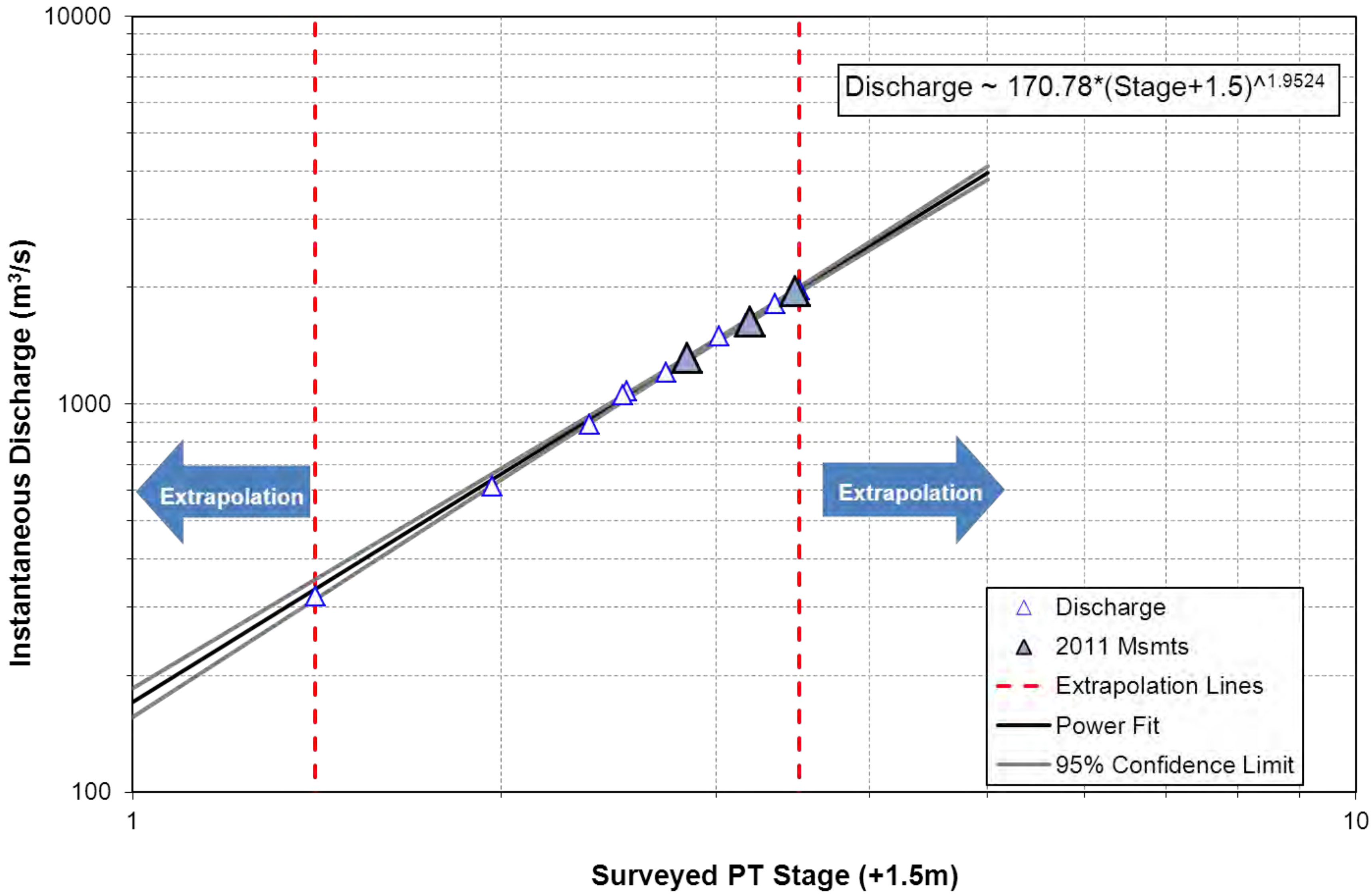

Figure 3 Peace 3 hydrometric station (18 km); November 2011 measurements overlaid on pre-existing stage-discharge rating curve

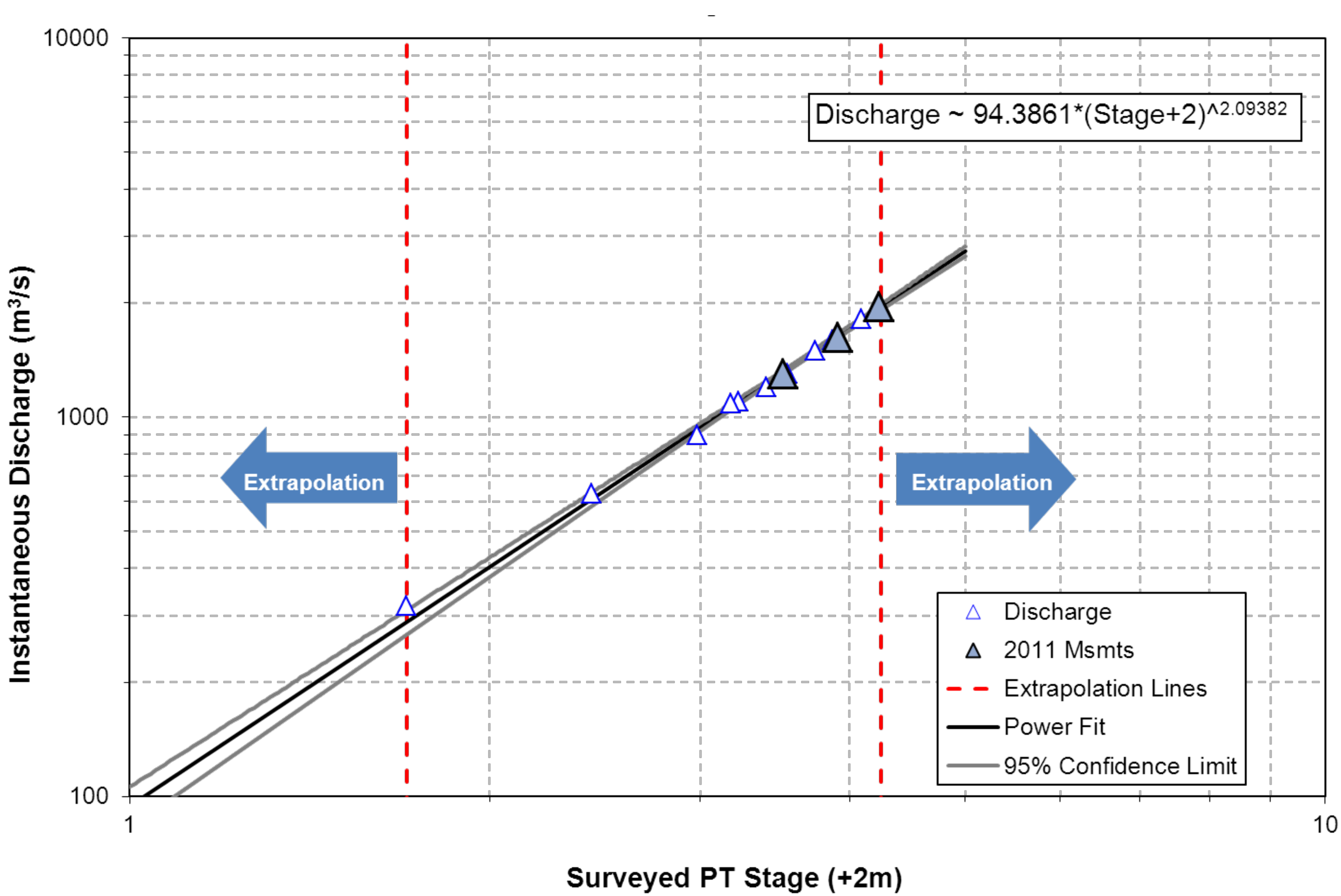

Figure 4 Peace 9 hydrometric station (30 km); November 2011 measurements overlaid on pre-existing stage-discharge rating curve

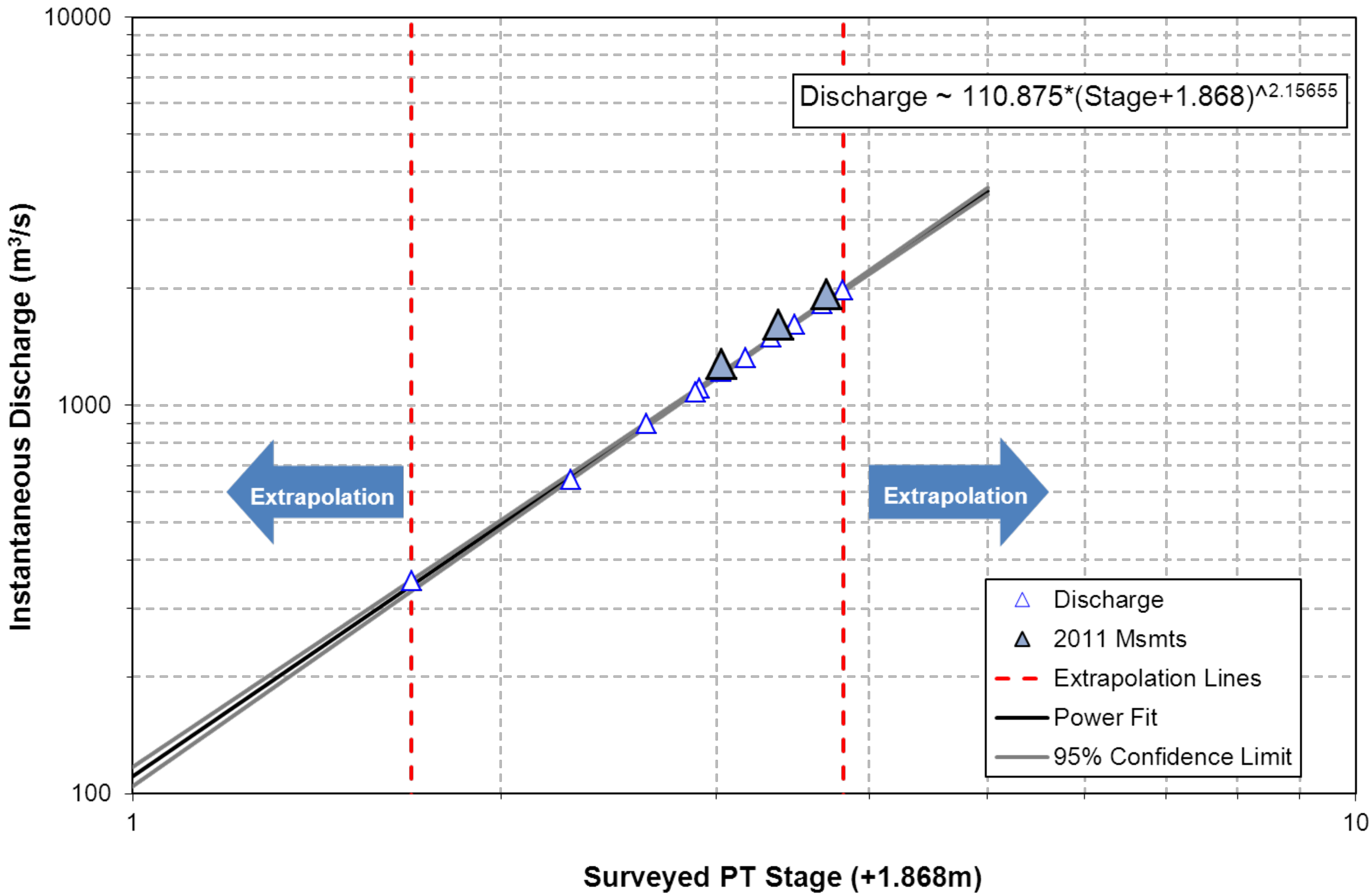

Figure 5 Peace 25 hydrometric station (56 km); November 2011 measurements overlaid on pre-existing stage-discharge rating curve

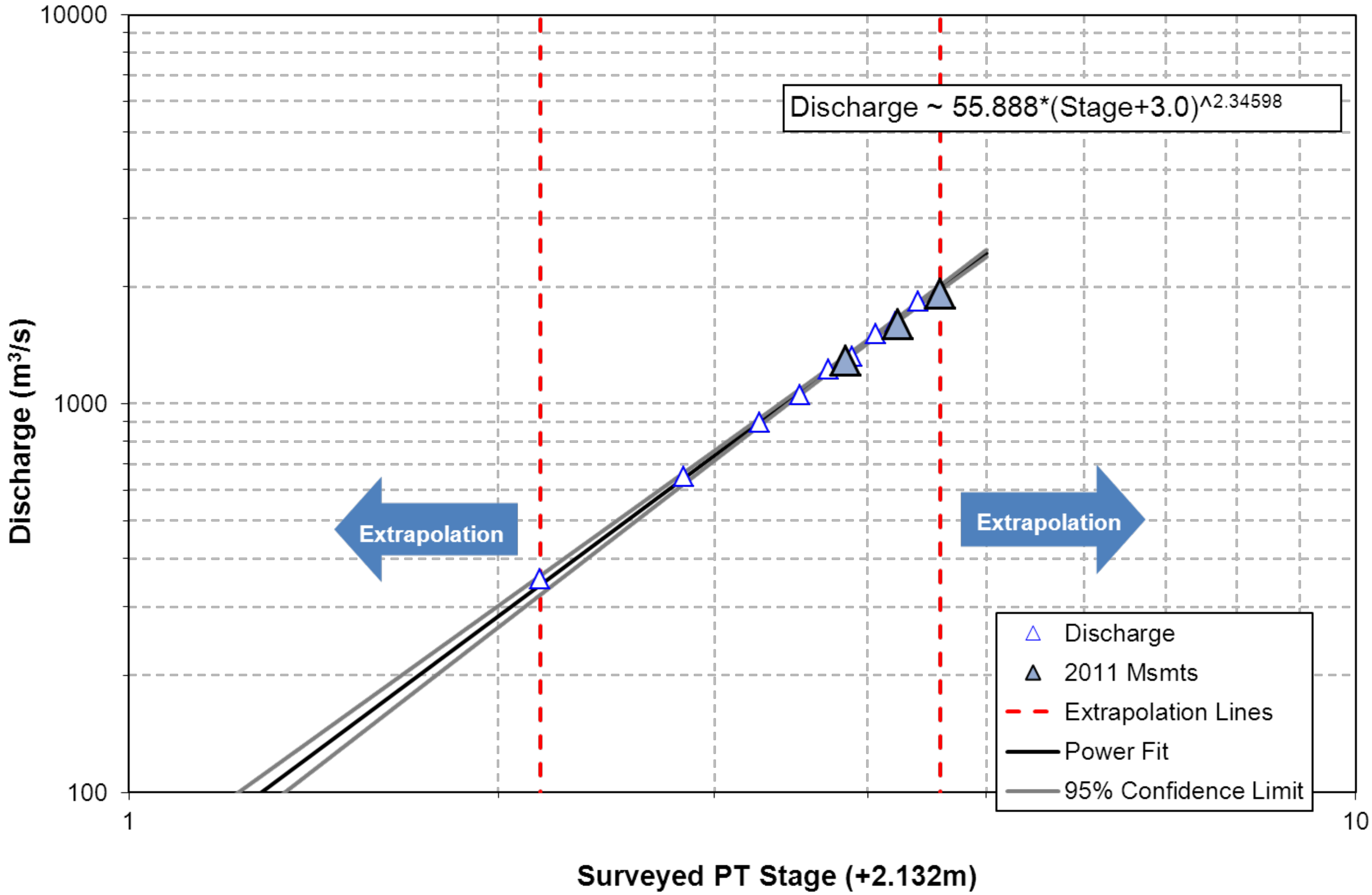

Figure 6 Peace 29 hydrometric station (64 km); November 2011 measurements overlaid on pre-existing stage-discharge rating curve

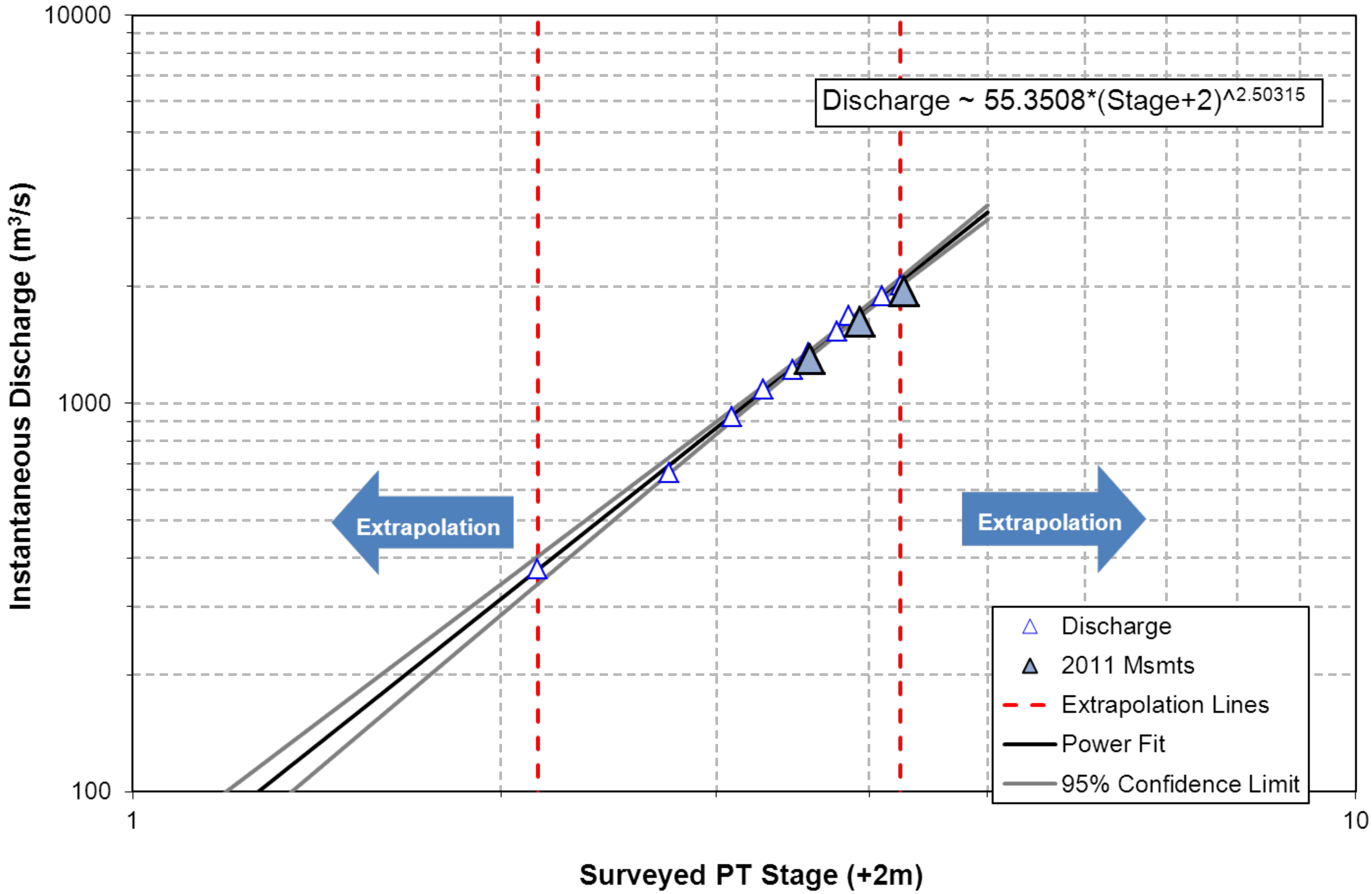

Figure 7 Peace 35A hydrometric station (81 km); November 2011 measurements overlaid on pre-existing stage-discharge rating curve

PHOTOGRAPHS

Photo 1 Jet boat on the Peace River

Photo 2 Discharge measurement with ADCP alongside jet boat

Photo 3 Hydrometric station and level survey

Photo 4 Shot solar panel

Photo 5 Shot hydrometric station