Cheakamus River Water Use Plan

Monitoring Channel Morphology in Cheakamus River

Implementation Year 5

Reference: CMSMON-8

Cheakamus River Hydrometric Monitoring

Study Period: February 28, 2011 to April 8, 2012

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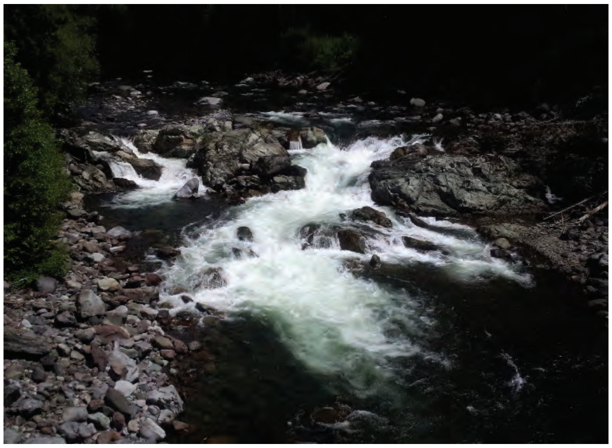

Cheakamus Water Use Plan
Cheakamus River
Hydrometric Monitoring
Year 5 Reporting

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2 May 2014
NHC 34730

Notification

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1 Hydrometric Monitoring

1.1 Overview

Hydrometric monitoring of water stage and corresponding flows has been ongoing at three (3) locations along the Cheakamus River between the Daisy Lake Dam and Cheakamus-Cheekye River confluence since February 2008 as part of the Cheakamus River Water Use Plan. The monitoring sites are (Figure 1):

- *Cheakamus River above Chance Creek* (Forest Service Road bridge below Daisy Lake Dam), hereinafter referred to as 'Cheakamus FSR';
- *Cheakamus River above Culliton Creek* (pedestrian suspension bridge crossing Cheakamus River above the Culliton Creek confluence), hereinafter referred to as 'Cheakamus Pedestrian'*;* and
- *Culliton Creek above Cheakamus River* (Jack Webster Bridge crossing Culliton Creek), hereinafter referred to as 'Culliton Creek'.

In Year 1 NHC voluntarily undertook additional tributary flow gauging at four additional sites, as well as installing an additional hydrometric station on the Cheakamus River below the Cheekye River confluence. This work was carried out to supplement our understanding of tributary flow contributions to the Cheakamus River and to develop rating curves for these sites in anticipation of the need for a greater spatial extent of discharge information on the system by the CMSWUP Monitoring Program working group.

Partial rating curves were developed for each of these sites using 3 to 4 dissimilar discharge measurements at each site, and were presented in the Year 1 report (NHC, 2009). Work at these additional sites was discontinued as of June 2009 as there was no apparent interest in expanding the Cheakamus hydrometric network beyond the initial three sites. The hydrometric station below the Cheekye confluence was buried by a debris flood in 2009 and subsequently abandoned.

Hydrometric stations at the three sites continuously log water temperature and water level (stage) data at fifteen minute intervals with a Solinst Levelogger®, with barometric pressure and air temperature measured in synchrony with a Solinst Barologger® at a site situated by the Culliton Creek hydrometric station. When situated underwater, a Levelogger senses absolute pressure (hydrostatic and atmospheric) and requires compensation with a nearby Barologger (measures atmospheric pressure) for accurate measurement of the actual water level above the sensor at any given time.

Estimates of flow for Cheakamus River ranging from minimum levels up to 60 m^3/s are required for this project, while estimates of the full range of flows are required for Culliton Creek as it is the largest single source of inflow to the Cheakamus River reach falling between the Daisy Lake Dam and the Cheekye River.

Discharge measurements from Year 4 have been used to further refine rating curves submitted in the Year 3 report (NHC, 2011). Significant rating curve shifts have been identified at two of the gauging sites, although no shifts have been detected during the Year 4 reporting period. These shifts occur due to changes in channel geometry that alter the relation between stage and discharge, due to aggradation and degradation of the streambed or erosion of channel banks during high flow events alter the gauging cross section. To monitor for such possible changes, new discharge measurements are compared to the existing rating curve and yearly stage record to determine if a new relation must be developed.

Instantaneous measurements of flow for the development of site-specific stage-discharge rating curves have been conducted using a variety of methods. Whenever possible, we have employed a velocity-area approach to estimate instantaneous discharge on the Cheakamus mainstem with an Acoustic Doppler Current Profiler (ADCP). If stream flow conditions are not suitable for this method, our second choice is to use either mechanical (Price®) or Acoustic Doppler Velocity (ADV) meters to provide mean velocities at a minimum of 20 or more intervals across a stream cross-section (RISC, 2009). A Price velocity meter was used on only one occasion at the Cheakamus FSR site (**Table 1**). In high flow conditions, excessively turbulent stream conditions (such as at Culliton Creek) preclude the use of acoustic or mechanical velocity meters, and instantaneous flows have been measured with salt dilution gauging methods.

Details on flow gauging and monitoring methodologies are briefly described in subsequent sections, and for more detail the reader is referred to the following publications:

- Moore (2004a, 2004b, 2005) and Hudson and Fraser (2005) for salt dilution methods: and
- Teledyne RD Instruments (2009a, 2009b) for acoustic profiling methods.

2 Hydrometric Station Sites

A detailed description and coordinates of each hydrometric station is provided in

Appendix A. Specifics to each gauge are provided below

2.1 Cheakamus FSR

The Cheakamus FSR site is located at the Chance Creek Forest Service Road bridge crossing, which is situated below the Rubble Creek and above the Chance Creek confluences (**Figure 1**, **Photograph 1** and **Photograph 2**). The lower reach of Rubble Creek has an active fan at its confluence with the Cheakamus River, and does not provide a stable anchor point for the installation of a hydrometric station. Rubble Creek flow contributions can be estimated by subtracting Daisy Lake Dam flow releases from discharge estimated at Cheakamus FSR since other contributions to the river are negligible.

The Cheakamus FSR hydrometric station is secured to the downstream side of the bridge footing on the right bank. This site was selected for its close proximity to Rubble Creek and partial bedrock control of the channel, which minimizes possible changes in channel geometry. Flow gauging at this site is limited to use of an ADCP as there is insufficient lateral mixing across the channel for dilution methods and the channel is too deep to wade. During high flows there is significant localized turbulence at this section that can disrupt gauging with an ADCP due to air entrainment in the water column, and measurements in such conditions have had greater uncertainty. Between February 2011 and April 2012 the site was gauged 6 times (**Table 1**).

2.2 Cheakamus Pedestrian

This site is located at the pedestrian suspension bridge crossing the Cheakamus River approximately 500 meters upstream of its confluence with Culliton Creek (**Figure 1**, **Photograph 3**, and **Photograph 4**). The hydrometric station is anchored to bedrock on the right bank of the river, just upstream of the bridge. Several small tributaries flow into Cheakamus River between this site and Chance Creek.

Instantaneous discharge has been measured at this site with an ADCP, but difficulties have arisen from fast flow conditions and air entrainment resulting from the steep channel slope, which creates an extended riffle along this reach. Gauging with an ADV immediately upstream of the hydrometric station is possible when flows are low enough to permit wading. This site has been successfully gauged six times since February 2011 (**Table 1**).

2.3 Culliton Creek

Culliton Creek is one of the main tributaries to the Cheakamus River and the catchment includes Conroy Creek and half of the Brohm Ridge glacier. The hydrometric station is installed on the left bank below the Jack Webster bridge crossing Culliton Creek (**Figure 1**, **Photograph 5**, and **Photograph 6**). A series of riffles and step pools that extend approximately 100 metres upstream and downstream of the bridge create turbulent conditions ideal for dilution methods during high flow.

During low flow conditions, dilution injection solutions can become trapped in pools and discharge measurements with an ADV are preferred. A Barologger, measuring pressure and air temperature at a sheltered site in the nearby forest is used for compensating all Leveloggers on this project. This site has been successfully gauged seven times since February 2011 (**Table 1**).

3 Hydrometric Monitoring Program

3.1 Overview

The hydrometric stations in this project consist of a pressure transducer with an internal data logger installed in a relatively stable deep part of the channel. Water level (stage) and temperature data are recorded every fifteen minutes. Each sensor is capable of storing 40,000 measurements of pressure and temperature, which at a 15-minute logging interval allows for 414 days (13.5 months) of continuous data collection. Instantaneous discharge measurements made in Year 4 range from 12 to 81m^3/s on the Cheakamus River and 2 to 10 m^3/s on Culliton Creek. Various gauging methods have been used, including ADCP, ADV, dilution (salt and Rhodamine WT), and mechanical velocity meters (Price).

Instantaneous discharge measurements are plotted against the corresponding stage measured at the hydrometric station at the time of the measurement to produce a rating curve. The resulting rating curve relation is then used to transform the continuous stage record from the pressure transducers to a continuous record of discharge.

3.2 Site Equipment

Each hydrometric station consists of a Solinst Model 3001 Levelogger Gold® pressure transducer encased in a protective housing. As previously mentioned, a Levelogger measures absolute pressure (hydrostatic and atmospheric) and requires a nearby Barologger to compensate for changes in atmospheric pressure. A single Barologger may be used to compensate several Leveloggers as long as these are in relatively close proximity to each other. Detailed sensor specifications are provided in **Table 2**.

NHC conducts in-house testing on all pressure transducers and data loggers prior to field deployment to ensure functionality and manufacturer specified maximum and typical accuracies. This consists of testing each pressure transducer in a testing tank and verifying physical water levels to sensor readings for rapid short term water level fluctuations and longer term stable water levels.

The advantage of the Levelogger and Barologger sensors is that these are a stand-alone system containing a datalogger, a pressure transducer and battery within a compact unit (7/8” x 6”), so there is no potential for damage to vented cables as in standard pressure transducers. Leveloggers also provide the most cost-effective solution for a high level of accuracy (Table 2):

- Levelogger: ±2 mm typical accuracy for 4 metre range; and
- Barologger: ±1 mm typical accuracy for air only.

The loggers have been downloaded periodically to ensure that the sensors are functioning correctly, and sensor readings have been verified with physical water level measurements whenever possible during downloads.

Installation hardware typically consists of a rigid galvanized conduit pipe that is secured to stable material such as a boulder or concrete. The potential for vandalism is best addressed with a low-profile installation that is either concealed from passers-by or, where possible, installed in locations that are difficult to access. The latter was achieved at the Cheakamus Pedestrian site, but robust installations were required for the more exposed Culliton Creek and Cheakamus FSR sites. Some of the hardware is beginning to rust and should be replaced during the next year of fieldwork.

3.3 Hydrometric Installations

The hydrometric stations for this project were designed to meet Grade A standards according to the Manual of British Columbia Hydrometric Standards (RISC, 2009). Water level recorders and flow metering have been undertaken with calibrated standardized equipment to limit measurement error to 10%.

Frequent rating curve shifts related to channel instability have been an issue at the Cheakamus Pedestrian site, and this station would be classified as falling between Class A and B standards due to greater measurement uncertainty. Site selection considered minimizing errors related to changing bed topography, but the majority of the Cheakamus River above Culliton Creek consists of a mobile cobble bed, a difficult variable to account for in the development of rating curves. As ease of access must be considered in site selection, Cheakamus Pedestrian remains the best compromise despite the unstable cross section.

The Cheakamus Pedestrian pressure transducer is housed in a thick-walled galvanized steel pipe with a standard lockable well cap, and this in combination with challenging access has been sufficient in preventing vandalism or tampering. The Cheakamus FSR and Culliton Creek stations are more exposed, and these stations have been fitted with a more robust thick steel housing. Thus far, these measures have proven to be adequate in preventing tampering or vandalism. A minimum of three benchmarks have been established at each site to provide vertical reference points for the pressure transducer (RISC, 2009).

These benchmarks were surveyed in by Total Station and tied to nearby control points where possible; otherwise local control points have been established. The housing pipes are mounted to galvanized steel angle iron and bolted to bedrock, large stable boulders or concrete with stainless steel rock bolts and anchors. Access during a range of flow levels has been given consideration during the selection of each hydrometric station site.

Whenever possible, physical water levels are measured during each site visit on a staff gauge at Culliton Creek or a reference bolts at Cheakamus FSR and Cheakamus Pedestrian sites. Staff gauges were not installed at the latter two locations as a less visible installation was preferred. The reference bolts are tied into the local survey and have provided consistent physical water level measurements.

3.4 Instantaneous Flow Measurements

Instantaneous flow measurements for this project meet Grade A standards according to RISC (2009). Gauging equipment is regularly tested and calibrated to control for any errors arising from flow measurement. Velocity meters are calibrated with a known flow orifice, conductivity meters are calibrated with known concentrations, and acoustic equipment receives regular maintenance and testing to ensure that all are within manufacturer specifications.

At sites where conditions allow manual measurements to be made, discharge is calculated by measuring depth and velocity at 20 or more points across the channel cross-section (RISC, 2009). This is accomplished using a high-precision ADV, or mechanical Price AA® or Swoffer® propeller-type current meters. An ADV is preferred where low-flow conditions permit wading, as it allows for high precision (0.001 m/s) and accurate (±1% of measured velocity) measurements. Where wading is not possible, measurements are made with an ADCP or with dilution methods for turbulent conditions.

An ADCP operates on a similar velocity area method to an ADV or Price meter, except that it is capable of measuring different velocities at various depths in the water column rather than using depth integrated velocity to represent a water column. At the end of 2011 NHC acquired a Teledyne RD Instruments RiverRay ADCP which allowed for more precise gauging of discharge at low water levels. Technological improvements have allowed for more accurate measurement of velocity profiles as well as the ability to measure velocity in shallower depths. This has reduced the error associated with discharge measurements leading to better rating curve relations.

In turbulent conditions with adequate mixing and where wading is not possible (common at Culliton Creek), dilution methods are preferred. Dilution requires thorough post-processing, and post-measurement stream water calibrations (titrations) to determine concentration curves for mass balance calculations used in the estimation of flow.

Flow measurements are typically calculated on site when possible and a qualified crew member (hydrologist or fluvial geomorphologist) assesses whether measured flows are within the expected range of flows based on field observations or dam releases and Water Survey of Canada (WSC) reported gauge flows in the case of Cheakamus River (WSC *08GA043 Cheakamus River near Brackendale*). This is to prevent erroneous flow measurements and is a standard component of our company hydrometric QA/QC protocol. Qualified personnel rely on their experience and training to determine adequate instantaneous gauging locations for each site that will provide the most reliable discharge measurement.

If data spikes are suspected during a review of stage data, once discharge measurements are recorded, calibrated, and verified, hydrographs can be corroborated by examining other regional stream flow data, nearby precipitation data, and internal gauged areas to validate flow records at a site.

3.5 Data Handling and Storage

Gauge data is also downloaded when required during flow measurement site visits. Downloading involves removal of the Levelogger, connection to a field laptop and extraction of data files. Observed surface water elevations and offset data are documented, and the logger set-up, timestamp and battery condition are reviewed. A similar process is used to extract the barometric data from a Barologger, and this data is compared to a nearby Environment Canada climate station to confirm readings.

As the Solinst loggers are sealed units, there is no atmospheric venting and the water level data is barometrically compensated within the software using the barometric data. The corrected file is reviewed for data quality prior to leaving the site (physical water level and sensor readings are confirmed) and stored in an NHC database by site and date later on the same day. Once logger functionality and accuracy has been confirmed, the Levelogger is re-initiated and returned to the gauge, and seated properly within the housing. QA/QC procedures are especially critical if freezing water conditions were reported in the temperature logs, significant flows occurred, or anomalous readings are identified.

Data for all three stations is stored in an Aquarius database. Aquarius is specialized hydrometric software used for the maintenance and QA/QC of hydrometric records. Following the logger downloads, a second QA/QC process is performed in Aquarius. Any data spikes or gaps in the records are identified and corrected.

Discharge measurements are also stored in Aquarius so that rating curve development. The tools that are specifically designed for rating curve development have improved the rating curve history at the three hydrometric sites for this project. The Pedestrian Bridge site remains the most problematic due to changes in the bed morphology which alters the channel control at this site.

4 Gauge Analysis

4.1 Rating Curves

As previously discussed, water level (stage) is compared to stream flow discharge at various water levels over the range of measured stage to construct a stage-discharge or rating curve. A rod and survey level is used to survey water level and sensor elevations to site benchmarks. Rating gauge plots will typically follow the *Power Law* form:

$$Q(S) \approx b_0 \cdot S^{b_1}$$

where:

S = gauge stage (m)

Q = flow (m^3/s)

b_0 and b_1 = coefficients determined from analysis.

The timing of instantaneous flow measurements for rating curve development is a function of available access to the site and stream flows. The field program has been designed to rate each gauge over a wider range of discharge than what is to be estimated in order to acquire adequate upper and lower bound flow estimates.

At the Cheakamus River sites, flows are to be estimated from minimum flows up to 60 m^3/s, while the full range of flows are required at the Culliton Creek site. During base flow conditions, discharge only increases by approximately 10 m^3/s between Daisy Lake and the WSC gauge, or an increase of 3.3 m^3/s on average between the gauging sites. As measurements with an ADCP nominally have a measurement error of approximately 10%, gauging a 3 m^3/s increase in a 20 m^3/s flow is a difficult change to capture.

The equations for each rating curve are provided below for each station. Several rating curve shifts are apparent at the Pedestrian Cheakamus site, and it is suspected that sediment transport is constantly reshaping the cross-sections at this site. For comparison, instantaneous discharge measurements reported for WSC Brackendale in 2010 indicate a similar shift to our sites, varying from the previously established rating curve at that site by up to 25%.

Rating curves are subject to change and adjustment due to an increase in the record of gauge points that better define the rating curve, or on the basis of physical changes to the rating section. Physical changes are typically a result of channel or bank erosion from flood events, changes in sediment regimes, or anthropogenic alterations to the river channel. As part of the initial assessment of gauging sites, an effort was made to locate these sections in relatively uniform stable reaches where these impacts are limited. Sections are checked during each rating, and re-surveyed if bed movement or erosion is noted, or following a significant flood.

Streamflows are estimated using the rating curves and recorded stage data. Streamflows are often estimated beyond the measured bounds of ratings at the section, and these estimates are subject to change as additional rating data are collected, hence all values are considered draft and subject to change until completion of the project.

Rating curves for each site are provided in **Figure 2** to **Figure 8**, with a detailed discussion on rating curve development in the following sub-sections. The development of mean daily stream flow hydrographs are discussed in the following section, with hydrographs provided for each site

4.1.1 Cheakamus FSR

Cheakamus FSR has the most laterally stable cross-section of the three gauging sites as it is bounded by bed rock on the left bank and partially bounded by a bridge abutment on the right bank. This site is susceptible to changes in bed elevation, however, due to aggradation and degradation of the channel. This bed changes may lead to temporary shifts in the rating curve, but they are transient. Further gauging at high and medium flow levels should continue to verify that the current ratings needed to refine the new rating curve. The equation for the rating curve R1, is provided below:

$$Q(S) = 32.346(\,S\text{-}0.42)^{1.419}$$

4.1.2 Cheakamus Pedestrian

Cheakamus Pedestrian is the most challenging site for rating curve development as the cobble bed is mobile during high flow events and the size of the lateral bar on the left bank is modified each year due to sediment transport and deposition. Due to this instability, a total of four rating curve shifts have been identified over the entire study period. A single large event in January 2010 caused a significant shift in the rating curve. Following this event, there was a shift in the lower end of the rating curve towards a lower discharge and a higher stage, indicating aggradation in this reach.

One subsequent shift occurred in July, when daily average discharge peaked at over 100m³/s. These shifts are indicative of a cycle of aggradation and degradation at this site. Due to the dynamic nature of the bed at this site, further gauging over the full range of flow levels is required with priority for higher flows.

Four rating curves were derived for this site and are provided below:

$$Q(S) = 32.14(\,S - 0.09)^{1.746}$$

$$Q(S) = 61.83(-0.20)S^{1.354}$$

$$Q(S) = 25.697(S-0.06)S^{2.211}$$

$$Q(S) = 31.569S^{1.893}$$

4.1.3 Culliton Creek

Only one rating curve shift is apparent at the Culliton Creek site over the period of record (**Figure 7**, **Figure 8**). The channel morphology at this site is controlled by large boulders, which have not been observed to mobilize during the largest events on record. The rating curve shift is likely due to bedload transport, which has led to deposition at this site. Unlike the Cheakamus River, however, it is difficult to correlate the rating curve shift with a single high flow event, and it is likely associated with a series of high flow events that occurred between late October 2009 and mid-January 2010.

There is currently only one high flow event used to fix the upper end of the rating curve at this site (Figure 7), and gauging higher flows is a priority to confirm the upper anchor point. The rating curve equations for Culliton Creek are as follows:

$$Q(S)=20.22(S-0.05)^{1.969}$$

$$Q(S)=20.61(S-0.05)^{1.689}$$

4.2 Stream flows

Using the resulting stage-discharge relations from the rating curves (**Figure 2** to **Figure 7**), discharge and mean daily stream flow hydrographs were developed for each site (**Figure 9** to

Figure 11), with barometric pressure from the Culliton Creek site. Extrapolation occurs at the level above which estimates of flow are greater than measured flows. It is important to take this level into consideration when examining the hydrograph, as the rating curve above this level is undefined.

For practical reasons, rating curve shifts are treated as instantaneous changes when calculating discharge from the 15-minute stage data even though this is actually a continuous process. This assumption is valid when shifts are caused by large events, such as the January 2010 event, and reasonable when inter-rating curve shifts occur from smaller events, or due to partial mobility of bed material, since these are more difficult to detect and result in slight temporary deviations from the applied rating curve.

It is also important to reiterate that WSC Brackendale should not be assumed to be assuredly correct. WSC complete their data approvals in the spring following a monitoring year, so that data reported on the real-time website is unapproved and subject to change if rating curve shifts are identified during the following spring review. Data from 2008 and 2009 have been approved, while at the time of analysis 2011 and 2012 was preliminary. Thus Cheakamus mainstem (Cheakamus FSR, Cheakamus Pedestrian, and WSC Brackendale) hydrographs for 2011-2012 are draft and should be revised once the finalized WSC data are available, and further flow measurements are made. A shift in the curve appears to have occurred around June 1st, 2012.

5 Future Work

Year 4 of this project has involved the continuation of hydrometric monitoring and flow gauging at three established sites (Cheakamus FSR, Cheakamus Pedestrian, and Culliton Creek in **Figure 1**). Preliminary rating curves from Year 1 - 3 have been confirmed, and new rating curves have been developed with updated discharge hydrographs. Future work should involve the continued development and refinement of rating curves for each site. Gauging should be conducted at all sites following the freshet period or high flow events to determine if any rating curve shifts have occurred.

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Tables

Table 1. Summary of discharge measurements to date; entries in bold indicate measurements in Year 4.

Site	Date-Time	Discharge (m^3/s)	Error(m^3/s)	Method
Cheakamus FSR 810 km^2	Feb 10, 2009 11:00	13.0	±0.8	ADCP
	Apr 13, 2009 07:00	16.9	±1.3	ADCP
	Apr 21, 2009 07:00	12.5	±0.6	ADCP
	May 27, 2009 13:58	64.3	±6.7	ADCP
	Sep 17, 2009 10:45	38.6	±3.7	ADCP
	Mar 10, 2010 09:00	16.9	±2.1	ADCP
	Mar 29, 2010 13:30	16.3	± 2.0	ADCP
	May 19, 2010 15:19	54.0	±3.2	ADCP
	Nov 12, 2010 11:30	18.1	±0.6	ADCP
	Jan 17, 2011 15:17	15.8	±1.5	Price Meter
	Jan 28, 2011 13:44	10.3	±0.6	ADCP
	Feb 3, 2011 15:50	11.0	±0.6	ADCP
	Jun 1, 2011 11:00	51.2	±2.6	ADCP
	Jun 6, 2011 12:00	75.4	±3.5	ADCP
	Jan 25, 2012 11:40	12.0	±1.4	ADCP
	Mar 30, 2012 11:27	12.3	±0.6	ADCP
	Apr 10, 2012 09:00	14.6	±1.1	ADCP
Cheakamus Pedestrian 868 km^2	Aug 12, 2008 13:30	36.3	±3.6	Price Meter
	Feb 10, 2009 14:00	13.9	±1.7	ADCP
	Apr 13, 2009 11:00	21.9	±1.6	ADCP
	Apr 21, 2009 09:30	19.4	±1.8	ADCP
	May 27, 2009 17:39	66.7	±5.7	ADCP
	Sep 17, 2009 12:45	42.3	±4.0	ADCP
	Mar 10, 2010 11:15	16.6	±2.1	ADCP
	Mar 26, 2010 11:15	15.3	±1.9	ADCP
	May 19, 2010 14:16	77.3	±2.7	ADCP
	Nov 12, 2010 14:53	22.9	±1.4	ADCP
	Jan 17, 2011 11:30	32.8	±2.3	ADCP
	Jan 28, 2011 11:37	13.9	±2.3	ADCP
	Feb. 3, 2011 12:46	14.7	±2.8	ADCP
	May 12, 2011 15:22	55.7	±1.9	ADCP
	Jun 1, 2011 14:00	60.6	±1.8	ADCP

Site	Date-Time	Discharge (m^3/s)	Error(m^3/s)	Method
	Jun 6, 2011 13:00	80.7	±2.4	ADCP
	Sep 20, 2011 17:07	16.8	±0.4	ADV
	Mar 30, 2012 11:00	21.4	±1.1	ADCP
	Apr 10, 2012 09:00	21.4	±0.6	ADCP
Culliton Creek 82 km^2	Jun 19, 2008 12:20	5.3	±0.4	Rhodamine WT
	Jun 19, 2008 16:00	5.0	±0.4	Salt dilution
	Aug 12, 2008 08:00	4.4	±0.3	Salt dilution
	Feb 3, 2009 12:45	1.7	±0.1	Salt dilution
	Feb 3, 2009 13:00	1.7	±0.1	Salt dilution
	Feb 3, 2009 13:20	1.7	±0.1	Salt dilution
	Apr 13, 2009 13:15	2.6	±0.2	Salt dilution
	Sep 17, 2009 14:57	3.3	±0.2	Salt dilution
	Sep 17, 2009 15:12	3.4	±0.2	Salt dilution
	Nov 16, 2009 13:54	23.1	±1.1	Salt dilution
	Nov 17, 2009 15:15	9.6	±0.5	Salt dilution
	Mar 10, 2010 12:30	2.0	±0.1	Salt dilution
	Mar 26, 2010 14:06	2.4	±0.1	Salt dilution
	May 19, 2010 11:20	7.3	±0.5	Salt dilution
	May 19, 2010 18:35	8.8	±0.6	Salt dilution
	May 19, 2010 11:22	11.1	±0.7	Rhodamine WT
	May 19, 2010 18:40	13.4	±0.9	Rhodamine WT
	Nov 12, 2010 10:55	*3.38*	*±0.2*	Salt dilution
	Feb 16, 2011 13:15	3.6	±0.1	ADV
	Feb 16, 2011 14:21	3.1	±0.3	Salt dilution
	May 12, 2011 12:44	4.2	±0.3	Salt dilution
	Jun 1, 2011 14:15	6.7	±0.6	Salt dilution
	Jun 6, 2011 15:43	10.2	±1.0	Salt dilution
	Sep 20, 2011 12:45	3.4	±0.1	ADV
	Jan 25, 2012 09:30	3.2	±1.0	Salt dilution
	Mar 30, 2012 10:30	2.7	±0.2	Salt dilution
	Apr 10, 2012 10:20	2.0	±0.2	Salt dilution

Table 2. Water level gauge specifications.

Parameter	Specifications
Water depth range	0-4 metre
Sensor accuracy	Accuracy (Typical): 0.05% of net full scale Accuracy (Max Error): 0.1% of net full scale
Resolution	0.001% of full scale for 4 metre water fluctuation range
Outputs	Internal datalogger
Operating temperature	Levelogger: -20°C to 80°C (pressure transducer will be submerged so temperatures will not fall below this range) Barologger: -40°C to 80°C (not submerged)
Voltage supply	Internal batter with a lifetime of 10 years based on one reading/min
Transducer size	7/8" x 6" (22 mm x 154 mm)
Weight	6.3 oz (179 grams)
Housing materials	All rust proof: galvanized thick-walled steel pipe anchored with stainless steel rock bolts and industrial hose clamps to a large boulder or bedrock, stainless steel cable to hang transducer, and a well cap and padlock for security.
Cable	Sensor has no cables unless real-time telemetry is utilized. The direct read cable for a telemetry connection is infra-red and the logger is still sealed from all electrical interference through a Faraday cage design. Armoured cable would be utilized for real-time installations.
Life	3 year warranty for sensors.
Storage capacity	40,000 measurements of pressure and temperature, which at a 15-minute logging interval would allow for 414 days (13.5 months)

Figures

Figure 1. Location map.

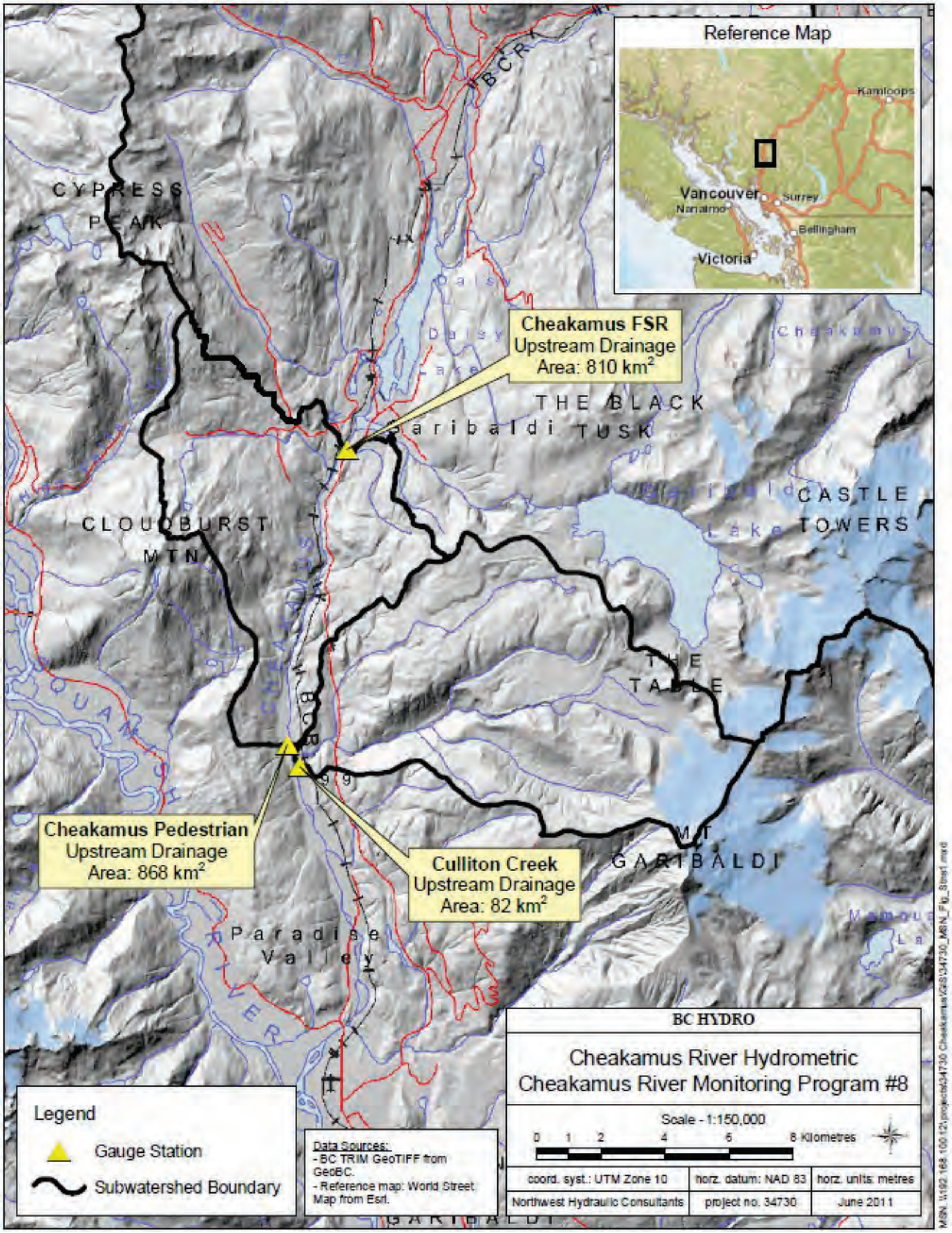


Figure 2. Rating Curve for Cheakamus FSR from February 3, 2008 until present. Discharge measurements made in the past hydrometric years are shown in red.

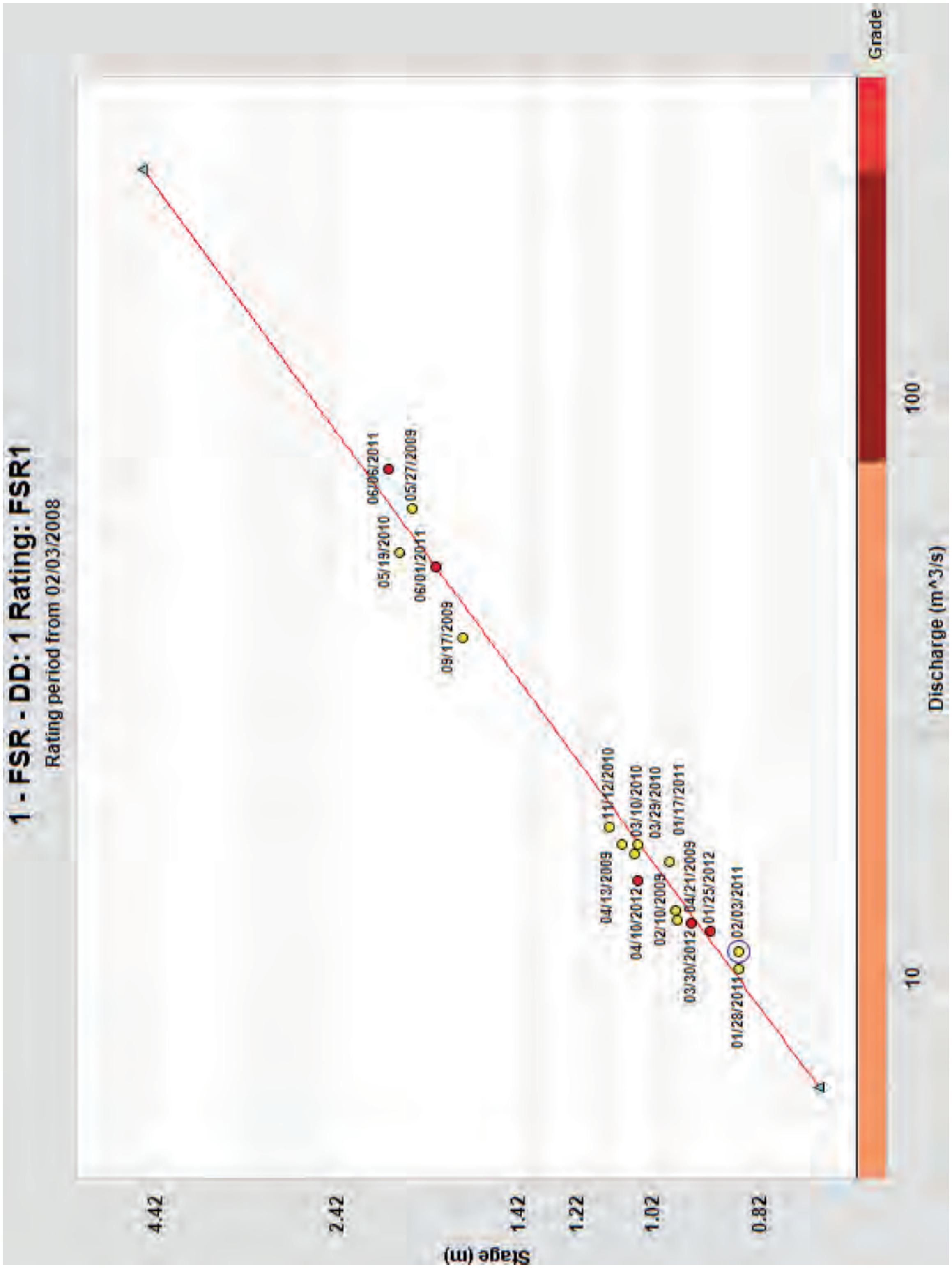


Figure 3. **Rating Curve R1 or Cheakamus Pedestrian effective from the start of record until June 10th 2008. No flow measurements made during this time. Curve based on WSC data.**

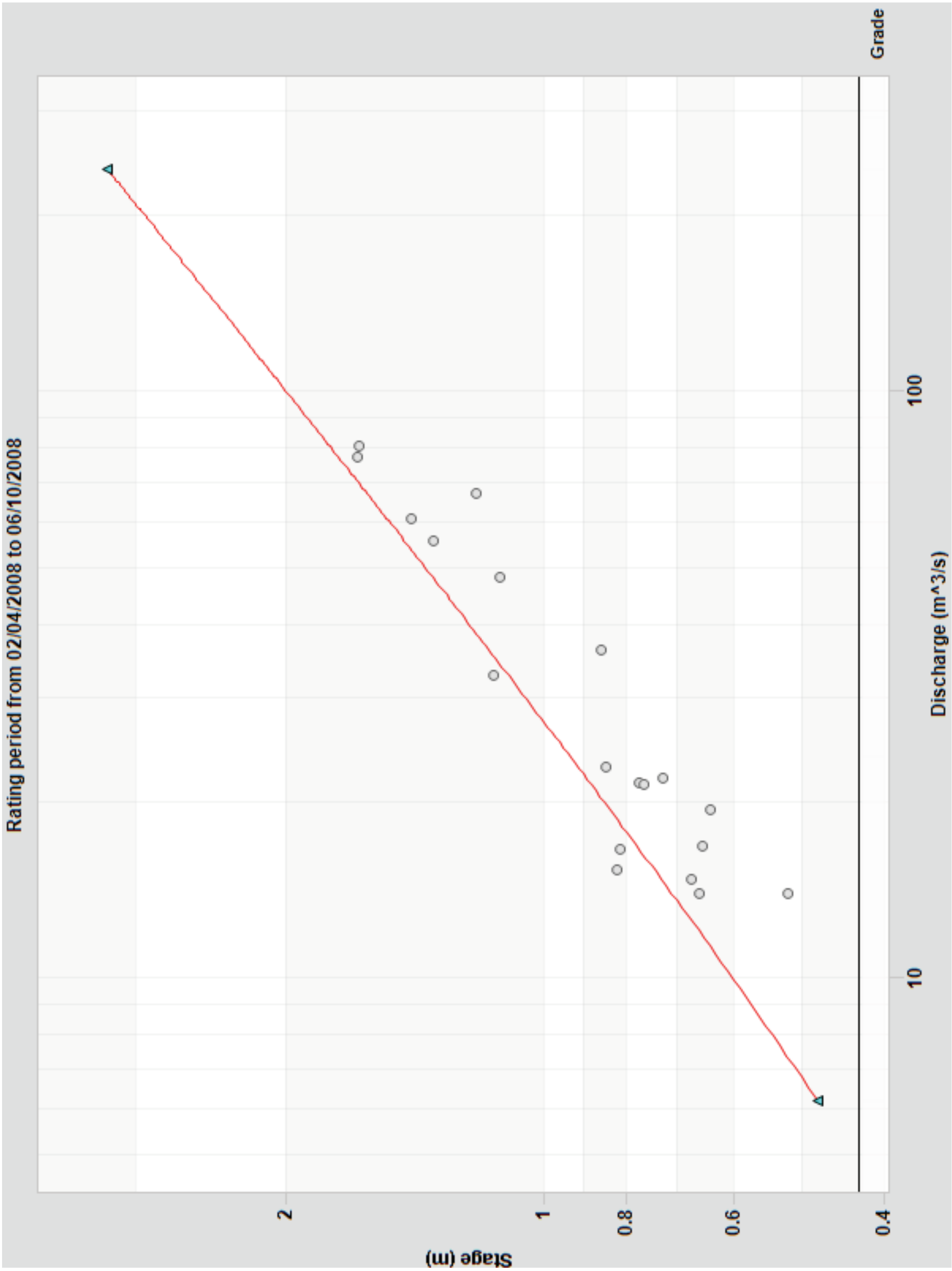


Figure 4. **Rating curve R2 for Cheakamus Pedestrian effective from June 10th 2008 until January 15, 2010.**

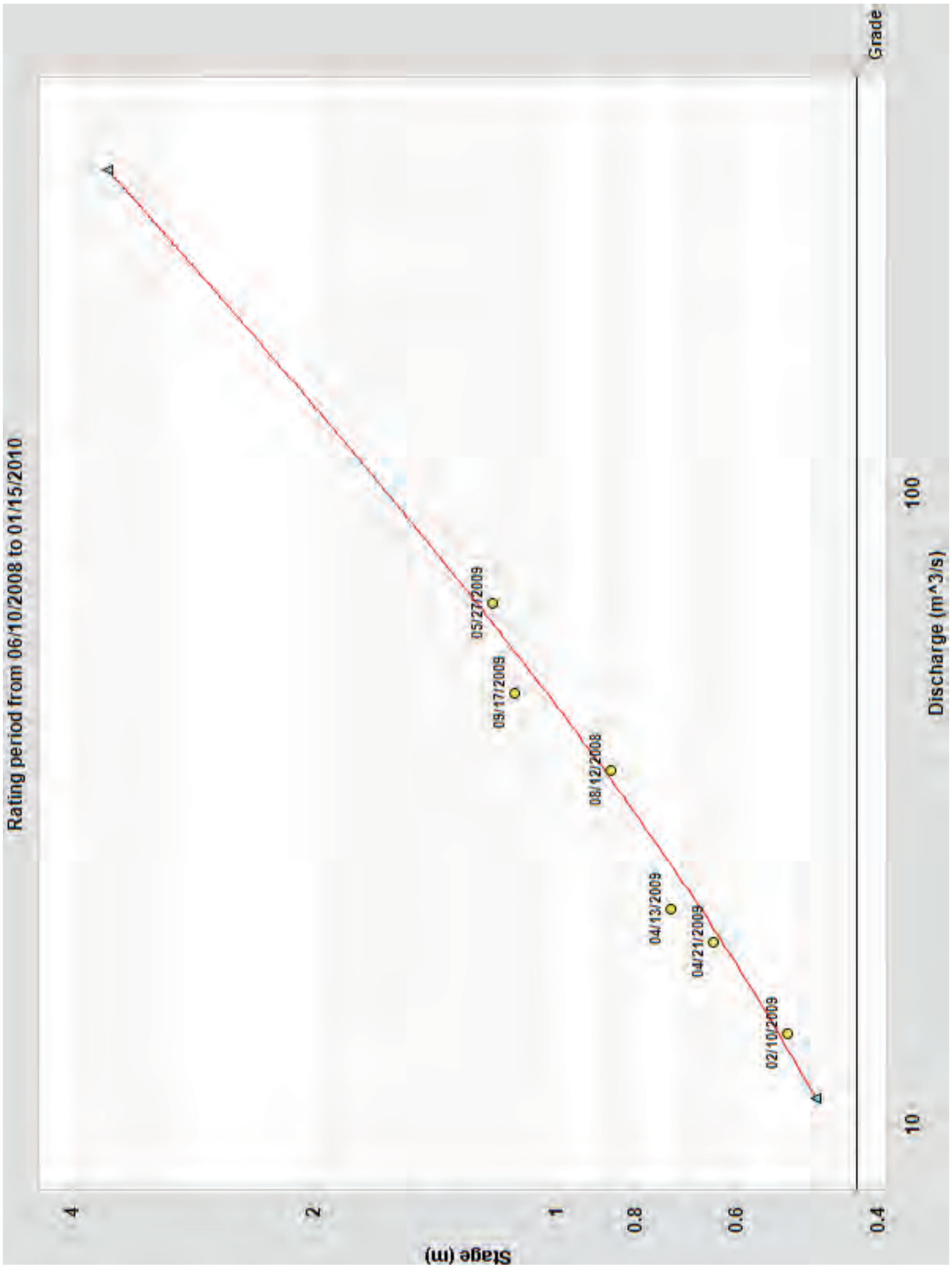


Figure 5. **Rating curve R3 for Cheakamus Pedestrian valid from January 15, 2010 until July 11th, 2010.**

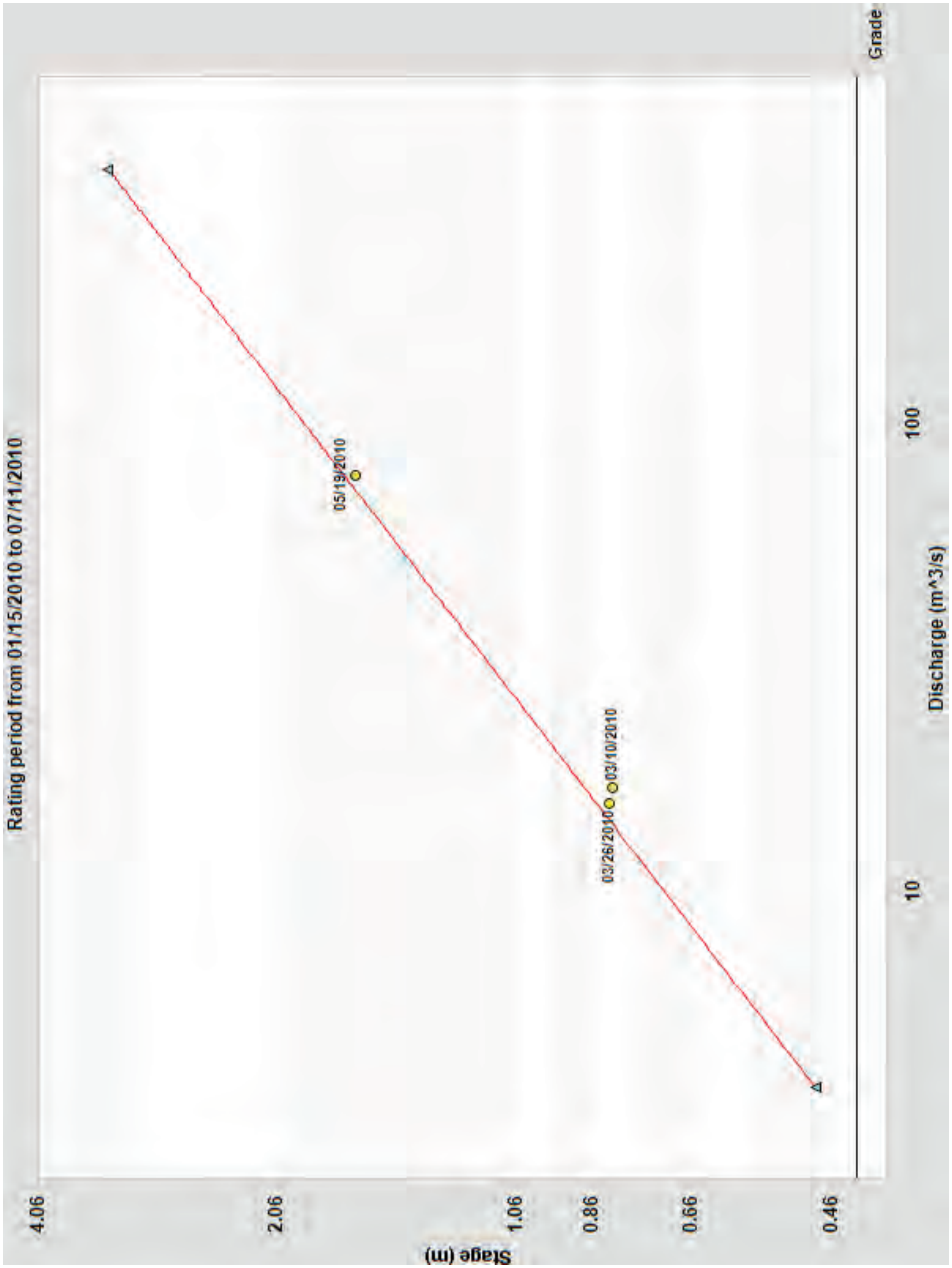


Figure 6. **Rating curve R4 for Cheakamus Pedestrian valid from July 11th, 2010 until present.**

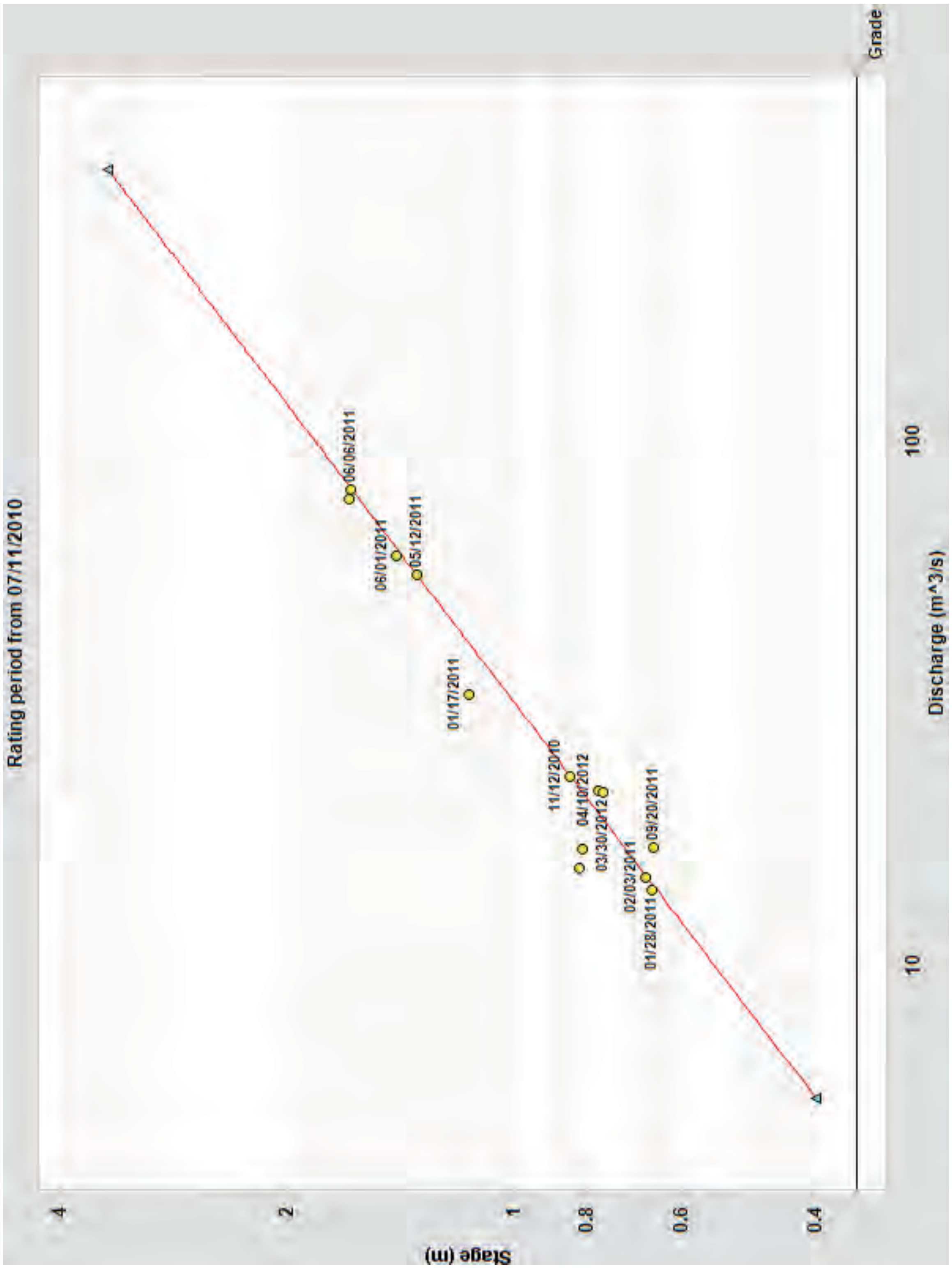


Figure 7. **Rating Curve R1 for Culliton Creek valid from February 4th 2008 until January 15, 2010.**

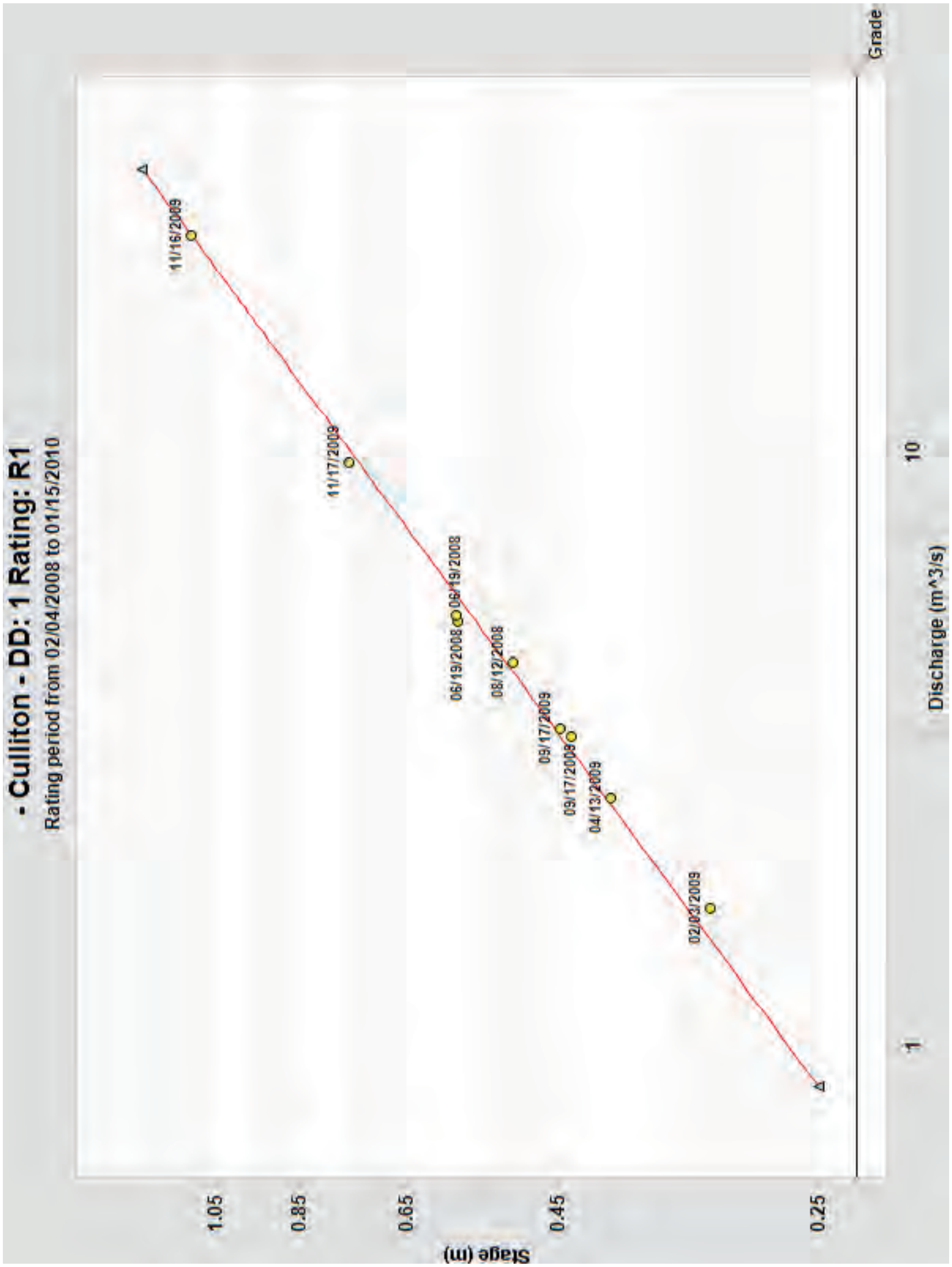


Figure 8. **Current Rating curve R2 for Culliton Creek effective as of January 15, 2010. Discharge measurements made in the past hydrometric year are shown in red.**

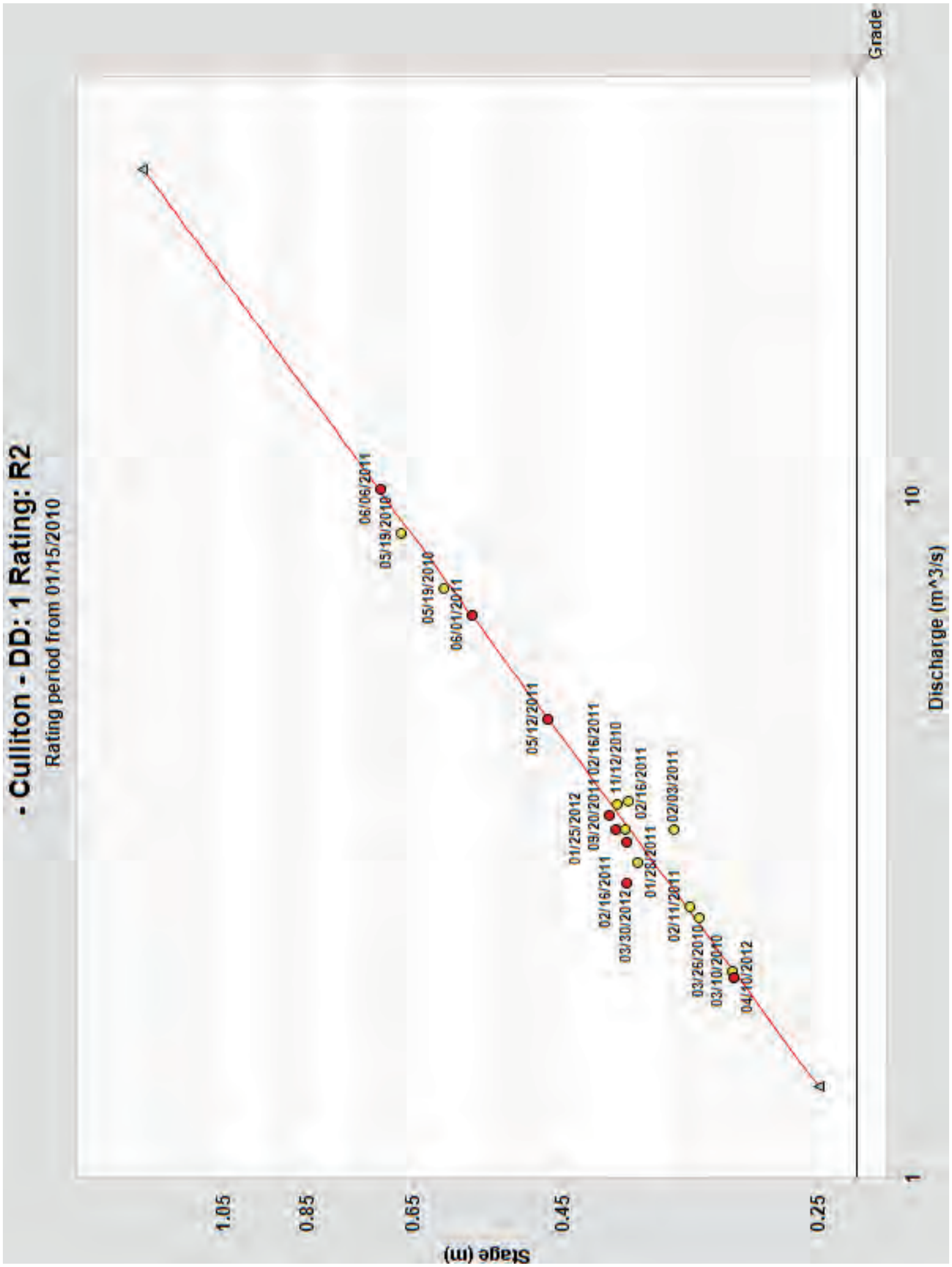


Figure 9. **Discharge hydrograph for the Cheakamus River gauge at the Chance Creek Forest Service Road (FSR) Bridge crossing; estimates of flow over 75 m^3/s are based on extrapolation of the rating curve beyond the highest gauged discharge.**

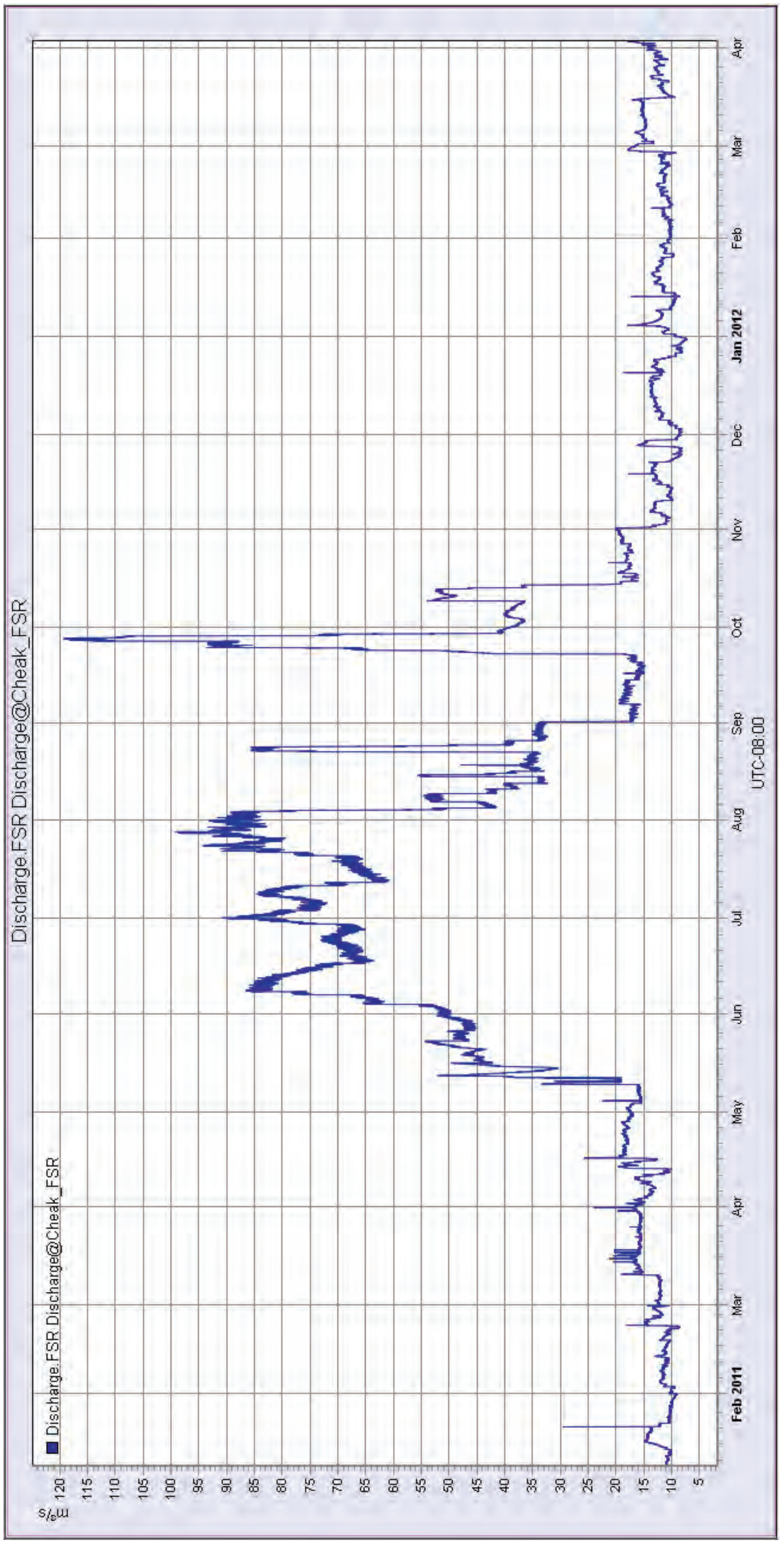


Figure 10. **Discharge hydrograph for the Cheakamus River gauge at the pedestrian suspension bridge upstream of the Cheakamus River-Culliton Creek confluence; estimates of flow over 81 m³/s are based on extrapolation of the rating curve beyond the highest gauged discharge.**

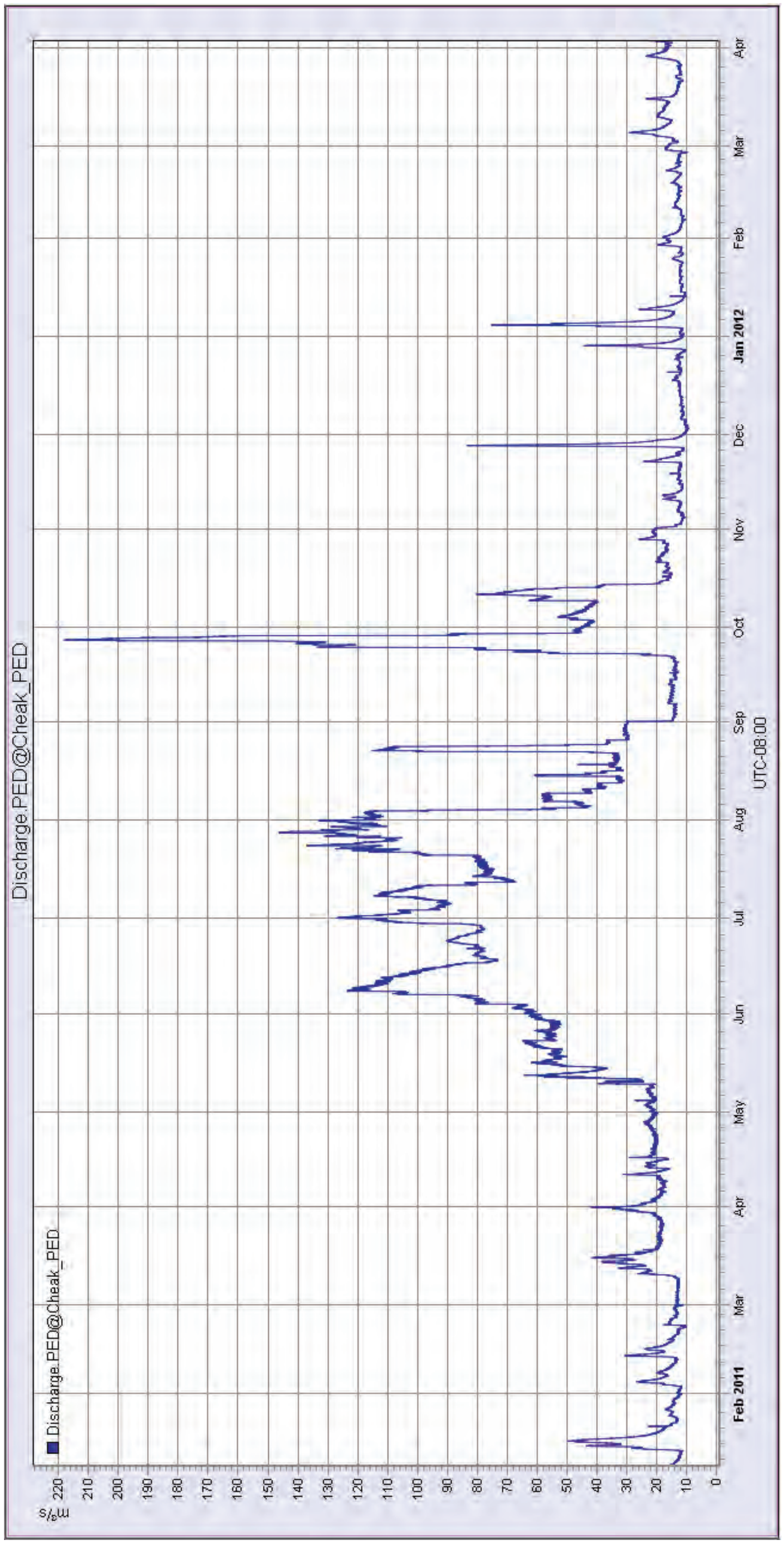
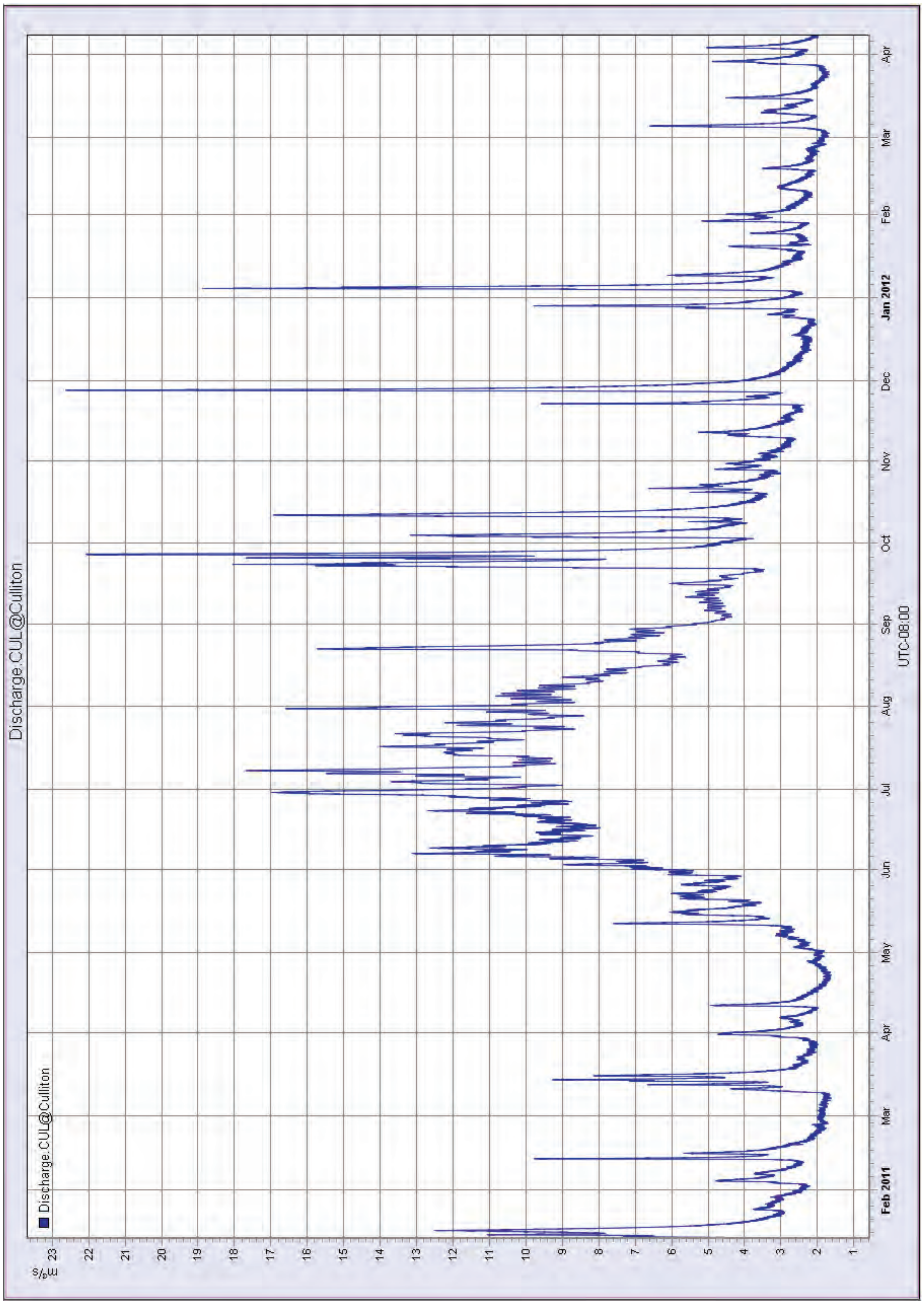


Figure 11. Discharge hydrograph for the Culliton Creek gauge upstream of the Culliton Creek-Cheakamus River confluence; estimates of flow over 23 m³/s are based on extrapolation of the rating curve beyond the highest gauged discharge



Photographs

Photograph 1. Looking downstream from the Chance Creek FSR Bridge at the gauging cross section.

Photograph 2. Cheakamus FSR Hydrometric Station.

Photograph 3. Hydrometric station for the Cheakamus Pedestrian Bridge site.

Photograph 4. Looking up from the Cheakamus Pedestrian Bridge hydrometric station.

Photograph 5. **Looking downstream from the Jack Webster Bridge to the Culliton Creek gauging station. The gauge is located on the left bank.**

Photograph 6. **Culliton Creek Hydrometric Station.**

Appendix A: Hydrometric Site Sheets

Cheakamus River at Pedestrian Bridge			
Stream Name	Cheakamus River		
Installation Date	8-Feb-2008		
Installed By	P. Kuras, W. Skitmore		
Sensor/Data Logger	Solinst Levelogger Gold and Barologger (at Culliton site)		
Sensor/Data Logger Serial Number	1026820		
Logger Location	Right bank of Cheakamus River 50 m upstream of pedestrian bridge		
Logger UTM	10 U 486925 5525145 +/- 10m		
Program Header	N/A		
Logger Time	PST		
Sampling Frequency	15 minute (level), 15 minute (baro)		
Download Frequency	1/yr		
Geodetic Elevation	111m +/- 20m		
Elevation of sensor	0.035		
Geodetic Datum	N/A		
Datum	Local (Spike)		
BM	**Elev.**	**Geodetic**	**Description**
Spike	0		
Orange Bolt	-1.681		rock bolt halfway up pipe, painted orange
PT bolt	-1.743		bottom bolt in stand pipe

Install Document:

Location Photo:


Notes

Barologger located at Culliton Bridge site (10 U 487322 5524428).

Last visit

June 3rd, 2013

Comments

Logger mounting hardware beginning to corrode. Should replace in near future.

Cheakamus River Gauge at Forrest Service Bridge			
Stream Name	Cheakamus River		
Installation Date	8-Feb-2008		
Installed By	P. Kuras, W. Skitmore		
Sensor/Data Logger	Solinst Levelogger Gold and Barologger (at Culliton site)		
Sensor/Data Logger Serial Number	1026828		
Logger Location	Right bank of Cheakamus River on FSR bridge abutment.		
Logger UTM	10 U 488728 5534393 +/- 10m		
Program Header	N/A		
Logger Time	PST		
Sampling Frequency	15 minute (level), 15 minute (baro)		
Download Frequency	1/yr		
Geodetic Elevation	336m +/- 20m		
Elevation of sensor	0.035m		
Geodetic Datum	N/A		
Datum	Local (spike)		
BM	**Elev.**	**Geodetic**	**Description**
Spike	0		
NHC643	1.828		
Mag	1.681		
Orange Bolt	-10.379		spray painted bolt in side of abutment
PT bolt	-13.746		bottom bolt in vertical stand pipe

Install Document:

Location Photo:

Notes

Physical water level should be recorded from orange bolt down to WL as well as from PT bolt to WL
PT sensor is located 3.5 cm above PT bolt.
Barologger located at Culliton Bridge site (10 U 487322 5524428).

Last visit

June 3rd, 2013

Comments

Logger mounting hardware beginning to corrode. Should replace in near future.

Culliton Creek at 'Jack Webster' Bridge

Stream Name	Culliton Creek
Installation Date	8-Feb-2008
Installed By	P. Kuras, W. Skitmore
Sensor/Data Logger	Solinst Levelogger Gold and Barologger
Sensor/Data Logger Serial Number	1023536 (level) 1024987 (baro)
Logger Location	Left bank of Culliton Creek 50 m downstream of bridge
Logger UTM	10 U 487350 5524462 +/- 10m
Program Header	N/A
Logger Time	PST
Sampling Frequency	15 minute (level), 15 minute (baro)
Download Frequency	1/yr
Geodetic Elevation	127m +/- 20m
Elevation of sensor	0.037m
Geodetic Datum	N/A
Datum	Local (Spike)

BM	**Elev.**	**Geodetic**	**Description**
Spike	0		
NHC518	0.435		
NHC544	0.209		
Staff Gauge 'zero'	-6.211		
Orange Bolt	-5.599		spray painted bolt in rock
PT bolt	-6.281		bottom bolt in stand pipe

Install Document:

Location Photo:

Notes

PT sensor is located 3.7 cm above PT bolt.
Barologger located at 10 U 487322 5524428

Last visit

June 3rd, 2013

Comments

Logger mounting hardware beginning to corrode. Should replace in near future.