Washington State Department of Ecology

Environmental Assessment Program

Standard Operating Procedures for Correction of Continuous Stage Records Subject to Instrument Drift, Analysis of Instrument Drift, and Calculation of Potential Error in Continuous Stage Records

Version 1.1

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Signatures on file

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Although Ecology follows the SOP in most instances, there may be instances in which Ecology uses an alternative methodology, procedure, or process.

SOP Revision History

Revision Date	Rev number	Summary of changes	Sections	Reviser(s)
10/5/2012	1.0	New SOP	all	Kammin
12/30/2015	1.1	Added language indicating newly developed automated error analysis application.	1.1	Shedd
12/30/2015	1.1	Added Sensitivity Drift Analysis and Correction method.	6.2.2.3	Shedd
12/30/2015	1.1	Updated References section.	10.2	Shedd
12/30/2015	1.1	Grammatical and formatting.	all	Shedd
12/31/2015	1.1	Recertified	all	Kammin

1.0 Purpose and Scope

1.1 This Environmental Assessment Program (EAP) Standard Operating Procedure (SOP) describes methods of correcting continuous stage records subject to instrument drift. This document explains methods of identification, analysis, and management of various types of instrument drift occurring in continuous stage records. Methods of calculation of potential error caused by instrument drift are also discussed. An automated error analysis application, developed after the initial writing of this document identifies and computes error introduced to daily flow values caused by instrument drift. However, staff must understand the basis of these calculations in order to correctly evaluate and apply the results of the error analysis application.

2.0 Applicability

2.1 EAP staff will follow this Standard Operating Procedure when correcting stage records to match gage height observations with corresponding points in the stage record.

2.2 Staff will follow the methods presented in this document to identify and analyze instrument drift. Refer to this document when analyzing and correcting potential error introduced to daily flow values caused by logger drift.

3.0 Definitions

3.1 Primary Gage Index (PGI)—The most stable and reliable gage at a site, the PGI serves as the base gage for the station to which the recording gage is directly referenced. Consider all other gages at a station as secondary.

3.2 Gage Height—The water surface level, usually measured in hundredths of a foot on a readable stationary gage.

3.3 Calibration—The check of a measuring instrument against an accurate standard to determine any deviation and correct for errors. For purposes of the following discussions regarding calibration, the ‘measuring instrument’ refers to the data logger. The ‘accurate standard’ refers to the gage height of the PGI. ‘Correct for errors’ in this context does not necessarily mean direct correction of the instrument in the field, rather the correction or accounting of errors in the stage record resulting from drift.

3.4 Potential Error—A calculated percentage expressing the highest probable error in the stage record for a designated time period, usually a day or a year.

3.5 Drift— An undesired change in instrument output over time, not a function of real changes in water surface elevation (Freeman et al., 2004).

3.6 Zero Drift— A shift between an initial calibration (a point at which the record matches the PGI observation) and later calibrations where the differences between PGI observations and instrument output are equal (Freeman et al., 2004).

3.7 Stable Drift—A zero drift condition in which the calibration shift stabilizes over time and reflects a consistent difference between true gage height and instrument output. Note that stable drift can contain relatively small errors due to minor variations between gage height and instrument output.

3.8 Data Shift—A factor used to compensate for instrument drift that represents the difference between PGI observations and the logged stage record. These shift factors adjust the stage record to individual gage height observations. Data shifts are applied automatically to a data set whenever a report is generated from Hydstra™.

3.9 Sensitivity Drift— A change in slope of the best fit straight line between an initial calibration and later calibrations where the differences between true gage height and instrument output changes linearly (Freeman et al., 2004). Sensitivity drift exhibits a clear pattern in the data, trending either upward (positive drift) or downward (negative drift) as stage increases or decreases, with a strong correlation between corrected stage and data shift.

3.10 Random Drift— A condition in which drift occurs, but lacks a specific type or identifiable cause. The amount of drift or the distance between corresponding points of initial and later calibrations are not consistent. We assume random drift occurs incrementally over time between calibrations.

3.11 Measurand— The value of the measured physical property. For purposes of this discussion the measurand value corresponds to the gage height of a body of water.

3.12 Aliased Data Set—In the context of this SOP, a raw stage dataset where the Hydstra™ parameter reference is changed to that of corrected stage without applying data shifts. This "aliased" data set is then compared to the original raw data set, to which data shifts are applied, to assess the magnitude of potential drift error.

4.0 Personnel Qualifications/Responsibilities

4.1 Users of this document will typically work in the Hydrogeologist job classification. Mostly those with Principle Investigator or Basin Lead responsibilities will apply the procedures presented herein. Sufficient training in the Hydstra™ data management software is required to perform the operations in this SOP.

5.0 Equipment, Reagents, and Supplies

5.1 An Ecology issued computer with network and web access

5.2 Access to Hydstra™ Time Series Management software.

6.0 Summary of Procedure

6.1 Correction of Instrument Drift

6.1.1 At the time a flow monitoring station is initially installed the datalogger and transducer are calibrated such that the reported stage matches the water level read from the PGI. This equipment detects and reports fluctuating differences in gage height as flow increases or decreases at predetermined time intervals (typically 15 minutes). Over time the value reported by the instrument may drift from the actual water level at the PGI resulting in an inaccurate stage record. This condition requires correction if the drift exceeds the variability (water surface bounce) in the water level observed at the PGI. If the record goes uncorrected, erroneously reported discharge values will result.

6.1.2 Depending on the type and severity of the drift, the data logger may be recalibrated in the field at the time of the gage height observation. However, field recalibrations should remain limited to circumstances when severe drift error, or when damage or movement of station infrastructure occurs. If consistently severe random drift persists, take steps to mitigate the situation such as increasing sampling times, installing bubble chambers, and programming regular auto-purging on bubbler systems. Clean and, if necessary, replace submersible transducers. Check the mounting and calibration of radar levels. If severe drift conditions continue consider repositioning infrastructure or moving the entire station to a more suitable location.

6.1.3 The underlying assumption in most cases of instrument drift is that it occurs incrementally over time. This assumption holds that the least amount of drift is found at the start of the data set or the initial calibration and progresses over time until reaching the next calibration point where the amount of drift is presumed greatest.

6.1.4 Likewise the same assumption holds in the correction of logger drift. Adjustments to the data set are made on a time-weighted basis such that the gap between the logger record and observed gage heights closes incrementally from the start of the data set to the end of the data set.

6.1.5 There are two ways to apply corrections to data sets in which drift has occurred: Time-weighted filter adjustments and data shift adjustments.

6.1.5.1 Time-weighted Filter Adjustments

6.1.5.1.1 We apply time-weighted filter adjustments directly to the raw stage record. This method is largely outdated and no longer the preferred procedure. We discontinued this method beginning with the 2008 water year. We only apply time weighted filter adjustments to records prior to 2008.

6.1.5.1.2 The time-weighted filter adjustment method uses explicit changes to the data set to correct the continuous data incrementally from one observed stage height to the next. See Chapter 4 of the Hydstra User's Manual for detailed instructions on how to make time-weighted data adjustments.

6.1.6 Data Shift Adjustments

6.1.6.1 The current method for correcting stage height data uses the Hydstra™ data shift function to apply shift factors to correct for instrument drift. This method provides significant advantages over the previous method, both in terms of ease of use and immediacy of results. Data shift capabilities permit corrections to telemetered stage records immediately upon entry of independent PGI observations into Hydstra™. These corrections are automatically applied to both the archive and telemetry data records.

6.1.6.2 The use of data shifts renders the time-weighted adjustments for the most part unnecessary. The new process for correcting continuous data is detailed in the Hydstra User's Manual addendum "Preparing Continuous Data and Data Shifts for Annual Review".

6.2 Analysis of Logger Drift

6.2.1 Prior to submittal of annual discharge records for senior-level review carefully analyze the stage record as well as the record of corrections to determine the types of drift occurring throughout the record. The type of drift will affect how the final stage record is edited, how daily error percentages are determined, as well as influence the overall evaluation of the quality of the discharge record.

6.2.2 There exists four basic types of logger drift; random, sensitivity, stable, and zero drift. Figure 1 illustrates sensitivity and zero drift.

6.2.2.1 Random drift, characterized by contiguous differences between the record and PGI observations are not consistent in their magnitude. Random drift does not meet the requirements of stable drift described below. The differences between record and PGI observations do not form a linear relationship consistent with sensitivity drift, also described below.

6.2.2.2 We adjust random drift in the final data record by applying either time-weighted filter adjustments or data shifts.

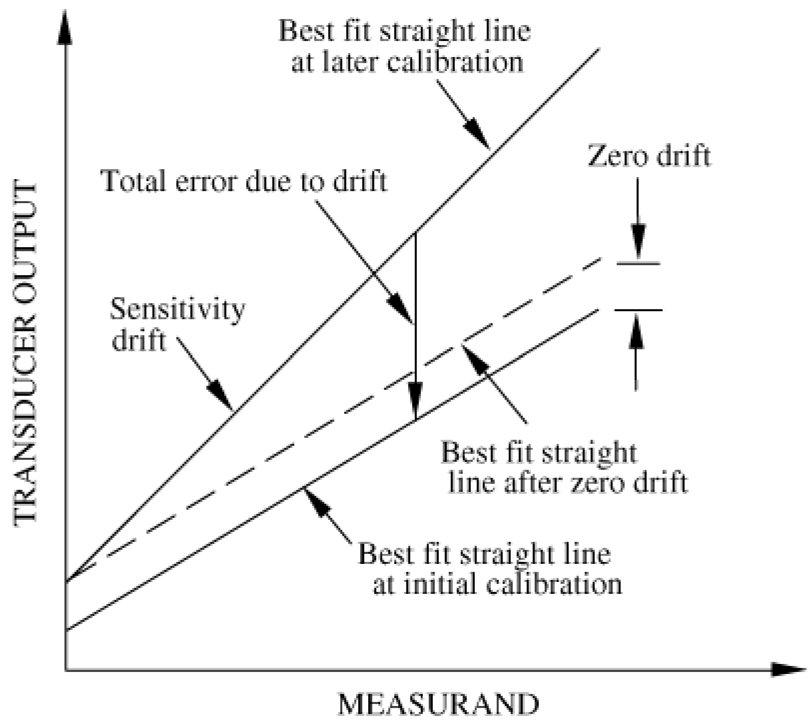


Figure 1. Illustration of zero and sensitivity drift. (Illustration from USGS Publication, Use of Submersible Pressure Transducers in Water-Resources Investigations, pg. 13.)

6.2.2.3 Sensitivity Drift Analysis and Correction

6.2.2.3.1 In preparation for the annual review process, analyze instrument drift using linear regression to determine whether or not sensitivity drift occurs at each station. Do this by regressing the corrected stage values against the data shifts.

6.2.2.3.2 Sensitivity drift will exhibit a clear pattern in the data, trending either upward (positive drift) or downward (negative drift) as stage increases, and shows a strong correlation ($r \geq 0.80$) between corrected stage and data shift.

6.2.2.3.3 If sensitivity drift is found at a station, data shifts alone may not adequately correct it, as they may tend to underestimate the magnitude of drift at high flows. In cases of more extreme sensitivity drift, use the results of the stage vs. data shift regression to derive a "drift curve" that varies the magnitude of drift by stage height. Steps for correcting sensitivity drift in a data set are detailed below.

6.2.2.3.4 If the results of the stage vs. data shift regression detailed above are $r \geq 0.80$, note the linear regression equation on the HYPLOTXY output (in the form $y = mx + b$) for use in subsequent steps.

6.2.2.3.5 In the Hydstra Data Workbench (HYDMWB), export the stage data (variable 232.00) from the data archive to a working file. This document will refer to this working file as the "B" file, although the actual file suffix may differ if the station in question already contains a B file.

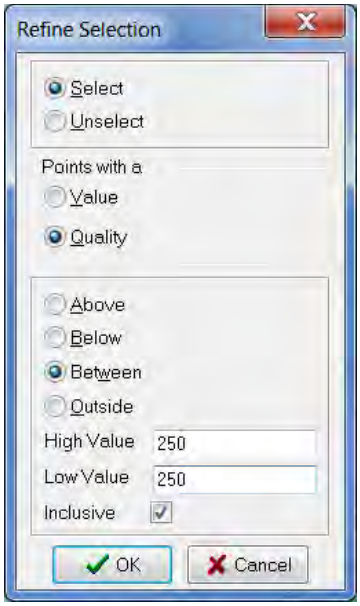
6.2.2.3.6 Eliminate all data blocks from the working file that are outside the bounds of the water year(s) of interest (i.e. those water years for which you are conducting the drift analysis/correction).

6.2.2.3.7 If there are any data in the B file that have a quality code of 165 or greater, these will have to be temporarily changed to a proxy quality code that is less than 165. The proxy code you choose should not exist elsewhere in the data set, and you should choose one proxy per "bad" data code. For example, if the file contains data coded QC 179 and data coded QC 250, you can change the QC 179 data to QC 75, and the QC 250 data to QC 77. Without making these changes Hydstra will not be able to properly calculate corrected data values in subsequent steps.

6.2.2.3.8 To recode data with a given "bad" quality code, first select all data blocks, then navigate to the Graphics tab.

6.2.2.3.9 Select all data points using the  icon.

6.2.2.3.10 From the Selection menu choose "Refine Selection…" and refine the selection such that only points with the given bad quality are selected and click "OK". (NOTE: You must deal with each bad quality code individually. Do not attempt to capture different quality codes in a single operation).

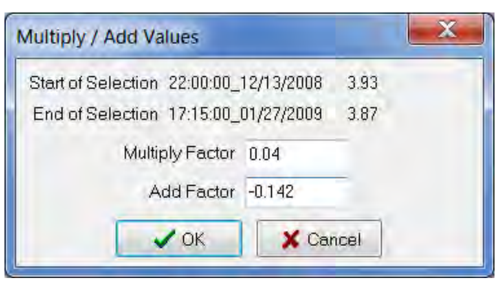


6.2.2.3.11 Now that only the desired data are selected, use the Quality Edit ( ) icon to change the given bad quality code to your desired proxy code. Repeats steps 6.2.2.3.7 through 6.2.2.3.10 for each bad quality code (QC ≥ 165) found in the data set.

6.2.2.3.12 Copy the B file to another working file (which this document will refer to as "C"), leaving the original B file intact.

6.2.2.3.13 Open the C file, highlight all data blocks, and navigate to the Graphics tab.

6.2.2.3.14 Select all data using the icon. Then, with all data points selected, from the Filter menu select "Multiply/Add…" Enter the "m" and "b" factors from the y = mx + b drift curve equation derived earlier, and click "OK".

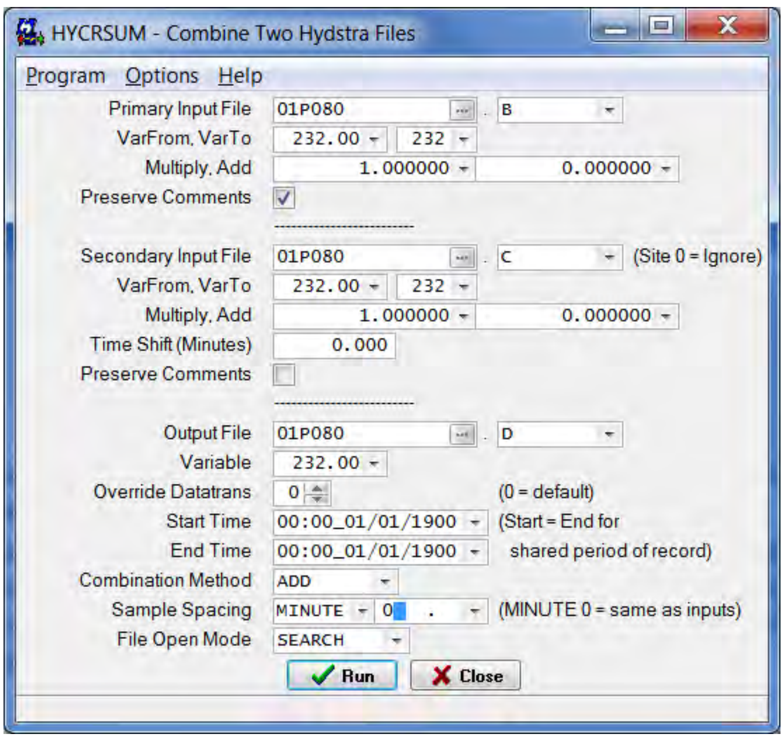


6.2.2.3.15 A "Quality Edit" prompt will pop up. Click "OK". The resulting data set is a continuous record of corrections to the stage record, based on the sensitivity drift curve. Close and save the C file.

6.2.2.3.16 There are now two working files: one containing the continuous stage data for the water year(s) of interest, and one containing a record of sensitivity drift corrections for those same stage data. Now we will combine these data sets using HYCRSUM.

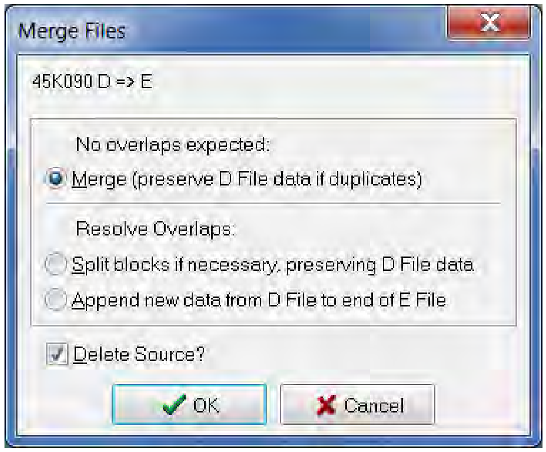
6.2.2.3.17 Find and open HYCRSUM using the "Programs by Name" grouping in HYXPLORE (the main Hydstra interface).

6.2.2.3.18 Configure HYCRSUM per the screenshot below. Note that the "Preserve Comments" box is checked for one, but not both input files. Since the C file is a copy of the B file, which is a limited copy of the Archive, comments appearing in each file will be the same. We only need preserve them from one of the files. Click "Run" to create a D file that adds data values in the C file (corrections) to the data values in the B file (raw stage).



6.2.2.3.19 The data set in the D file must now be re-archived. However, this cannot be done directly, as the time ranges for the two files are not the same (since the D file represents a subset of the archived stage data). Below are the steps for archiving the D file.

6.2.2.3.20 First, make a full copy of the Archive file (we'll call it "E")
Drag the D file onto the E file, keeping the default selection from the "Merge Files" prompt of preserving D file data if duplicates are encountered.



6.2.2.3.21 Now drag the E file back onto the Archive, again using the default selection from the "Merge Files" prompt. This will embed the corrected stage data into the archive data set.

6.2.2.3.22 This method should only be used to correct sensitivity drift that is extreme in magnitude (large differences between logged and observed stage heights) and consistent in occurrence (as evidenced by a high correlation coefficient in the stage vs. data shift regression).

6.2.2.3.23 Once this regression is applied to the continuous data set, the existing data shifts must be replaced by new data shifts that adjust the regressed continuous data to the primary gage index observations. This is a critical step, and without it the resulting data set could be wildly inaccurate. It is best to temporarily create an aliased variable 233 data set from your newly corrected data, and run SHU Review Raw based on this data set. This will render an updated list of staff gage observations compared to corrected logger values. The original data shifts can be replaced based on the SHU Review results.

6.2.2.3.24 Remember to change back to the original value any quality code previously switched to a temporary proxy code of less than 165. This reverses the action taken in section 6.2.2.3.11.

6.2.2.4 Stable drift Analysis

6.2.2.4.1 Stable drift occurs when the difference between recorded stages and PGI observations remains steady and nearly equal over the course of two or more site visits.

6.2.2.4.2 Neglecting to address stable drift can result in substantial inaccuracies of published annual potential error determinations as well as inappropriate data quality assignments.

6.2.2.4.3 Consider periods of stable drift when assessing potential error caused by instrument drift. We define stable drift as a set of two or more contiguous differences between logger recordings and gage height observations where the range of differences between highest and lowest exceeds no more than 0.03 feet and the standard deviation of the differences do not exceed 0.015 feet.

6.2.2.4.4 The automated error analysis application, referred to in section 1.0 of this document identifies and computes stable drift errors and applies these errors to the daily record of potential error.

6.2.2.4.5 Stable drift error takes the form: $U = \frac{\sum_{n}^{i=1} \left| \left(\frac{x-y}{x} \right) \right|_i}{n} * 100$

Where U = mean error for the stable drift period expressed in percent
x= discharge corresponding to an observed gage height
y= discharge corresponding to offset logger value
n=number of x and y pairs in the stable drift period.

6.2.2.4.7 Offset logger value in the above equation is expressed in the form

$\emptyset = r - \frac{\sum_{n}^{i=1} (r-g)_i}{n}$

Where $\emptyset$=offset logger value (in feet)
r=raw logged stage value (in feet)
g=observed gage height value (in feet)
n=number of r and g pairs in stable drift period.

6.2.2.4.8 Appendix A provides a table and brief summation presenting the identification and calculation methods involved in computing stable drift error.

6.3 Potential Error Calculation and Quality Code Assignments

6.3.1 In finalizing water year data we report the amount of potential error introduced to the record from instrument drift and assign an appropriate quality designation.

6.3.2 The automated error analysis application determines potential error due to instrument drift and calculates daily differences in predicted discharge between the aliased raw record and the original raw record.

6.3.3 To correctly calculate potential error through the automated error analysis application, do not include in the drift assessment erroneously recorded data due to instrument damage, low battery voltage, anomalous spikes or any other invalid data. In addition, exclude periods of channel icing from the assessment. For periods of backwater condition, if a valid rating curve exists for the backwater period, include the continuous data for that period in the assessment. Otherwise, exclude these data from the assessment. While these circumstances may still produce a correct record of gage height, in the absence of a valid stage-discharge relationship the error calculations will be incorrect.

6.3.4 Treat stage records influenced by tidal spikes the same as normal stage records. While these spikes represent a temporary breakdown of the stage-discharge relationship, a comparison of tidally influenced stations in Ecology's streamflow monitoring network showed an impact of less than 2% of total discharge.

6.3.5 In order to preclude erroneous data from reporting assign a quality code of 200 to any erroneously recorded data in the aliased raw data set, as well as to periods with invalid stage and discharge relationships (i.e., backwater, ice-impacted, etc.). If erroneous data reports, the resulting calculated error does not reflect instrument drift even if data points match and the percent error is zero. Zero percent values computed from erroneous stage data and subsequently calculated in the annual drift error will cause an underestimation of the annual drift error. Erroneous data assigned quality code 200 will show up on the daily discharge table as a blank value and excluded from all calculations.

6.3.6 Potential error caused by instrument drift is calculated in the following form:

$$e = \frac{|y-x|}{x} * 100$$

Where e = the absolute value of the percent error between daily discharge reported from the raw record and discharge reported the aliased record. Thus,

x= mean daily reported discharge from the raw record (with data shifts applied) and

y= mean daily reported discharge from the aliased raw record.

6.3.7 Continuous stage data collected during periods of unstable drift are assigned quality codes based on the results of the automated error assessment. Quality codes derived from the error assessment application are determined using a tiered approach whereby the difference and percent difference between raw and adjusted data sets are used to determine the appropriate quality code:

Tier	***% Diff***		***Diff Q***	***QC***
1	0-20%	OR	<0.5	2
2	≥20%	AND	≥0.5	50
3	≥50%	AND	≥5	164
4	≥100%	AND	≥50	179

6.3.8 Data must meet both the % Diff and Diff Q criteria to be coded according to that tier. If data meets one, but not both criteria, it falls into the tier above. For example, if a day has a difference of 100% and a difference in Q < 5 cfs, that meets the criteria for tier 2, and thus coded 50. If the difference was >100% and the difference in Q was greater than 5 cfs but less than 50 cfs, it would get a code 164. In order for the data to be coded 179, it would have to have a percent difference greater than 100% and a difference in discharge greater than 50 cfs.

6.3.9 Quality codes are applied on a daily basis. If a day meets the criteria for a given tier, all stage values for that day are coded according to that tier.

6.3.10 For a detailed description on how to quality code the continuous data, refer to the addendum to the Hydstra™ User's Manual titled "Preparing Continuous Data and Data Shifts for Annual Review."

7.0 Records Management

7.1 Several databases in the Hydstra™ Time Series Management Software store continuous stage records, instantaneous gage height observations, and applied data shifts.

7.2 It is possible to compile Data Review Worksheets at any time as these are produced from stored records in the Hydstra™ Time Series Management Software.

7.3 Sensitivity drift regression run in the Hydstra™ regression analysis package HYPLOTXY are saved in a graphics format such as jpeg.

7.4 Typically staff will store analyses of instrument drift including stable drift analysis in Microsoft© Excel® workbooks.

7.5 All electronic files and Hydstra™ related materials are saved to a folder on a network server. The contents of this server are backed up daily to prevent data loss.

8.0 Quality Control and Quality Assurance Section

8.1 Senior staff, through the senior-level review process evaluates all submitted records and data analyses materials for accuracy and compliance with the methods presented in this document.

9.0 Safety

9.1 Most of the work described in this document takes place in an office setting. Staff will follow building and office safety policies and procedures when working in the office. Refer to the agency safety manual (Washington Department of Ecology, 2008) for information regarding building and office safety.

9.2 When collecting streamflow information in the field, staff will follow all EAP safety policies and guidelines. Refer to the EAP Safety Manual (EAP, 2015) for further information.

10.0 References

10.1 Freeman, L., et al., 2004. Use of Submersible Pressure Transducers in Water-Resources Investigations: Chapter A of Book 8, Instrumentation Section A Instruments for Measurement of Water Level. United States Geological Survey, Publication.

10.2 Environmental Assessment Program, 2015. Environmental Assessment Program Safety Manual, March, 2015. Washington State Department of Ecology, Olympia, WA.

10.3 Washington Department of Ecology, 2008. Washington Department of Ecology Safety Program Manual, July, 2008. Washington State Department of Ecology, Olympia, WA.

Appendix A

Table 1 below presents analysis of 31 samples submitted by Freshwater Monitoring Unit staff. The samples as submitted, consisted of date and time stamped logger recordings and corresponding primary gage index (PGI) observations. The samples were subjectively identified by staff as stable drift periods.
The criteria of range (0.03 ft.) and standard deviation (0.015 ft.) are the respective averages of the 31 sample sets. As a result, 22 of the samples met or exceeded the average range and standard deviation of the 31 samples. The 22 samples meeting the criteria yielded a mean error of 2.4 percent.

The true error of any stable drift period may be higher or lower than the 2.4 percent figure. The high and low error values in the sample set were 8.4 and 0.4 percent respectively. The standard deviation of the 2.4 percent average was 1.9 percent. The median error was 2.1 percent.

Date	Log St.	Log St. Q	Obs St.	Obs St. Q	Diff Ft.	Avg.Diff Ft.	Log-Avg. Diff Ft.	Log-Avg. Diff Ft. Q	% Diff
Sample 1	**35L050 (from rating 10)**								
2/19/2008	5.73	27.5	4.96	10.6	0.77	0.78	4.95	10.4	**1.89**
2/28/2008	5.69	26.4	4.9	9.11	0.79	0.78	4.91	9.36	**2.74**
								Average	**2.32**
Sample 2	**01A140 (from rating 5)**								
10/11/2007	7.61	2821	7.01	1688	0.6	0.61	7	1673	**0.89**
10/25/2007	8.13	4433	7.51	2593	0.62	0.61	7.52	2615	**0.85**
								Average	**0.87**
Sample 3	**01A140 (from rating 5)**								
11/8/2007	7.34	2250	6.56	1060	0.78	0.8	6.54	1035	**2.36**
11/15/2007	7.49	2551	6.67	1200	0.82	0.8	6.69	1226	**2.17**
Sample 4	**01A140 (from rating 2)**								
12/13/2007	8.21	4776	6.42	966	1.79	1.80	6.41	956	**1.04**
12/18/2007	8.16	4559	6.36	909	1.8	1.80	6.36	909	**0.00**
1/3/2008	8.06	4151	6.26	823	1.8	1.80	6.26	823	**0.00**
1/24/2008	7.84	3418	6.02	649	1.82	1.80	6.04	661	**1.85**
								Average	**0.72**
Sample 5	**01A140 (from rating 2)**								
2/6/2008	5.93	595	5.81	531	0.12	0.10	5.83	540	**1.69**
2/14/2008	6.39	937	6.29	848	0.1	0.10	6.29	848	**0.00**
2/28/2008	6.2	775	6.1	700	0.1	0.10	6.10	700	**0.00**
3/13/2008	6.64	1198	6.56	1109	0.08	0.10	6.54	1087	**1.98**
3/19/2008	6.32	874	6.2	775	0.12	0.10	6.22	791	**2.06**
4/3/2008	5.99	630	5.92	589	0.07	0.10	5.89	572	**2.89**
4/10/2008	6.03	655	5.91	583	0.12	0.10	5.93	595	**2.06**
4/24/2008	6.07	680	5.97	618	0.1	0.10	5.97	618	**0.00**
Sample 6	**01A140 (from rating 2)**								
4/29/2008	6.93	1571	6.92	1556	0.01	0.03	6.90	1528	**1.80**

4/30/2008	6.79	1381	6.75	1330	0.04	0.03	6.76	1342	**0.90**
5/13/2008	6.72	1293	6.68	1245	0.04	0.03	6.69	1257	**0.96**
Sample 7	**01C070 (from rating 4)**								
10/7/2007	2.19	21.6	2.16	20	0.03	0.03	2.16	20	**0.00**
10/25/2007	2.8	62.5	2.76	59.2	0.04	0.03	2.77	60	**1.35**
11/1/2007	2.38	33.9	2.36	32.8	0.02	0.03	2.35	32.3	**1.52**
11/8/2007	2.43	36.6	2.42	36.1	0.01	0.03	2.40	35	**3.05**
11/8/2007	2.43	36.6	2.4	35	0.03	0.03	2.40	35	**0.00**
11/16/2007	3.28	113	3.25	109	0.03	0.03	3.25	109	**0.00**
11/16/2007	3.3	116	3.25	109	0.05	0.03	3.27	112	**2.75**
								Average	**1.24**
Sample 8	**01C070 (from rating 4)**								
12/4/2007	3.41	131	3.31	117	0.1	0.07	3.34	121	**3.42**
12/6/2007	2.97	78	2.89	70.4	0.08	0.07	2.90	71.3	**1.28**
12/13/2007	2.5	40.8	2.44	37.2	0.06	0.07	2.43	36.6	**1.61**
12/17/2007	2.81	63.3	2.76	59.2	0.05	0.07	2.74	57.6	**2.70**
1/3/2008	2.82	64.2	2.75	58.4	0.07	0.07	2.75	58.4	**0.00**
Sample 9	**01C070 (from rating 5)**								
3/19/2008	2.66	64.7	2.55	57	0.11	0.12	2.54	56.3	**1.23**
4/3/2008	2.53	55.7	2.41	47.5	0.12	0.12	2.41	47.5	**0.00**
4/10/2008	2.61	61.1	2.48	52.4	0.13	0.12	2.49	53.1	**1.34**
								Average	**0.85**
Sample 10	**01C070 (from rating 2)**								
10/10/2006	0.84	5.05	0.83	4.87	0.01	0.01	0.83	4.87	**0.00**
10/19/2006	0.88	5.8	0.87	5.61	0.01	0.01	0.87	5.61	**0.00**
10/23/2006	0.86	5.42	0.86	5.42	0	0.01	0.85	5.23	**3.51**
10/25/2006	0.87	5.61	0.87	5.61	0	0.01	0.86	5.42	**3.39**
10/31/2006	0.91	6.42	0.9	6.21	0.01	0.01	0.90	6.21	**0.00**
								Average	**1.38**

Sample 11	**01C070 (from rating 3)**								
11/20/2006	2.4	79.6	2.26	60	0.14	0.14	2.26	60	**0.00**
12/4/2006	2.2	52.4	2.08	39.3	0.12	0.14	2.06	37	**5.85**
12/12/2006	2.93	178	2.78	146	0.15	0.14	2.79	148	**1.37**
								Average	**2.41**
Sample 12	**01C070 (from rating 3)**								
12/19/2006	2.63	117	2.36	73.7	0.27	0.26	2.38	76.6	**3.93**
1/2/2007	2.88	167	2.64	119	0.24	0.26	2.63	117	**1.68**
Sample 13	**01C070 (from rating 3)**								
1/18/2007	2.1	41.4	2.17	48.9	-0.07	-0.06	2.16	47.8	2.25
1/23/2007	2.59	110	2.64	119	-0.05	-0.06	2.65	121	**1.68**
2/1/2007	2.03	33.9	2.1	41.4	-0.07	-0.06	2.09	40.4	**2.42**
								Average	**2.12**
Sample 14	**01A140 (from rating 3)**								
10/10/2006	4.11	302	4.09	292	0.02	0.02	4.09	292	**0.00**
10/19/2006	4.26	377	4.26	377	0	0.02	4.24	367	**2.65**
10/25/2006	4.2	348	4.17	332	0.03	0.02	4.18	337	**1.51**
								Average	**1.39**
Sample 15	**01A140 (from rating 2)**								
12/12/2006	7.29	2157	7.5	2572	-0.21	-0.22	7.51	2593	**0.82**
12/19/2006	6.84	1447	7.1	1829	-0.26	-0.22	7.06	1765	**3.50**
1/2/2007	7.89	3561	8.1	4311	-0.21	-0.22	8.11	4351	**0.93**
1/9/2007	7.02	1703	7.24	2067	-0.22	-0.22	7.24	2067	**0.00**
1/18/2007	6.33	882	6.54	1087	-0.21	-0.22	6.55	1098	**1.01**
1/23/2007	7.08	1797	7.29	2157	-0.21	-0.22	7.30	2175	**0.83**
2/1/2007	6.26	823	6.47	1015	-0.21	-0.22	6.48	1025	**0.99**
2/13/2007	6.37	918	6.58	1131	-0.21	-0.22	6.59	1142	**0.97**

2/20/2007	7.2	1997	7.46	2488	-0.26	-0.22	7.42	2407	**3.26**
3/1/2007	6.25	815	6.45	995	-0.2	-0.22	6.47	1015	**2.01**
3/6/2007	6.42	966	6.64	1198	-0.22	-0.22	6.64	1198	**0.00**
Sample 16	**28C110 (from rating 1)**								
12/12/2006	4.27	2.75	4.35	4.49	-0.08	-0.07	4.34	4.31	**4.01**
12/19/2006	4.28	2.98	4.34	4.31	-0.06	-0.07	4.35	4.49	**4.18**
								Average	**4.09**
Sample 17	**28C110 (from rating 1)**								
8/21/2008	4.31	3.68	4.43	6.17	-0.12	-0.15	4.46	6.91	**11.99**
8/26/2008	4.2	1.5	4.35	4.49	-0.15	-0.15	4.35	4.49	**0.00**
9/9/2008	4.13	0.715	4.31	3.68	-0.18	-0.15	4.28	2.98	**19.02**
9/23/2008	4.16	1.04	4.33	4.12	-0.17	-0.15	4.31	3.68	**10.68**
9/24/2008	4.15	0.925	4.31	3.68	-0.16	-0.15	4.30	3.43	**6.79**
10/6/2008	4.24	2.15	4.39	5.27	-0.15	-0.15	4.39	5.27	**0.00**
10/23/2008	4.17	1.14	4.3	3.43	-0.13	-0.15	4.32	3.94	**14.87**
Sample 18	**28C110 (from rating 1)**								
5/18/2009	4.52	8.58	4.46	6.91	0.06	0.06	4.46	6.91	**0.00**
5/18/2009	4.5	7.99	4.45	6.66	0.05	0.06	4.44	6.42	**3.60**
6/1/2009	4.45	6.66	4.39	5.27	0.06	0.06	4.39	5.27	**0.00**
6/1/2009	4.45	6.66	4.38	5.06	0.07	0.06	4.39	5.27	**4.15**
								Average	**1.94**
Sample 19	**32A120 (from rating 12)**								
6/12/2008	4.7	711	4.48	617	0.22	0.24	4.46	609	**1.30**
6/16/2008	4.16	495	3.94	421	0.22	0.24	3.92	414	**1.66**
6/19/2008	3.76	365	3.53	299	0.23	0.24	3.52	296	**1.00**
6/26/2008	3.06	181	2.83	131	0.23	0.24	2.82	129	**1.53**
7/3/2008	2.55	75.9	2.3	42.4	0.25	0.24	2.31	43.6	**2.83**
7/10/2008	2.21	33.3	1.97	14.5	0.24	0.24	1.97	14.5	**0.00**
7/17/2008	2.16	28.8	1.91	11.5	0.25	0.24	1.92	11.9	**3.48**

7/23/2008	2.33	45.9	2.08	21.8	0.25	0.24	2.09	22.6	**3.67**
7/31/2008	2.23	35.2	1.99	15.7	0.24	0.24	1.99	15.7	**0.00**
8/7/2008	2.23	35.2	1.98	15.1	0.25	0.24	1.99	15.7	**3.97**
8/14/2008	2.19	31.5	1.94	12.9	0.25	0.24	1.95	13.4	**3.88**
8/21/2008	2.45	61.5	2.2	32.4	0.25	0.24	2.21	33.3	**2.78**
8/28/2008	2.14	26.9	1.89	10.6	0.25	0.24	1.90	11	**3.77**
9/4/2008	2.34	47.1	2.1	23.4	0.24	0.24	2.10	23.4	**0.00**
9/10/2008	2.31	43.6	2.07	21.1	0.24	0.24	2.07	21.1	**0.00**
9/18/2008	2.31	43.6	2.06	20.4	0.25	0.24	2.07	21.1	**3.43**
9/25/2008	2.55	75.9	2.3	42.4	0.25	0.24	2.31	43.6	**2.83**
								Average	**2.13**
Sample 20	**32A120 (from rating 12)**								
10/3/2008	2.43	58.9	2.18	30.7	0.25	0.25	2.18	30.7	**0.00**
10/10/2008	2.42	57.7	2.17	29.8	0.25	0.25	2.17	29.8	**0.00**
10/17/2008	2.35	48.3	2.1	23.4	0.25	0.25	2.10	23.4	**0.00**
10/21/2008	2.32	44.7	2.07	21.1	0.25	0.25	2.07	21.1	**0.00**
11/2/2008	2.41	56.3	2.16	28.8	0.25	0.25	2.16	28.8	**0.00**
11/7/2008	2.49	67	2.24	36.2	0.25	0.25	2.24	36.2	**0.00**
11/14/2008	3.15	201	2.9	148	0.25	0.25	2.90	148	**0.00**
11/21/2008	2.59	82.4	2.34	47.1	0.25	0.25	2.34	47.1	**0.00**
11/28/2008	2.61	85.8	2.36	49.6	0.25	0.25	2.36	49.6	**0.00**
12/7/2008	2.78	119	2.54	74.3	0.24	0.25	2.53	72.8	**2.02**
12/10/2008	3.03	174	2.79	122	0.24	0.25	2.78	119	**2.46**
								Average	**0.41**
Sample 21	**32A120 (from rating 12)**								
2/28/2009	3.44	274	3.4	264	0.04	0.05	3.39	261	**1.14**
3/2/2009	3.55	304	3.51	293	0.04	0.05	3.50	290	**1.02**
3/3/2009	3.83	386	3.78	371	0.05	0.05	3.78	371	**0.00**
3/13/2009	3.16	204	3.09	187	0.07	0.05	3.11	192	**2.67**
3/20/2009	3.67	339	3.61	321	0.06	0.05	3.62	324	**0.93**

3/27/2009	3.96	427	3.92	414	0.04	0.05	3.91	411	**0.72**
								Average	**1.08**
Sample 22	**32A120 (from rating 13)**								
6/12/2009	3.03	129	2.96	116	0.07	0.07	2.96	116	**0.00**
6/19/2009	2.81	87	2.74	75.7	0.07	0.07	2.74	75.7	**0.00**
6/25/2009	2.47	41	2.4	34.3	0.07	0.07	2.40	34.3	**0.00**
7/2/2009	2.14	15	2.06	10.7	0.08	0.07	2.07	11.2	**4.67**
7/13/2009	2.33	28.4	2.26	22.8	0.07	0.07	2.26	22.8	**0.00**
7/22/2009	2.11	13.4	2.04	9.7	0.07	0.07	2.04	9.7	**0.00**
7/31/2009	2.08	11.7	2	8.01	0.08	0.07	2.01	8.41	**4.99**
8/14/2009	2.22	20	2.14	15	0.08	0.07	2.15	15.5	**3.33**
								Average	**1.62**
Sample 23	**32A120 (from rating 13)**								
8/28/2009	2.16	16.1	2.08	11.7	0.08	0.07	2.09	12.2	**4.27**
9/11/2009	2.23	20.7	2.17	16.7	0.06	0.07	2.16	16.1	**3.59**
9/25/2009	2.22	20	2.14	15	0.08	0.07	2.15	15.5	**3.33**
								Average	**3.73**
Sample 24	**03B075 (from rating 1)**								
3/23/2006	3.79	74.9	3.8	76.2	-0.01	-0.01	3.80	76.2	**0.00**
4/19/2006	4.17	127	4.17	127	0	-0.01	4.18	128	**0.79**
6/7/2006	3.83	80.1	3.86	84.1	-0.03	-0.01	3.84	81.4	**3.21**
8/9/2006	3.22	22.4	3.22	22.4	0	-0.01	3.23	23	**2.68**
9/20/2006	3.18	20.1	3.19	20.6	-0.01	-0.01	3.19	20.6	**0.00**
								Average	**1.34**
Sample 25	**03B075 (from rating 2)**								
2/21/2007	5.32	370	5.34	375	-0.02	-0.02	5.34	375	**0.00**
4/11/2007	4.12	119	4.14	122	-0.02	-0.02	4.14	122	**0.00**
4/30/2007	4.21	133	4.24	138	-0.03	-0.02	4.23	136	**1.45**
								Average	**0.48**

Sample 26	**35L050 (from rating 13)**								
1/13/2009	5.29	18.2	5.23	16	0.06	0.08	5.21	15	**6.25**
1/29/2009	4.91	2.57	4.84	1.34	0.07	0.08	4.83	1.21	**9.70**
2/6/2009	4.94	3.26	4.84	1.34	0.1	0.08	4.86	1.62	**20.90**
2/19/2009	4.85		4.76		0.09				
2/24/2009	4.93	3.01	4.86	1.62	0.07	0.08	4.85	1.47	**9.26**
3/9/2009	5.12	10.4	5.04	6.49	0.08	0.08	5.04	6.49	**0.00**
3/23/2009	5.23	16	5.16	12.4	0.07	0.08	5.15	11.9	**4.03**
								Average	**8.36**
Sample 27	**35L050 (from rating 11)**								
4/24/2009	5.11	12	5.02	9.52	0.09	0.09	5.02	9.52	**0.00**
5/10/2009	5.03	9.78	4.95	7.9	0.08	0.09	4.94	7.68	**2.78**
5/13/2009	5.01	9.27	4.91	7.06	0.1	0.09	4.92	7.26	**2.83**
6/5/2009	4.8	5.09	4.71	3.65	0.09	0.09	4.71	3.65	**0.00**
6/17/2009	4.71	3.65	4.64	2.73	0.07	0.09	4.62	2.5	**8.42**
6/23/2009	4.74	4.1	4.65	2.85	0.09	0.09	4.65	2.85	**0.00**
								Average	**2.34**
Sample 28	**35L050 (from ratings 11, 12 and 13)**								
7/20/2009	4.58	2.09	4.5	1.35	0.08	0.08	4.50	1.35	**0.00**
8/10/2009	4.87	3.06	4.78	1.35	0.09	0.08	4.79	1.49	**10.37**
8/22/2009	4.92	3.6	4.84	1.9	0.08	0.08	4.84	1.9	**0.00**
8/30/2009	4.95	4.39	4.87	2.42	0.08	0.08	4.87	2.42	**0.00**
9/14/2009	4.93	3.85	4.85	2.06	0.08	0.08	4.85	2.06	**0.00**
9/22/2009	4.93	3.01	4.84	1.34	0.09	0.08	4.85	1.47	**9.70**
9/30/2009	4.93	3.85	4.84	1.9	0.09	0.08	4.85	2.06	**8.42**
								Average	**4.07**
Sample 29	**17C075 (from ratings 3 and 4)**								
12/21/2007	1.61	15.1	1.65	16	-0.04	-0.04	1.65	16.6	**3.75**

12/30/2007	1.45	9.95	1.48	10.8	-0.03	-0.04	1.49	11.1	**2.78**
1/4/2008	2.5	69.9	2.55	72.7	-0.05	-0.04	2.54	72.2	**0.69**
1/11/2008	1.9	28.5	1.95	31.4	-0.05	-0.04	1.94	30.8	**1.91**
1/17/2008	1.7	18.4	1.75	21	-0.05	-0.04	1.74	20.4	**2.86**
								Average	**2.40**
Sample 30	**17C075 (from rating 4)**								
6/6/2008	1.61	14.3	1.62	14.7	-0.01	-0.02	1.63	15.1	**2.72**
6/15/2008	1.51	10.4	1.53	11.2	-0.02	-0.02	1.53	11.2	**0.00**
6/23/2008	1.4	4.24	1.42	5.07	-0.02	-0.02	1.42	5.07	**0.00**
6/27/2008	1.36	2.94	1.38	3.54	-0.02	-0.02	1.38	3.54	**0.00**
7/2/2008	1.33	1.99	1.36	2.94	-0.03	-0.02	1.35	2.59	**11.90**
7/14/2008	1.3	1.33	1.31	1.53	-0.01	-0.02	1.32	1.74	**13.73**
7/18/2008	1.28	1	1.31	1.53	-0.03	-0.02	1.30	1.33	**13.07**
7/26/2008	1.27	0.87	1.3	1.33	-0.03	-0.02	1.29	1.16	**12.78**
8/3/2008	1.28	1	1.3	1.33	-0.02	-0.02	1.30	1.33	**0.00**
8/11/2008	1.28	1	1.3	1.33	-0.02	-0.02	1.30	1.33	**0.00**
8/23/2008	1.26	1.64	1.29	2.17	-0.03	-0.02	1.28	2	**7.83**
9/1/2008	1.25		1.28		-0.03				
9/7/2008	1.22		1.25		-0.03				
								Average	**5.64**
Sample 31	**17C075 (from rating 4)**								
2/2/2008	1.38	3.54	1.42	5.07	-0.04	-0.05	1.43	5.53	**9.07**
2/7/2008	1.48	8.53	1.52	10.8	-0.04	-0.05	1.53	11.2	**3.70**
2/15/2008	1.57	12.7	1.62	14.7	-0.05	-0.05	1.62	14.7	**0.00**
2/21/2008	1.49	9.28	1.54	11.6	-0.05	-0.05	1.54	11.6	**0.00**
2/27/2008	1.45	6.59	1.5	10.1	-0.05	-0.05	1.50	10.1	**0.00**
								Average	**2.56**

Table 1. Stable Drift Analysis

*Discharge values for observations during phased periods are averages of separate discharges at same stage between two phased ratings.

Stable Drift Analysis

Average Standard Deviation = 0.013
Percent Average Diff obs st. Q = 2.4
Stdev of Percent Average Diff obs st. Q= 1.9
Average Range= 0.03

Log St. = logged stage at time of PGI observation.
Obs. St. = observed stage at PGI.
Obs. St. Q = discharge as read from active rating table corresponding to observed gage height value at PGI.
Diff. Ft. = difference between the logged stage value and the PGI observation.
Avg. Diff Ft. = average of the set of differences in feet.
Log-Avg. Diff Ft. = stage of difference between logged stage value and average difference in feet
Log-Avg. Diff Ft. Q = discharge as read from appropriate rating table corresponding to Log-Avg. Diff Ft. value
% Diff = difference in discharge expressed in percent between Obs. St. Q and Log-Avg. Diff Ft. Q
Average % Diff = average of the set of % differences in discharges between Obs. St. Q and Log-Avg. Diff Ft. Q
Diff Ft. STDEV = standard deviation of differences between logged stage value and PGI observation. Threshold value for stable drift consideration is 0.15 ft.
Range = difference between greatest Diff Ft. value and least Threshold value for stable drift consideration is 0.03 ft.

Samples with average % diff met the established criteria for standard deviation and range of diff Ft.