Appendix B2

Assessment of the Discharge Records for the Three Gauges (Flynn Creek Gauge, Needle Branch Lower Gauge, and Deer Creek Gauge) in the Alsea Revisited Paired Watershed Study for Water Years 2006-2015

Assessment of the discharge records for three gauges (Flynn Creek Gauge, Needle Branch Lower Gauge, and Deer Creek Gauge) in the Alsea Revisited Paired Watershed Study for Water Years 2006-2015.

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Summary

This document details the QA/QC process conducted for the discharge data for water years 2006 – 2015 for the Flynn Creek, Needle Branch, and Deer Creek gauges (FCG, NBG, and DCG) operated as part of the Alsea Revisited Paired Watershed Study. This process considered all available sources of data including: a) 10-minute stage data, b) time series of the comparison between reference and electronic stages between 2011 and 2016, c) discharge-stage data pairs collected between 1959-2016, and d) precipitation records collected both in the study area (met station and three tipping buckets located at FCG, NBG, and DCG) and the Alsea FH station (No. 350145, Western Regional Climate Center). For all 3 gauges, the QA/QC process consisted of a) the development of a rating curve and assessment of the reliability of electronic stage recorded data collected simultaneously with stream gauging activities, b) the analysis of the sources of uncertainty in the discharge calculations including uncertainties associated with the rating curve and the stage measurements, c) the calculations of hydrographs and associated errors, and d) the comparison between the annual water yield and precipitation.

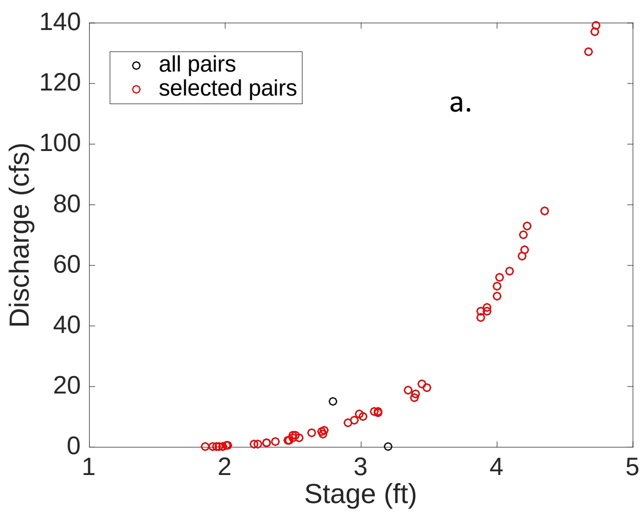
The QA/QC assumed that the uncertainty associated with the level logger is negligible, that the uncertainty of the electronic stage, computed based on data collected between 2012 and 2016, represents well the uncertainty prior to that period (i.e. between 2006 and 2011), and that the combined uncertainty considering both stage and rating curves can be computed assuming that these errors are independent and random.

The analysis indicated robust rating curves for all gauges. However, flow measurements should continue particularly at low and high flows. The raw stage data for FCG and NBG is 93 and 91% complete, respectively. In contrast the raw stage data for DCG is only reliable 70% of the time. At this gauge the electronically recorded stage appears to be erroneous between July 9, 2014 and Sep 20, 2015. The QA/QC process for the discharge data yield uncertainties between 11-18%, 11-23%, and 10-18%, for FCG, NBG, and DCG, respectively.

This document includes the analysis for each gauge independently including graphs and tables summarizing the process. The QA/QC data is included in text (.txt) files that accompany this document.

1. **Flynn Creek Gauge**

The stage-discharge data available for Flynn Creek Gauge (FCG) consist of 53 stage-discharge pairs collected between 1959 and 2014 (Fig. 1.1a). Out of those pairs, 50 were considered reliable to build a rating curve (red markers, Fig. 1.1.a). Some of the stage-discharge data (25%) was collected early in the record between 1959 and 1972. The remaining 38 data pairs were collected recently during 2005-2016 (Fig. 1.1b).



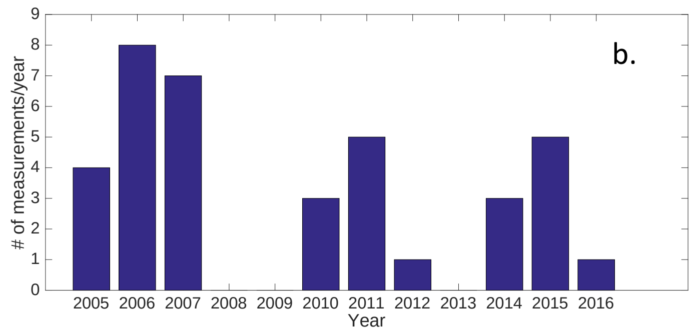


Fig. 1.1: a, Stage-Discharge pairs available for the Flynn Creek Gauge. Red markers correspond to data pairs considered reliable to build a rating curve; b, number of discharge measurements collected per water years 2005 - 2016.

1.1. Rating curve

A rating curve (Fig. 1.2) was calculated based on the mentioned 50 pairs. A 3rd order polynomial function computed over the data in logarithmic space was found to best describe the stage (H) - discharge (Q) relationship (Table 1.1, Equation 1.1).

$$logQ = a + b * log(H) + c * (\log(H))^2 + d * (\log(H))^3 \qquad R^2 = 0.99 \qquad (1.1)$$

where *H*, is stage in feet and *Q* is discharge in cfs.

The reliability of the electronically recorded stage during the gauging activities was assessed by comparing the electronic stage values in the database to electronic stage values recorded while downloading the data (field recorded electronic stege$_e$). Overall these values match (Fig. 1.3). However, this relationship should correspond exactly to a 1:1 line (both correspond to the values recorded in the data logger). The discrepancy between values could be related to inaccuracies in the field while recording the data either the stage value or the time of collection. A comparison between reference stage values (measured from staff gauge) and the electronically recorded values collected simultaneously with discharge measurements was also performed (see section 1.2.2).

Table 1.1: Coefficients of the 3rd order polynomial fit that best describes the rating curve in FCG. Coefficients and standard errors (Se) are included.

Coefficient	Value	Se
a (intercept)	-16.451	1.330
b*H	36.216	3.944
c*H^2	-24.725	3.759
d*H^3	6.627	1.156

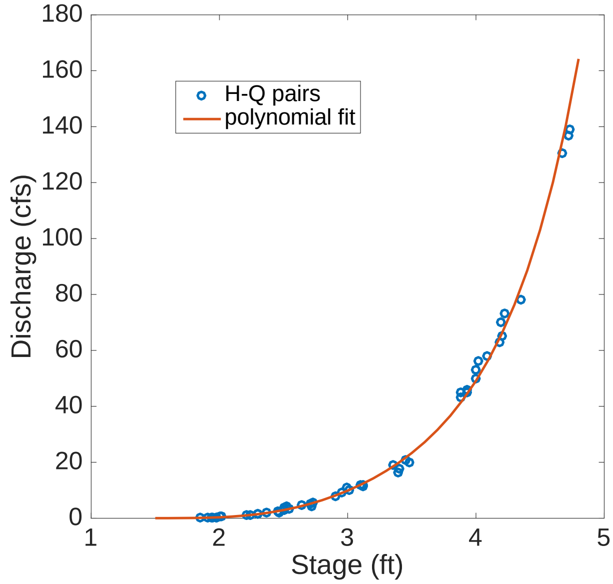


Fig. 1.2: Rating curve for the Flynn Creek Gauge, FCG, including 51 stage-discharge pairs (circles) and best 3rd order polynomial fit to the data.

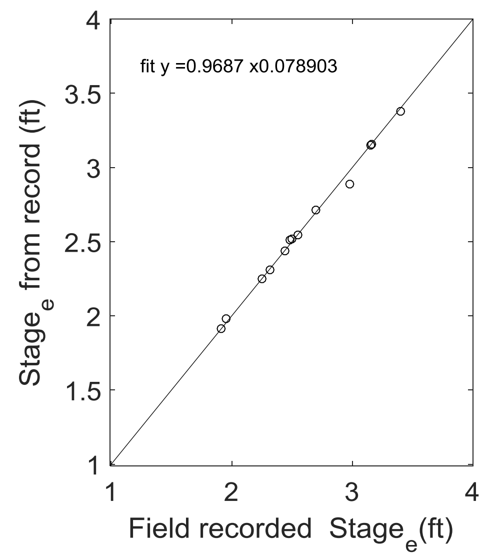


Fig. 1.3: Comparison of the field recorded electronic stage ($Stage_e$) to the corresponding value recorded in the database.

1.2. Source of uncertainty in the discharge calculations

The main sources of uncertainty in the discharge data include the accuracy of the water level loggers, the uncertainty associated to the accuracy of the rating curve, and the uncertainty associated to the stage measurements. For this QA/QC analysis, the level logger is assumed to be accurate.

1.2.1. Accuracy of the rating curve

The accuracy the rating curve fit (UQ) was assessed by conducting a 1x10^6 Monte Carlo simulations randomly varying the parameters of the polynomial fit (Equation 1.1., Table 1.1, Fig. 1.4a). This provided information about the uncertainty around the fits (Fig. 1.4b, red line). The relative uncertainty of UQ varies between 8 and 17 % within the stage range over which the rating curve was developed. As expected outside this stage range (stage <1.85 and stage>4.73 feet) the uncertainty is much higher.

1.2.2. Accuracy of stage data

In order to assess the reliability of the electronic stage data a comparison between the reference and electronic stage data collected between 2012 and 2016 was performed including both the instances in which discharge measurements were taken and other field visits conducted between 2012 and 2016 (Fig. 1.5). The comparison indicated a systematic over estimation of stage by the water level logger (Fig. 1.5); the mean difference is 0.05 ft. (15 mm). A correction factor (Equation 1.2) was computed assuming that the bias is systematic. This simple correction is, however, not entirely adequate for the FCG data given the cyclic pattern of sand accumulation in the flume during the wet months. Therefore, a more complex correction strategy was also explored below.

$$Stage_c = \frac{Stage_u - b}{m}, \quad m = 1.0085 \; and \; b = 0.0275 \tag{1.2}$$

where $Stage_c$ is corrected stage, $Stage_u$ is the uncorrected stage and *m* and *b* are the slope and intercept of the relation between reference stage and electronic stage, respectively.

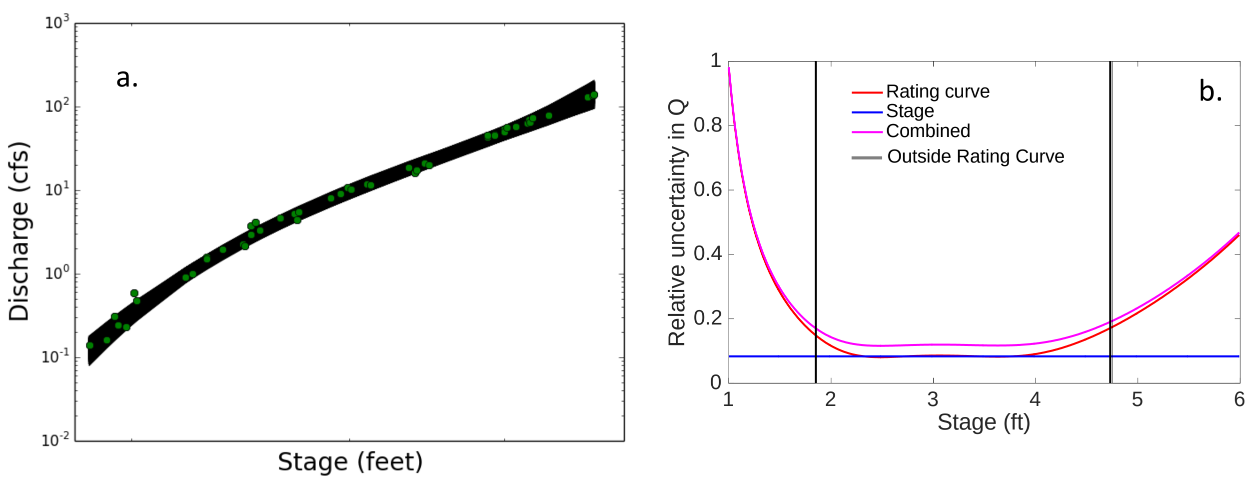


Fig. 1.4: a: Variability in the rating curve considering 1x10^6 Monte Carlo simulations randomly varying the parameters of the polynomial fit. Black lines correspond to the 1x106 relations and the green markers are the observations; b. Relative uncertainty in discharge, UQ, associated to the strength of the polynomial fit (red line), the uncertainty in discharge associate to the stage accuracy, US, (blue line), and the combined discharge uncertainty (magenta line).

The more complex correction scheme was calculated based on data collected between water years 2012 and 2016 and recognizes that there are differences between dry and wet months. Fig. 1.6a presents the number of instances in which a comparison between reference and electronic stage was performed (note that these instances add up to 159 that is an average of once every 13 days). Fig. 1.6b, presents the instances in which sediment had to be removed from flume. Note that no sediment removal occurred between June and September and that most accumulation events occurred in January and February likely associated to high storm events. The distributions of the differences between reference and electronic stage indicated not only greater discrepancy during the winter but also higher variability (Fig. 1.7), which would result in higher level of uncertainty for the higher flows.

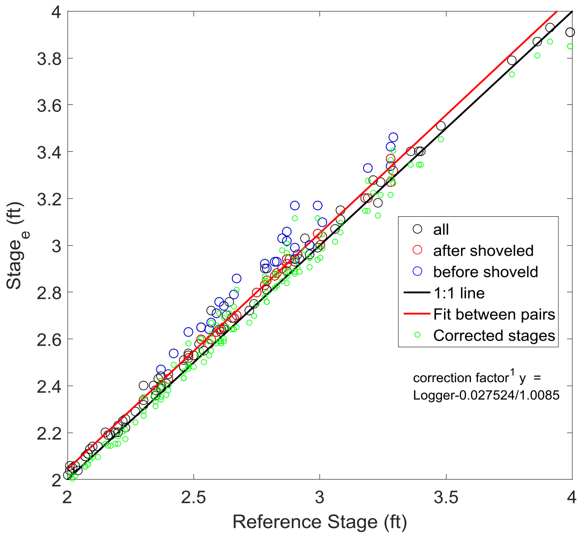


Fig. 1.5. Comparison of reference stage and electronic stage (stage$_e$). A factor can be applied to the stage data to correct the systematic overestimation of stage. Green markers correspond to corrected stages assuming this systematic bias and a single correction equation (Equation 1.2) for all points.

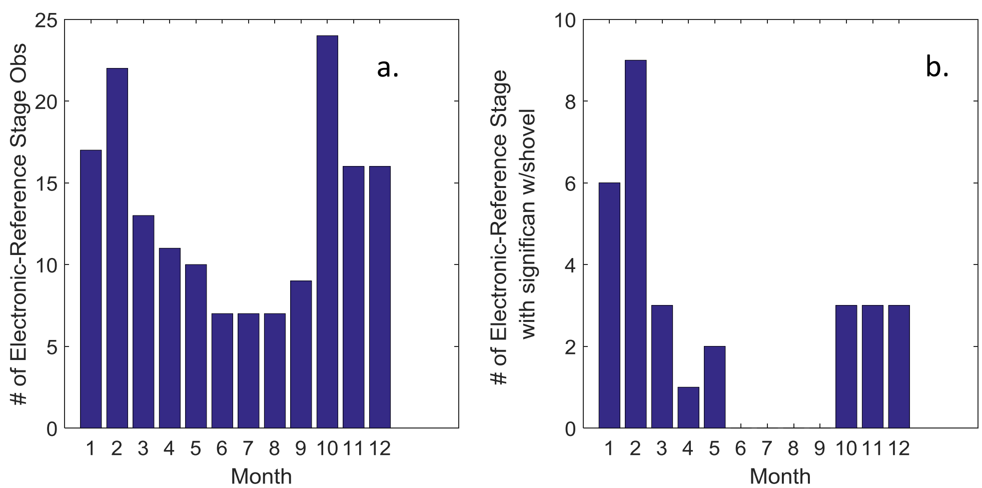


Fig. 1.6: a: number of reference-stage measurements collected per month (n = 159) and b: number of instances in which sand shoveling was required per month (n = 30).

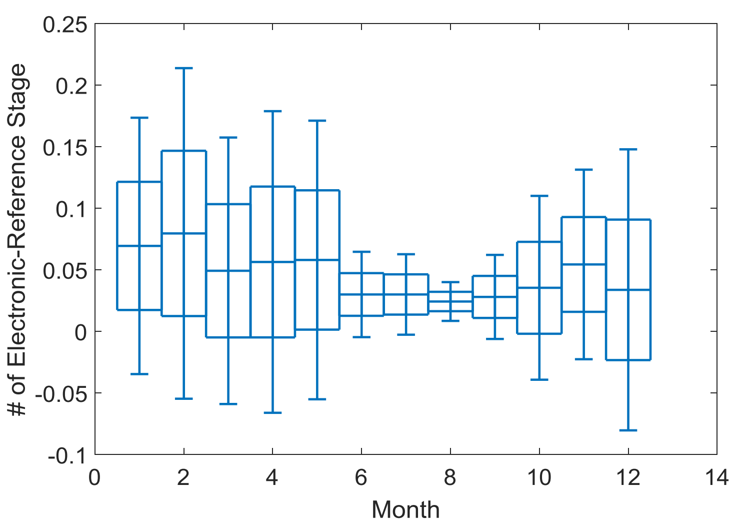


Fig. 1.7. Monthly distributions of the difference between electronic and reference stage.

The magnitude of the difference was also analyzed in time (Fig. 1.8) which indicated that large amounts of sediment were cleared from the flume between October and March during most years. However, there is also a decline in the discrepancies between May 2015 and the end of the record available (March 2016), which matches field observations refereeing to the disappearance of a depositional feature in the vicinity of the flume. Therefore, only data up to water year 2015 will be corrected.

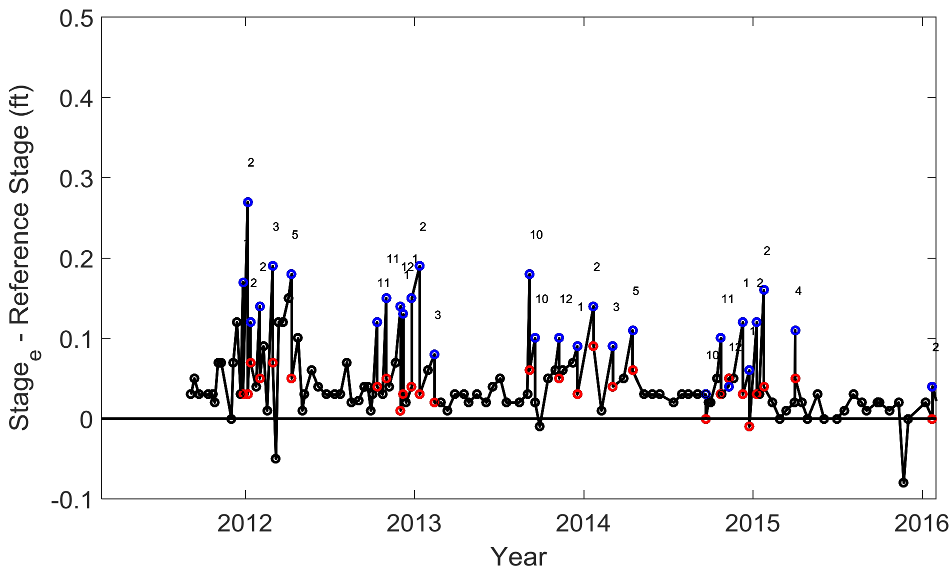


Fig. 1.8. Difference between electronic and reference stage values as indicative of the amount of sediment cleared out of the FCG flume between 2012 and 2016. The number above the time series indicates the month during which a given sediment removal episode took place (n = 30). Black markers indicate instances in which no sediment (i.e. no shoveling) was required. The blue and red markers represent instances in which sediment had to be removed. Blue markers correspond to the difference between reference and electronic stage values before sediment removal and the red markers refer to the corresponding difference after the sediment removal occurred.

Based on these data (Figs. 1.7 and 1.8) two correction factors were developed for electronic stages below and above 2.3 feet, respectively, recognizing that summer low flows are generally more accurate than the higher flows during the winter months, at least with regards to discrepancies related to sediment accumulation.

Low flow (stage<2.3 ft) correction: low flows were represented by 33 reference-electronic stage observations. Since no sediment removal was required during this period a simple correction factor similar to Equation 1.2 was developed based on the linear fit between reference and electronic stages (Equation 1.3).

$$Stage_c = \frac{Stage_u - b}{m}, \quad m = 0.9766 \; and \; b = 0.0768 \qquad (1.3)$$

High flow (stage>2.3 ft) correction: high flow periods were represented by 103 instances, out of which 30 involved sediment removal from the flume (Fig. 1.8). The over estimation of stage during these 30 instances varied between 0.01 and 0.27 ft (3-82 mm). However, in most cases (n=73) no sediment was removed. The correction factor for this stage was calculated considering all data:

$$Stage_c = \frac{Stage_u - b}{m}, \quad m = 0.9914 \; and \; b = 0.0892 \tag{1.4}$$

Fig. 1.9 presentes the uncorrected ($Stage_u$) and corrected ($Stage_c$) values over all available reference - electronic stage pairs considreing equations 1.3 and 1.4.

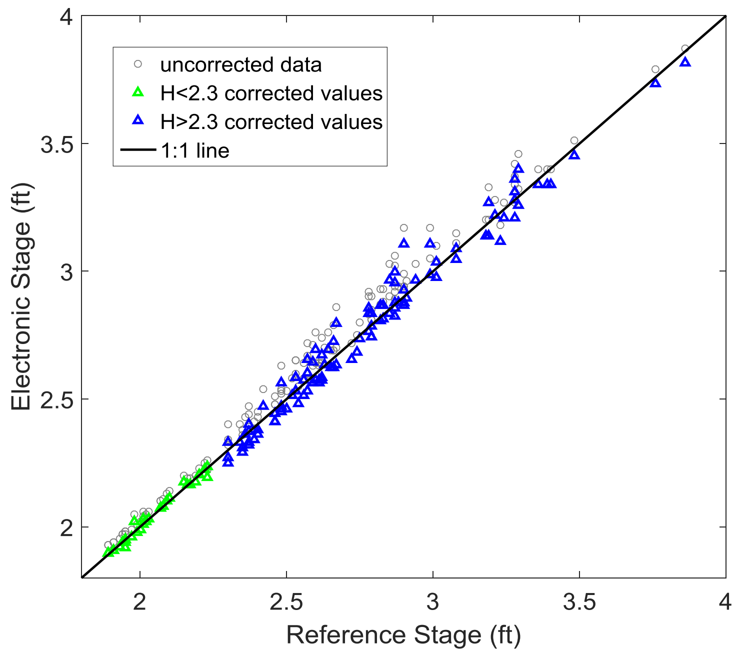


Fig. 1.9: Relationship between reference and electronic stage for 133 measurements collected in FCG between Oct 2011 and April 2015. The green and blue markers correspond to corrected electronic stage values using equations 1.3 and 1.4.

The uncertainty in discharge associated to the accuracy of the stage data (US) was calculated based on the difference between raw and the corrected stage values (green-blue markers) (Fig. 1.9) according to equation 1.5:

$$US = \frac{\sum_i^N ((Q_u(i) - Q_l(i))/(2 * Q_m(i))}{N} \tag{1.5}$$

where Q_u, Q_l, are the estimated discharge according to the rating curve (Equation 1.1) considering the mean stage plus and minus the uncertainty for every given stage level (i.e. from Fig. 1.8),respectively, Q_m is the estimate discharge according to the mean stage, and N is the total of instances considered to develop Equations 1.3 and 1.4.

The total uncertainty in discharge varies between 11 and 18% and was computed as the square-root of the sum of square uncertainties associated with both the rating curve (UQ) and the stage (US) (magenta line in Fig. 1.4).

1.3. Hydrographs and QA/QC discharge data

The available stage data consisted of the 10-minute records collected between Oct 1, 2005 and Sep 30, 2015 (file FC_Stage.txt). This record is 93% complete (i.e. there are 308 days with incomplete or missing discharge data). The QA/QC discharge data (green line Fig. 1.10) was calculated based on the:

a. Corrected stage data (equations 1.3 and 1.4)
b. Rating curve (Equation 1.1)
c. Combined uncertainty

A discharge record was also generated based on the uncorrected stage (black line, in Fig, 1.10) and the stage data corrected according with a simple correction factor (Equation 1.2, blue line in Fig, 1.10.) for comparison. The complete 10-min and daily time series are provided in 3 text files (Table 1.2). In addition, Fig. 1.11 presents the daily hydrograph with error bars in linear and log-space.

Table 1.2: Generated QA/QC time series of discharge for FCG.

Name	**Description**
FCG_10_Q_minute_data_2006-2015.txt	Date/time Raw uncorrected stage Simple corrected stage (equation 1.2) Complex corrected stage (equations 1.3 and 1.4) Discharge value calculated based on raw stage and rating curve Discharge value calculated based on simple-corrected stage and rating curve Discharge value calculated based on complex-corrected stage and rating curve
FCG_daily_Q_data_2006-2015.txt	Date Raw uncorrected stage Simple corrected stage (equation 1.2) Complex corrected stage (equations 1.3 and 1.4) Discharge value calculated based on raw stage and rating curve Discharge value calculated based on simple-corrected stage and rating curve Discharge value calculated based on complex-corrected stage and rating curve
FCG_daily_Q_data_2006-2015_with_error.txt	Date Discharge value calculated based on complex-corrected stage and rating curve Combined uncertainty

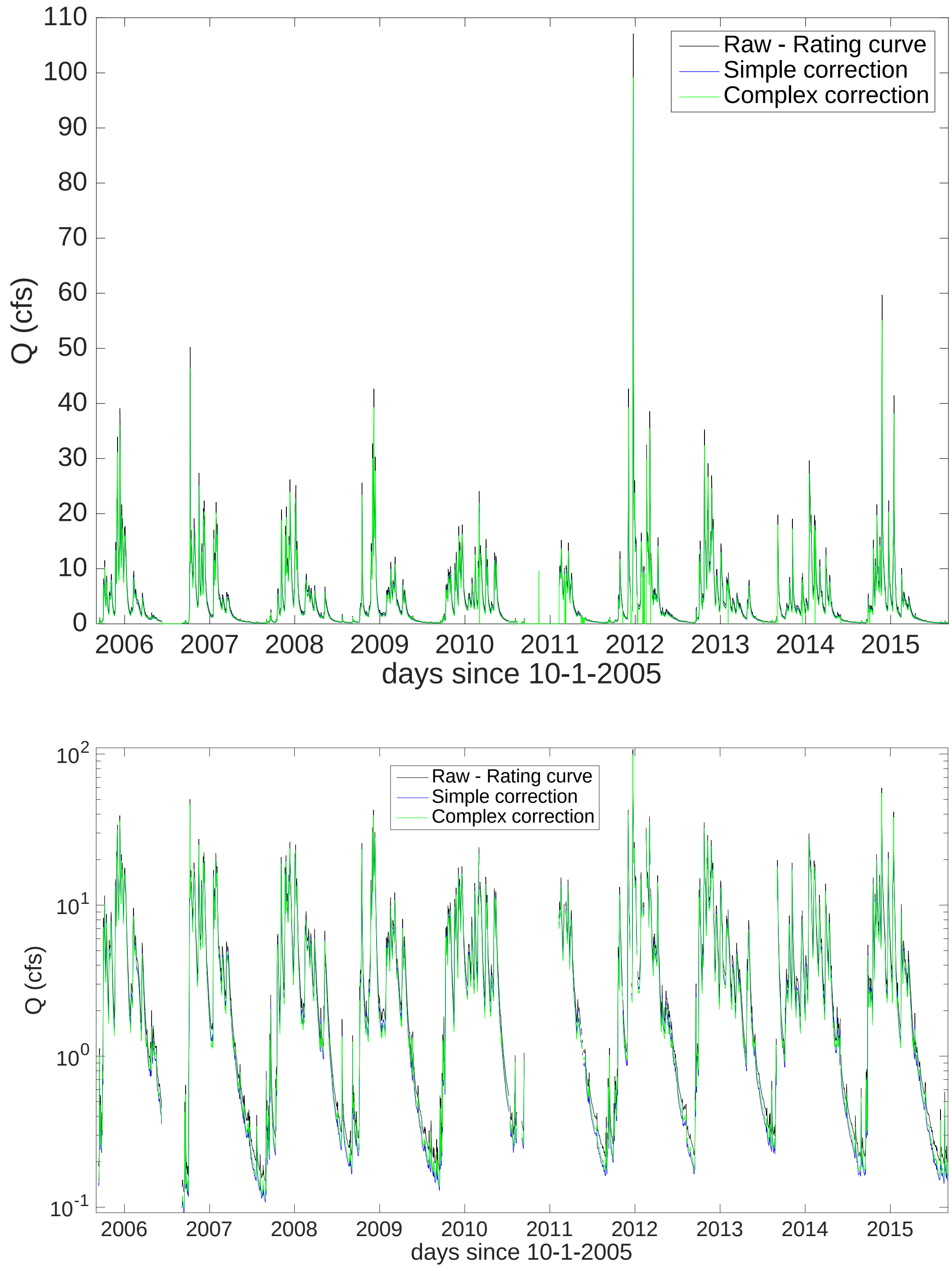
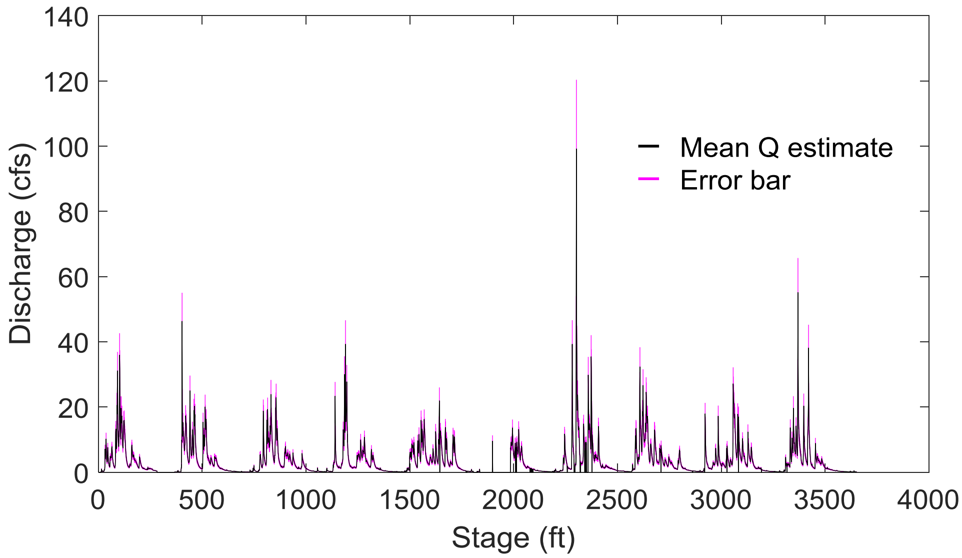


Fig. 1.10: Mean daily discharge for FCG between Oct 1, 2005 and 30 Sep 2015. Upper panel presents data in linear scale; lower panel presents data in logarithmic scale



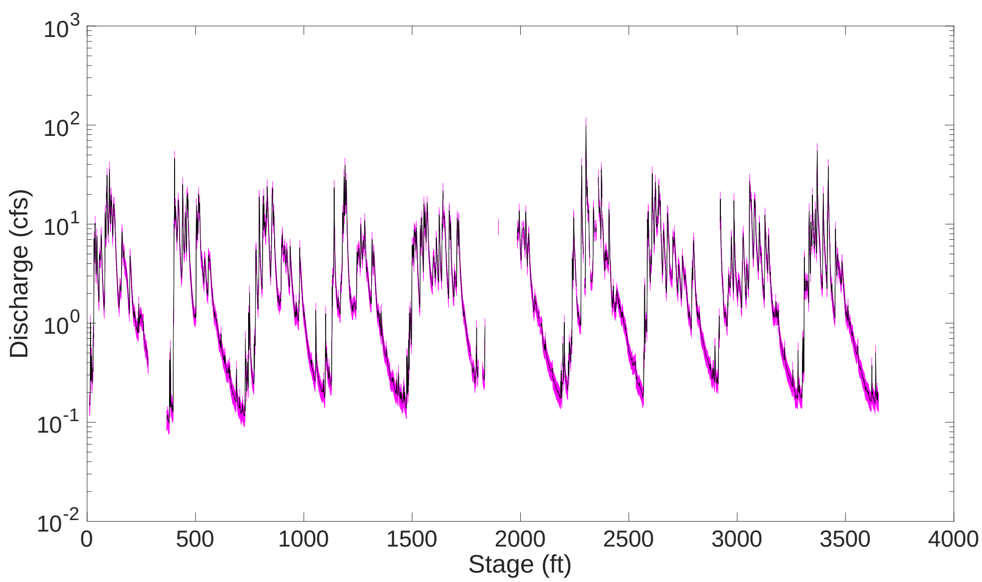


Fig. 1.11: Mean daily discharge with error bars for FCG between Oct 1, 2005 and 30 Sep 2015. Upper panel presents data in linear scale; lower panel presents data in logarithmic scale.

1.4. Annual water yield

Annual water yield (Fig. 1.12) was calculated for FCG considering all data available from complete days only. Note the number of days with data available per year (Fig. 1.13). The runoff coefficient (Q/P) was calculated considering both the precipitation in the study area and the precipitation in Alsea FH (Fig. 1.14).

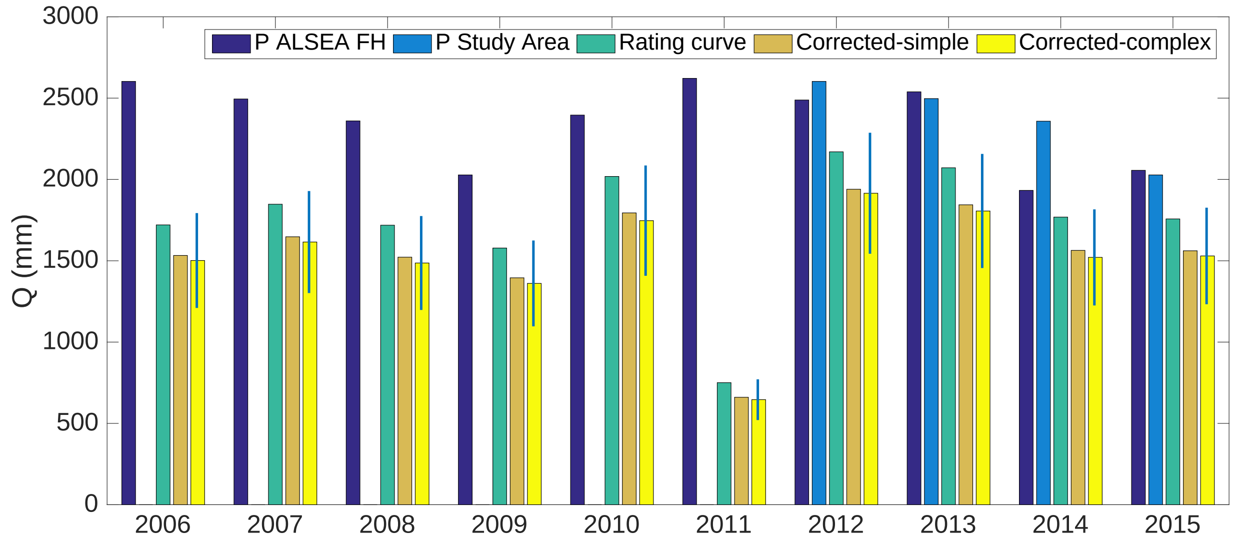


Fig. 1.12: Annual precipitation recorded at the Alsea FH station (No. 350145); annual precipitation computed combining precipitation data from 4 stations within the area of study (Appendix 1); annual water yield computed with 3 methods (raw rating curve, corrected simple (Equation 1.2), and corrected complex (equations 1.3 and 1.4). Error bars for the corrected water yield were calculated considering the mean combined uncertainty in Fig. 1.4.

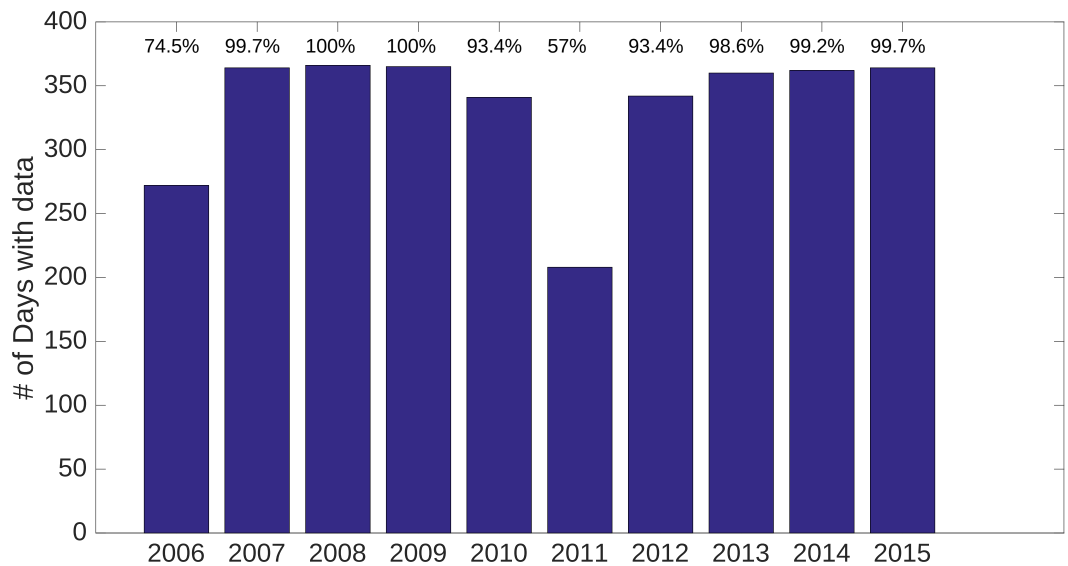


Fig. 1.13: Number of days per year with complete record for FCG. The percentage of the year with complete record is also indicated.

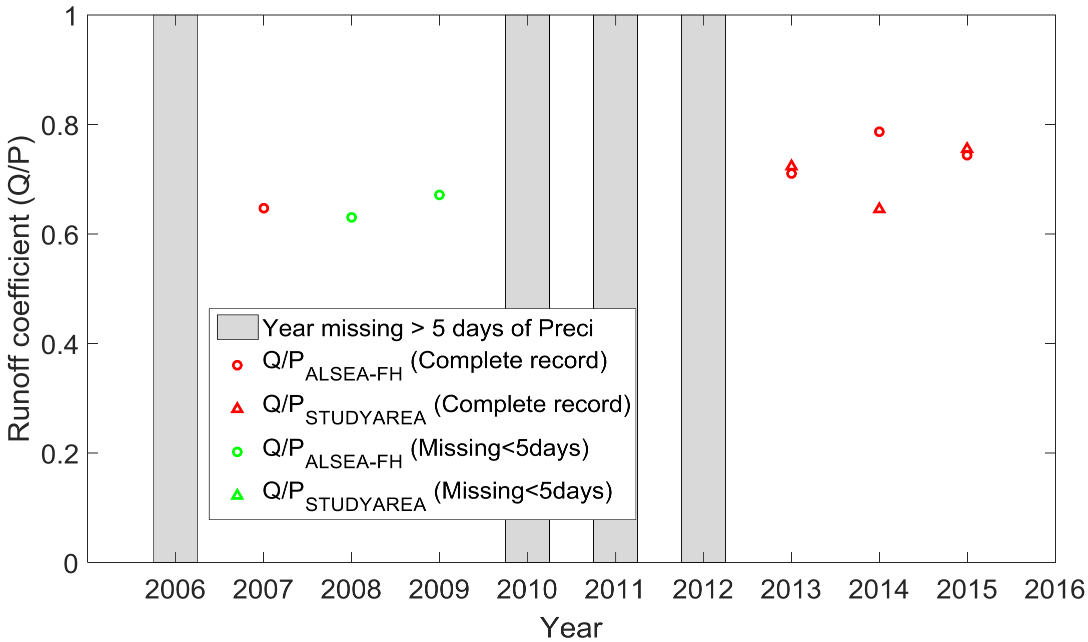


Fig. 1.14: Annual runoff coefficient (Q/P) in FCG based on discharge (Q) computed with the corrected stage data and precipitation (P) collected in the study area and the Alsea FH station. No calculation (grey bars) is presented for years missing more than 5 days of Q data

2. **Needle Branch Lower Gauge**

The record of stage-discharge pairs for the Needle Branch Gauge (NBL) consists of 50 pairs collected between 1959 and 2016 (Fig. 2.1a). Out of these 40 were considered reliable to build a rating curve (see red markers, Fig. 2.1a). Fifteen of these were collected during the 1959-1972 period, while the remaining 25 correspond to discharge measurements collected between 2005 and 2011 (Fig. 2.1b).

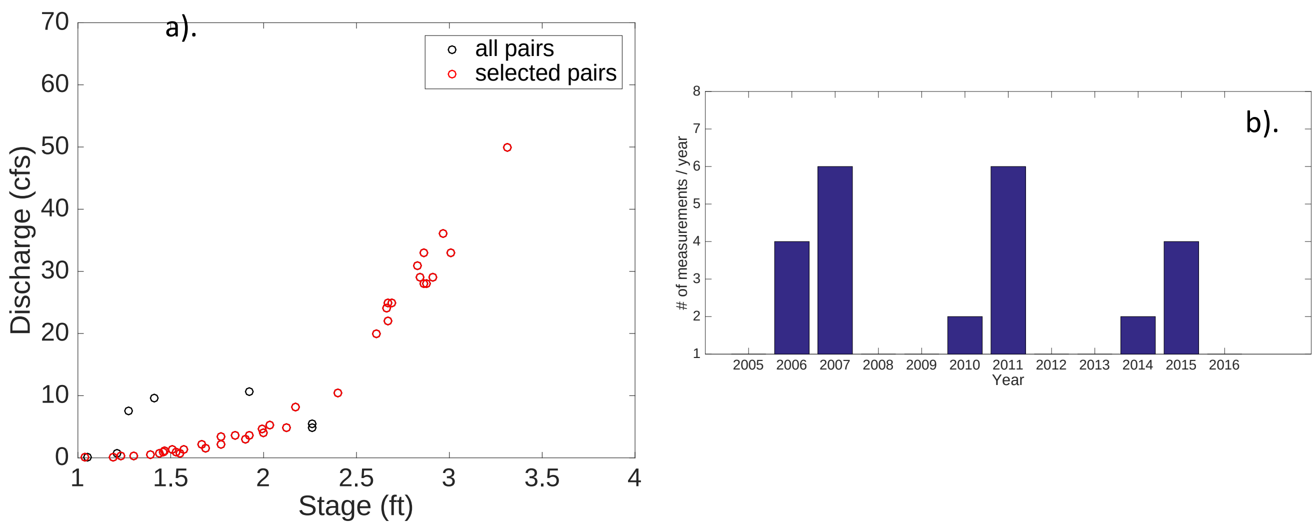


Fig.2.1. a: Stage-discharge pairs available for NBL; b: number of discharge measurements collected per year.

2.1. Rating curve

A rating curve (Fig. 2.2) was calculated based on the mentioned 40 pairs. A 2nd order polynomial fit computed over the data in log space produces a robust fit (Table 2.1, Equation 2.1).

$$logQ = a + b * log(H) + c * (\log(H))^2 \qquad R^2 = 0.99 \qquad (2.1)$$

where H, is stage in feet and Q is discharge in cfs.

Table 2.1: Coefficients of the polynomial that best describes the rating curve in FCG. Coefficients and standard errors (Se) are included.

Coefficient	Value	Se
a (intercept)	-3.208	0.139
b*H	8.501	0.441
c*H^2	-2.153	0.310

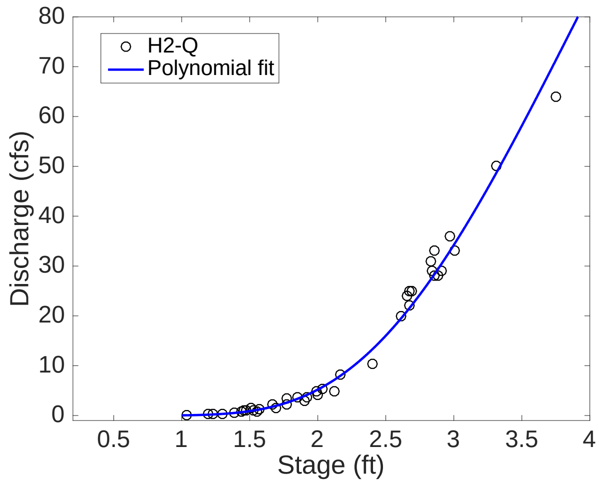


Fig.2.2: Rating curve Needle Branch Gauge, NBG, including 40 stage-discharge pairs (circles) and best 2rd order polynomial fit to the data.

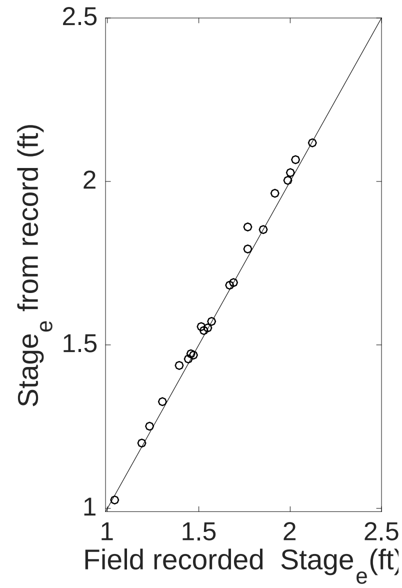


Fig. 2.3: Comparison of the field recorded logger stage value to the value in the database (left).

The reliability of the electronically recorded stage during the gauging activities was assessed by comparing the electronic stage values in the database to electronic stage values recorded while downloading the data (field recorded electronic stege$_e$). Overall these values match (Fig. 2.3). However, this relationship should correspond exactly to a 1:1 line (both correspond to the values recorded in the data logger). The discrepancy between values (Fig. 2.3) could be related to inaccuracies while recording the data either the stage value or the time of collection. A comparison between reference stage values (measured from staff gauge) and the electronically recorded values collected simultaneously with discharge measurements was also performed (see section 2.2.2).

2.1. Source of uncertainty in the discharge calculations

The main sources of uncertainty in the discharge data include the accuracy of the water level loggers, the uncertainty associated to the accuracy of the rating curve, and the uncertainty associated to the stage measurements. For this QA/QC analysis, the level logger is assumed to be accurate.

2.1.1. Accuracy of the rating curve

The accuracy the rating curve fit (UQ) was assessed by conducting a 1x10^6 Monte Carlo simulations randomly varying the parameters of the polynomial fit (Equation 2.1., Table 2.1, Fig.2.4a). This provided information about the uncertainty around the fits (Fig. 2.4b, red line).

The relative uncertainty of UQ varied between 13 and 24 % within the stage range over which the rating curve was developed. As expected outside this stage range (<1.04 and >3.75 feet) the uncertainty is much higher.

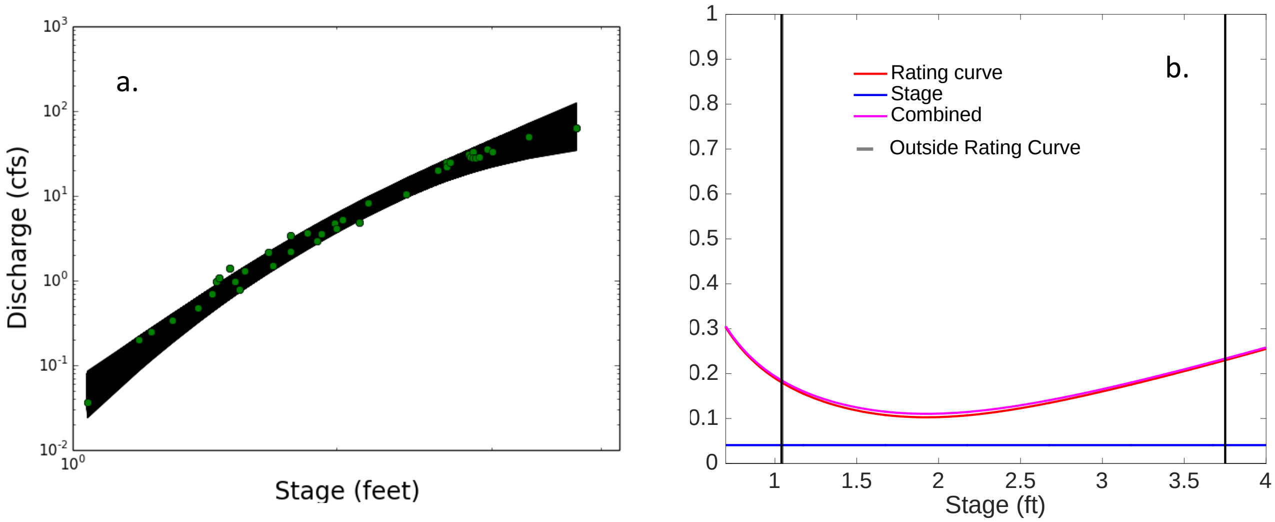


Fig. 2.4: a: Variability in the rating curve considering 1x10[6] Monte Carlo simulations randomly varying the parameters of the polynomial fit. Black lines correspond to the 1x106 relations and the green markers are the observations; b. Relative uncertainty in discharge, UQ, associated to the strength of the polynomial fit (red line), the uncertainty in discharge associate to the stage accuracy, US, (blue line), and the combined discharge uncertainty (magenta line).

2.1.2. Accuracy of stage data

In order to assess the reliability of the electronic stage a comparison between the reference (staff gauge) and electronic stage data was performed including both the instances in which discharge measurements were taken and other field visits conducted between 2012 and 2016 (Fig. 2.5). The comparison indicated a systematic over estimation of stage by the data logger (Fig. 1.5). The mean difference is 0.03 ft. (9 mm). There are 3 instances 2013/05/24, 2012/01/03, and 201/12/21 that appear to be erroneous. Those 3 data points were discarded to compute the correction factor (Equation 2.2). According to field notes, the flume at NBG has not experienced the same problem with sediment accumulation reported for FCG; therefore a simple correction factor was considered adequate.

$$Stage_c = \frac{Stage_u - b}{m}, \quad m = 0.98148 \; and \; b = 0.0659 \qquad (2.2)$$

where $Stage_c$ is corrected stage, $Stage_u$ is the uncorrected stage and *m* and *b* are the slope and intercept of the relation between reference stage and electronic stage, respectively.

The total uncertainty in discharge varies between 11 and 23% and was computed as the square-root of the sum of square uncertainties associated with both the rating curve and the stage (magenta line in Fig. 2.4).

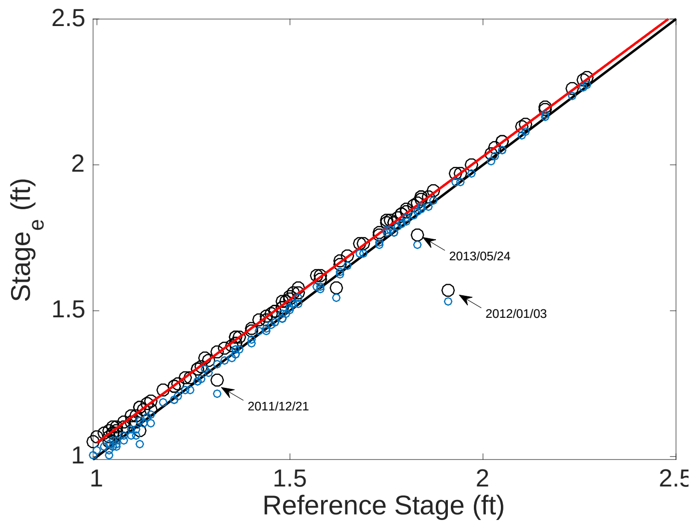


Fig. 2.5. Comparison of reference stage and electronic stage (stage$_e$). Blue markers correspond to corrected stages assuming systematic bias (equation 2.2) for all points.

2.1. Hydrographs and QA/QC discharge data

The available stage data consisted of 10-minute recorded data collected between Oct 1, 2005 and Sep 30, 2015. This record is 91% complete (i.e. there are 328 days with incomplete or missing discharge data). The QA/QC discharge data (green line Fig. 2.6) was based on the:

a. Corrected stage data (Equation 1.2)
b. Rating curve (Equation 1.1)
c. Combined uncertainty

The discharge record was also generated based on the uncorrected stage (black line, in Fig, 2.6 for comparison). The complete 10-min and daily time series are provided in 3 text files (Table 2.2). In addition, Fig.2.7 presents the daily hydrograph with error bars in linear and log-space.

Table 2.2: Generated QA/QC time series of discharge for NBG.

Name	**Description**
NBL_10_Q_minute_data_2006-2015.txt	Date/time Raw uncorrected stage Corrected stage (Equation 2.2) Discharge value calculated based on raw stage and rating curve Discharge value calculated based on corrected stage and rating curve
NBL_daily_Q_data_2006-2015.txt	Date Raw uncorrected stage Corrected stage (Equation 2.2) Discharge value calculated based on raw stage and rating curve Discharge value calculated based on corrected stage
NBL_daily_Q_data_2006-2015_with_error.txt	Date Discharge value calculated based on corrected stage and rating curve error

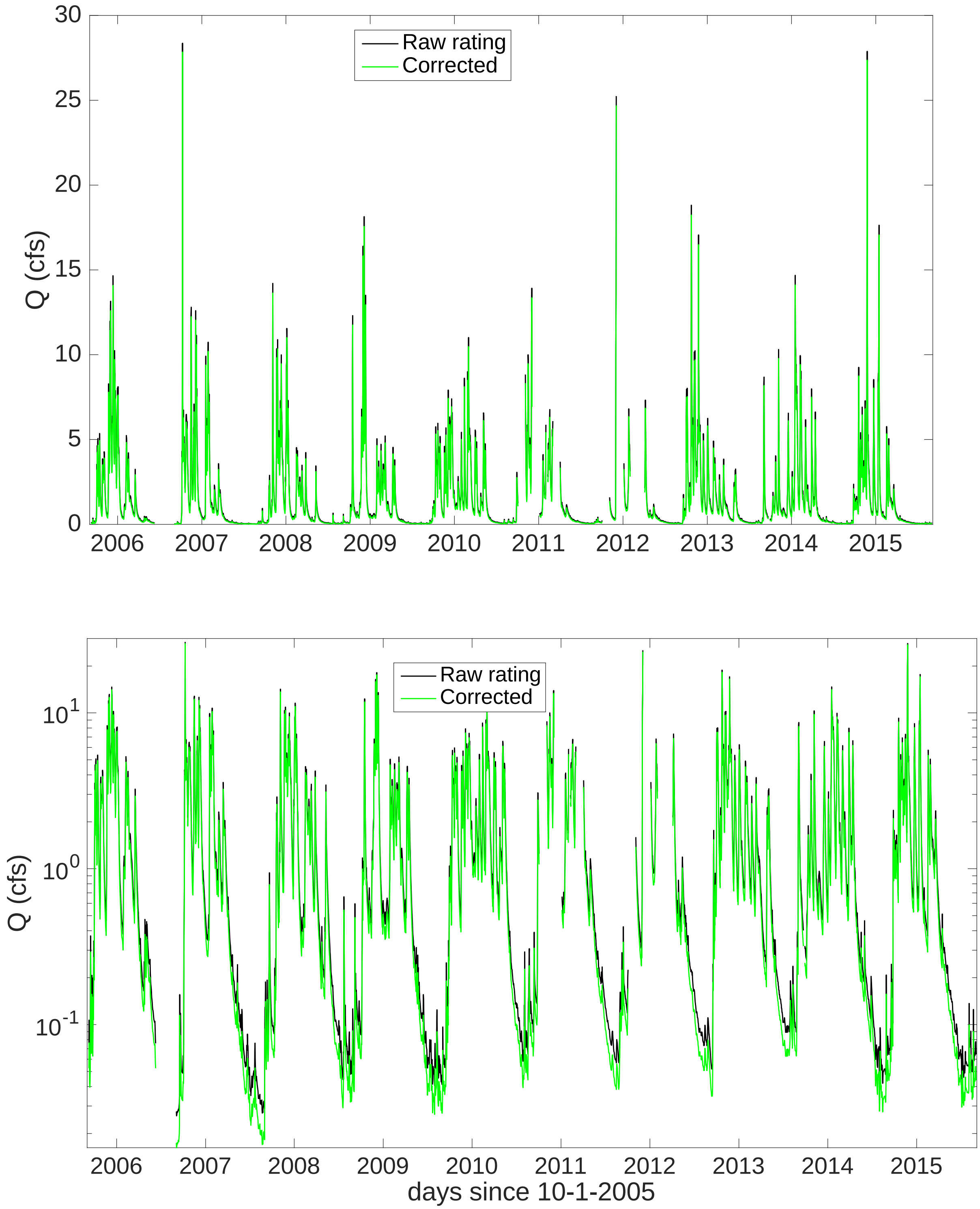


Fig. 2.6: Mean Daily discharge for NBG between Oct 1, 2005 and 30 Sep 2015. Upper panel presents data in linear scale; lower panel presents data in logarithmic scale

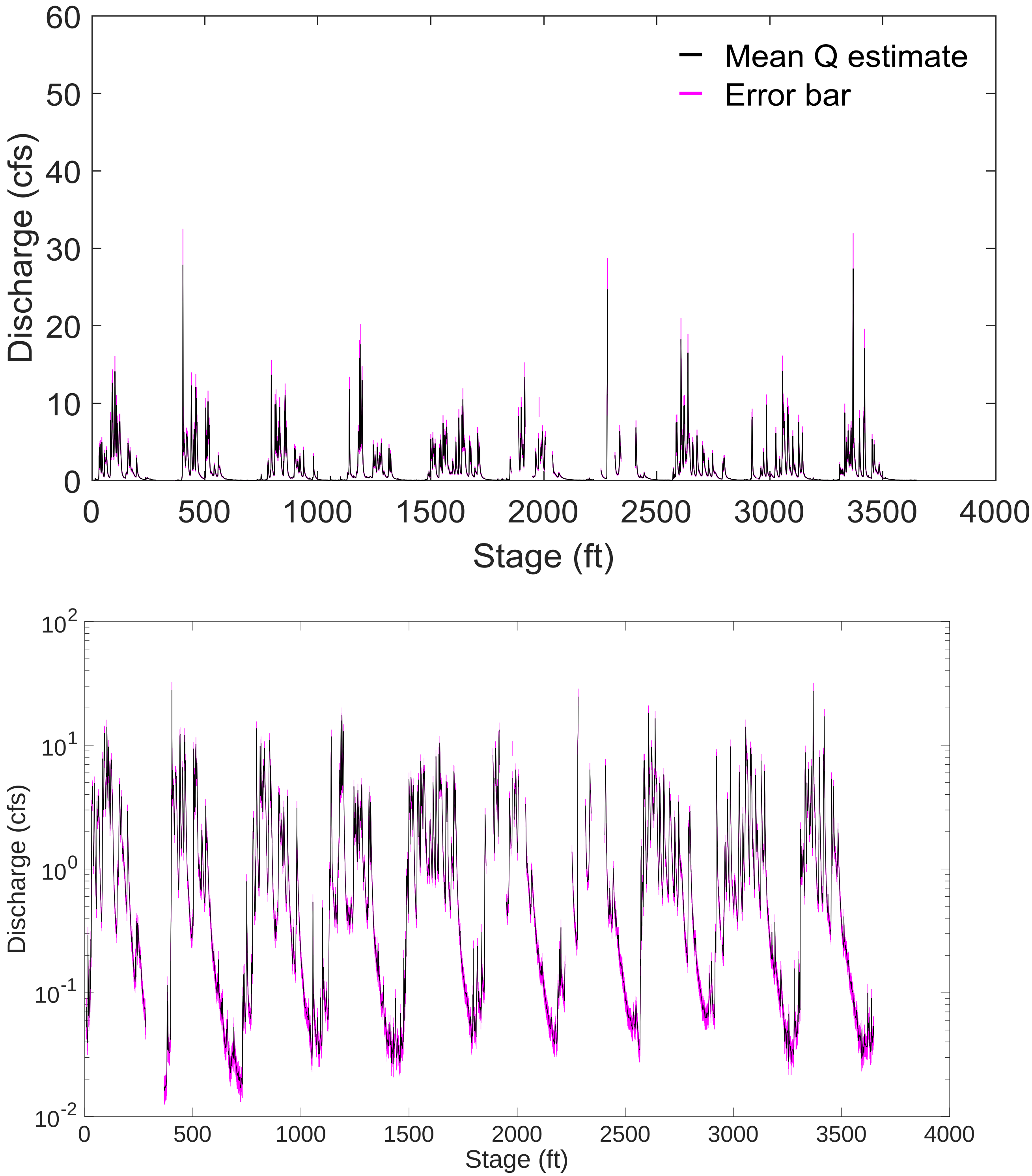


Fig. 2.7: Mean Daily hydrograph with error bars for NBG between Oct 1, 2005 and 30 Sep 2015. Upper panel presents data in linear scale; lower panel presents data in logarithmic scale

2.1. Annual water yield

Annual water yield (Fig. 2.8) was calculated for NBG considering all data available from complete days. Note the number of days with complete discharge record per year (Fig. 2.9). The runoff coefficient (Q/P) was calculated considering both the precipitation in the study area and the precipitation in Alsea FH (Fig. 2.10).

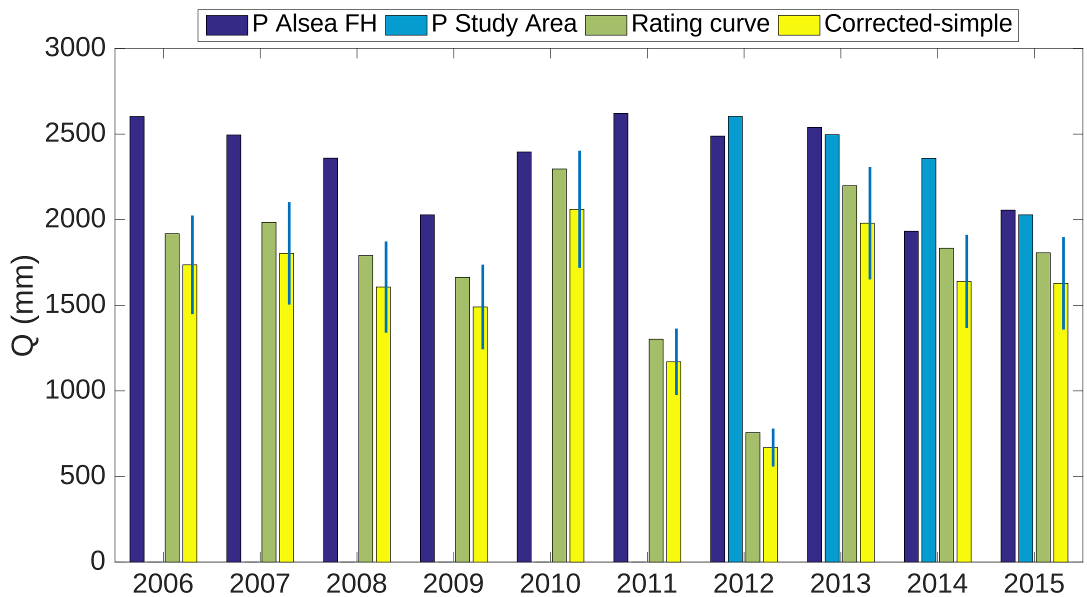


Fig. 2.8: Annual precipitation recorded at the Alsea FH station (No. 350145); annual precipitation computed combining precipitation data from 4 stations within the area of study (Appendix 1); annual water yield computed with 2 methods (raw rating curve, and corrected stage (equation 2.2). Error bars for the corrected water yield were calculated considering the mean combine uncertainty in Fig. 2.4).

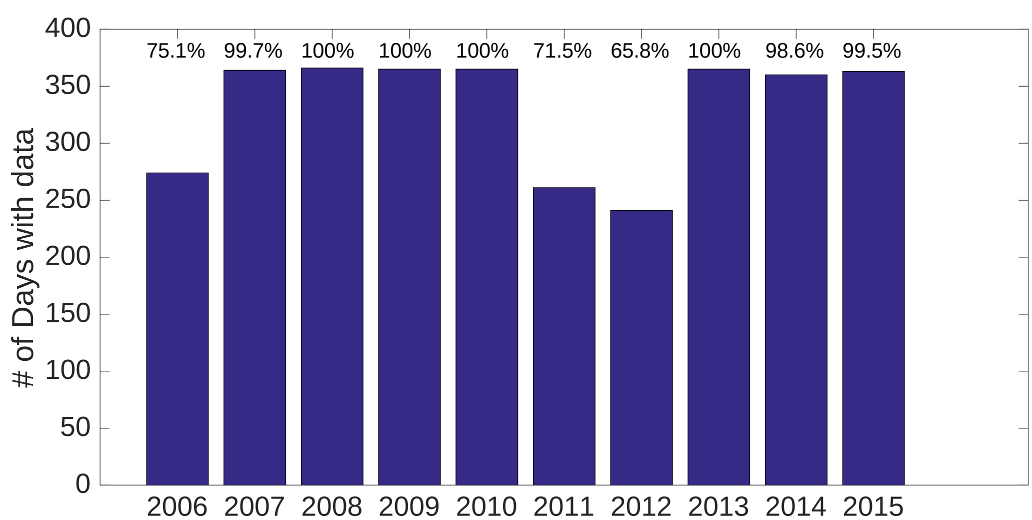


Fig. 2.9: Number of days per year with complete record for NBL. The percentage of the year with complete record is also indicated.

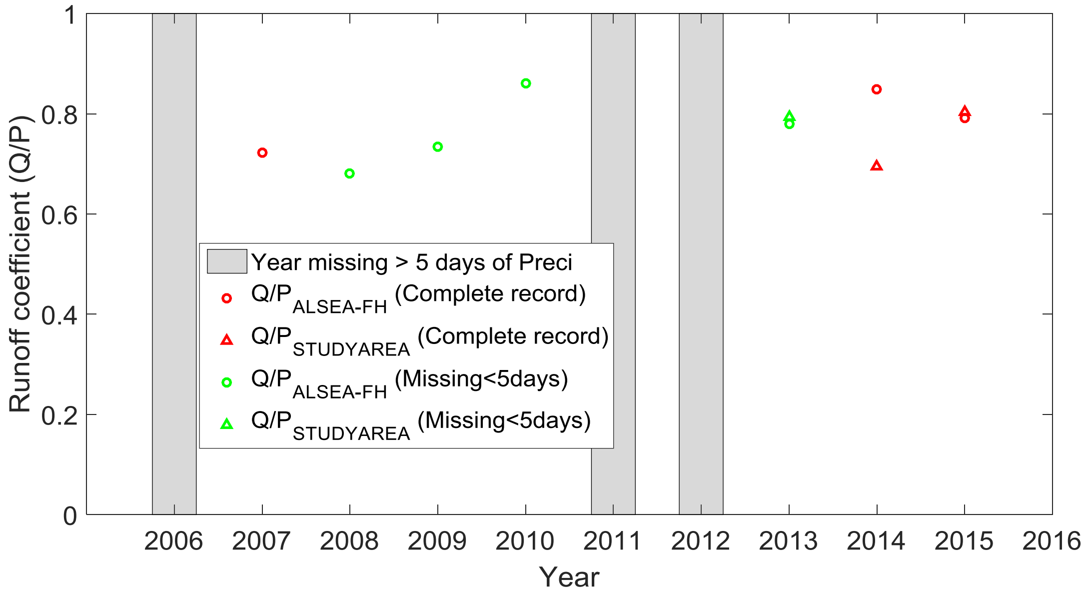


Fig. 2.10: Annual runoff coefficient (Q/P) in NBG based on discharge (Q) computed with the corrected stage data and precipitation (P) collected in the study area and the Alsea FH station. No calculation (grey bars) is presented for years missing more than 5 days of Q data

3. **Deer Creek Gauge**

The stage-discharge data available for the Deer Creek Gauge (DCG) consisted of 46 stage-discharge pairs collected between 1959 and 2014 (Fig. 3.1a). Out of those pairs, 43 were considered reliable to build a rating curve (red markers, Fig. 3.1.a). Some of the stage-discharge data (40%) was collected early in the record between 1959 and 1972. The remaining 28 data pairs were collected recently between 2005-2016 (Fig. 3.1b).

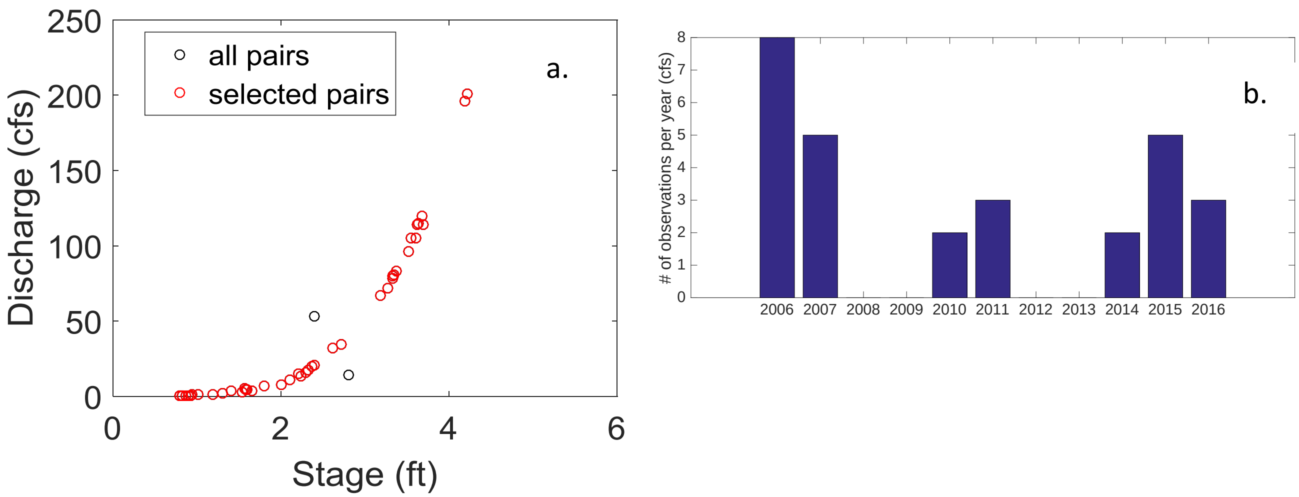


Fig.3.1. a: Stage-Discharge pairs available for the Deer Creek Gauge. Red markers correspond to data pairs considered reliable to build a rating curve; b: number of discharge measurements collected per water years 2005 - 2016.

3.1. Rating curve

A rating curve (Fig. 3.2) was calculated based on the 43 pairs of stage-discharge measurements. The relationship between stage and discharge is best described by a power function (Table 3.1, Equation 3.1).

$$Q = 0.68H^{3.94} \qquad R^2=0.99 \qquad (3.1)$$

where H, is stage in feet and Q is discharge in cfs.

The reliability of the electronically recorded stage during the gauging activities was assessed by comparing the electronic stage values in the database to electronic stage values recorded while downloading the data (field recorded electronic $stege_{e.}$ Overall these values match (Fig. 3.3). However, this relationship should correspond exactly to a 1:1 line (both correspond to the values recorded in the data logger). The discrepancy between values could be related to inaccuracies in the field while recording the data either the stage value or the time of collection. A comparison between reference stage values (measured from staff gauge) and the electronically recorded values collected simultaneously with discharge measurements was also performed (see section 3.1.2).

Table 3.1: Coefficients of the power fit that best describes the rating curve in DCG. Coefficients and standard errors (Se) are included.

Coefficient	Value	Se
a (intercept)	0.68	0.033
b	3.94	0.05482

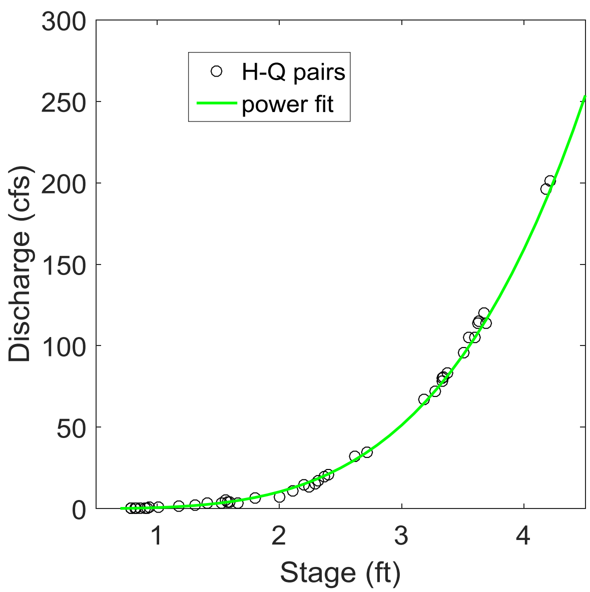


Fig. 3.2: Rating curve for the Deer Creek Gauge, DCG, including 43 stage-discharge pairs (circles) and best power fit to the data.

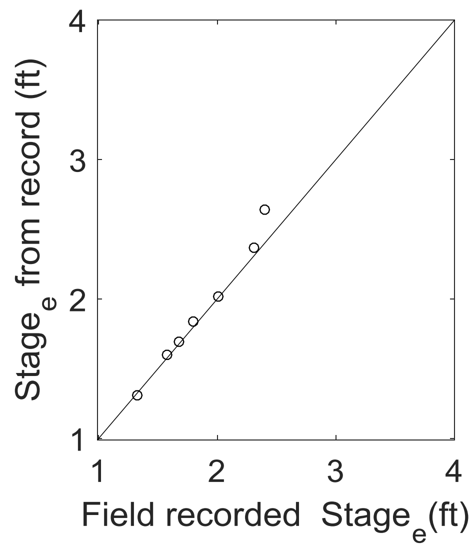


Fig. 3.3: Comparison of the field recorded electronic stage (Stage$_e$) to the value recorded in the database.

3.1. Source of uncertainty in the discharge calculations

The main sources of uncertainty in the discharge data include the accuracy of the water level loggers, the uncertainty associated to the accuracy of the rating curve, and the uncertainty associated to the stage measurements. For this QA/QC analysis, the level logger is assumed to be accurate.

3.1.1. Accuracy of the rating curve

The accuracy the rating curve fit (UQ) was assessed by conducting a 1x10^6 Monte Carlo simulations randomly varying the parameters of the power fit (Equation 3.1., Table 3.1, Fig.3.4a). This provided information about the uncertainty around the fits (Fig. 3.4b, red line). The relative uncertainty of UQ varies between 8.8 and 18 % within the stage range over which the rating curve was developed. As expected outside this stage range (stage <0.79 and stage>4.21 feet) the uncertainty is much higher (red line, Fig. 3.4).

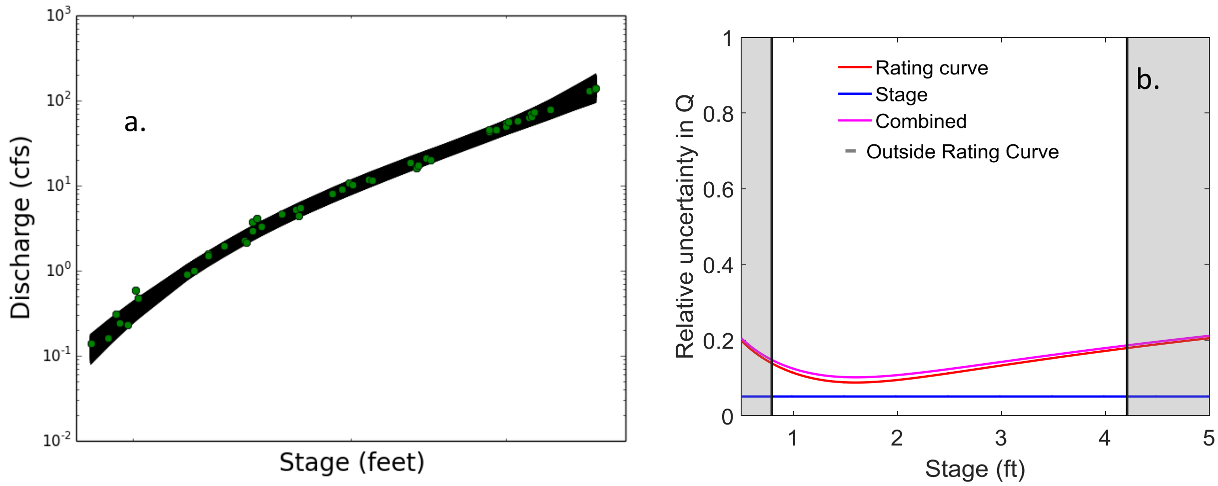


Fig. 3.4: a: Variability in the rating curve considering 1x10^{6} Monte Carlo simulations randomly varying the parameters of the power fit. Black lines correspond to the 1x10^{6} relations and the green markers are the observations; b. Relative uncertainty in discharge, UQ, associated to the strength of the power fit (red line), the uncertainty in discharge associate to the stage accuracy, US, (blue line), and the combined discharge uncertainty (magenta line).

3.1.2. Accuracy of stage data

In order to assess the reliability of the stage a comparison between the reference and electronic stage data was performed including both discharge measurements and other field visits conducted between 2012 and 2016 (Fig. 3.5). The comparison indicates that a simple correction factor (similar to Equation 2.2, for NBG) is appropriate between 10/3/2011 and 7/9/2014. After that, the data indicated that the electronic state had serious complications with discrepancies between reference and electronic stages up to 0.4 feet. Therefore, the data is only QA/QC'd up to July 9 2014 using Equation 3.2 (Fig. 3.6). It is also assumed that the uncertainty prior to 2011 is similar to the uncertainty between 2011 and 2014:

$$Stage_c = \frac{Stage_u - b}{m}, \quad m = 0.9954 \; and \; b = 0.0185 \qquad (3.2)$$

where $Stage_c$ is corrected stage, $Stage_u$ is the uncorrected stage and *m* and *b* are the slope and intercept of the relation between reference stage and electronic stage, respectively.

The total uncertainty in discharge varies between 10 and 18% and was computed as the square-root of the sum of square uncertainties associated with both the rating curve and the stage (magenta line in Fig. 3.4).

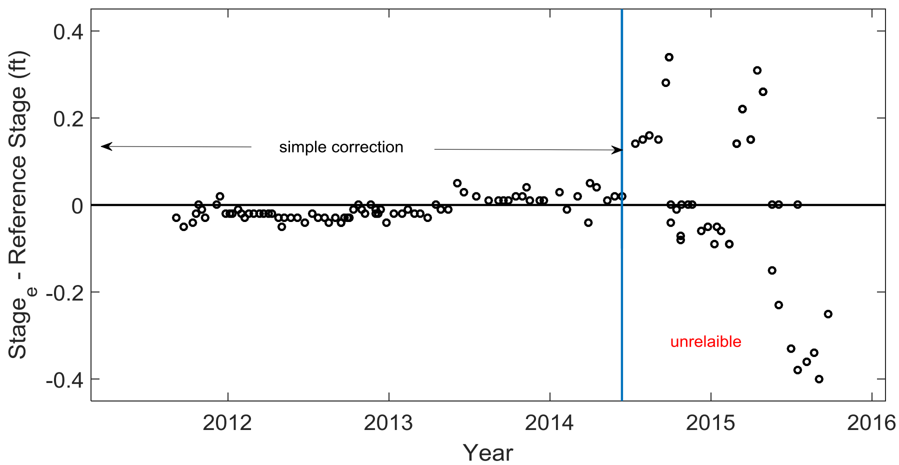


Fig.3.5: Difference between electronic and reference stage values between 2012 and 2016 in DCG. Data after July 9 2014 is considered unreliable.

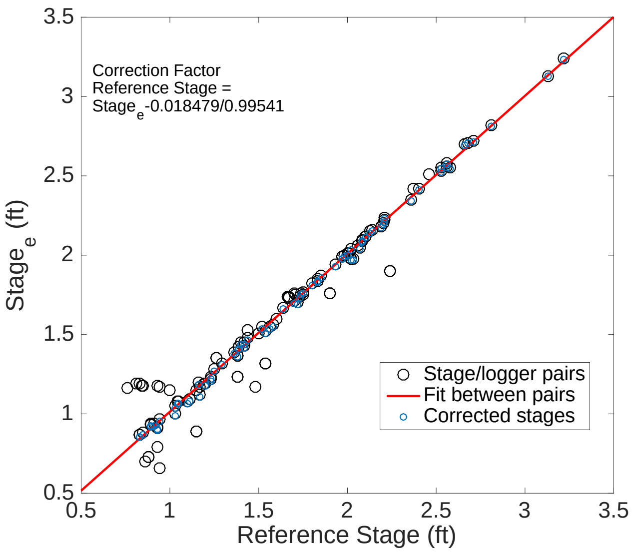


Fig. 3.6. Comparison of reference and electronic (stage$_e$) stage. A linear factor (Equation 3.2.) was applied to correct the stage data.

3.2. Hydrographs and QA/QC discharge data

The available stage data consisted of 10-minute stage data collected between Oct 1, 2005 and Sep 30, 2015. This record has complete data for 3,002 days (82%). However, the data after July 9 2014 was considered not reliable. Thus the actual number of days with complete record is 2555 (70%); that this there are 1,097 days with unreliable, incomplete, or missing discharge data. The QA/QC discharge data (blue line Fig. 3.7) was calculated based on:

a. Corrected stage data using Equations 3.2
b. Rating curve using Equation 3.1.
c. Assessment of uncertainty

The discharge record was also generated based on the uncorrected stage (black line, in Fig, 3.7) for comparison. The complete 10-min and daily time series are provided in 3 text files (Table 3.2). In addition, Fig. 3.8. presents the daily hydrograph with error bars in linear and log-space.

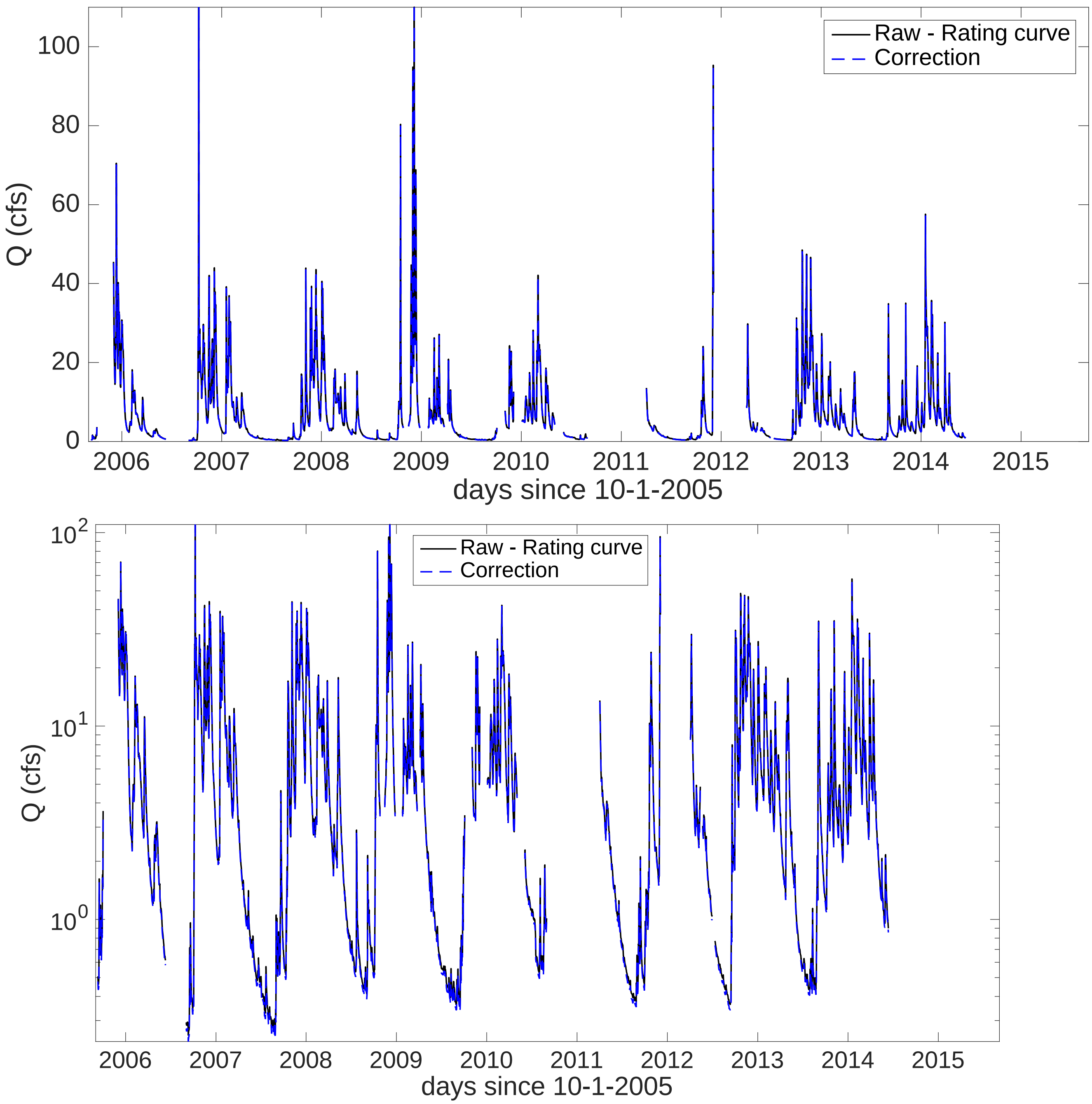
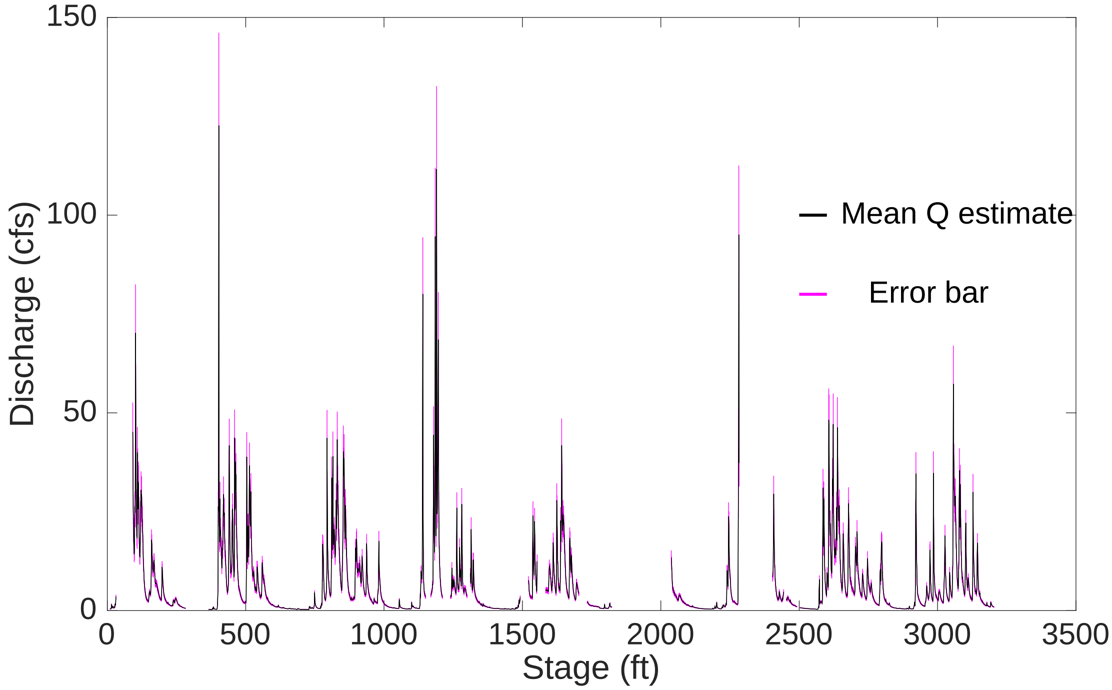


Fig. 3.7: Mean daily discharge for DCG between Oct 1, 2005 and 30 Sep 2015. Upper panel presents data in linear scale; lower panel presents data in logarithmic scale.



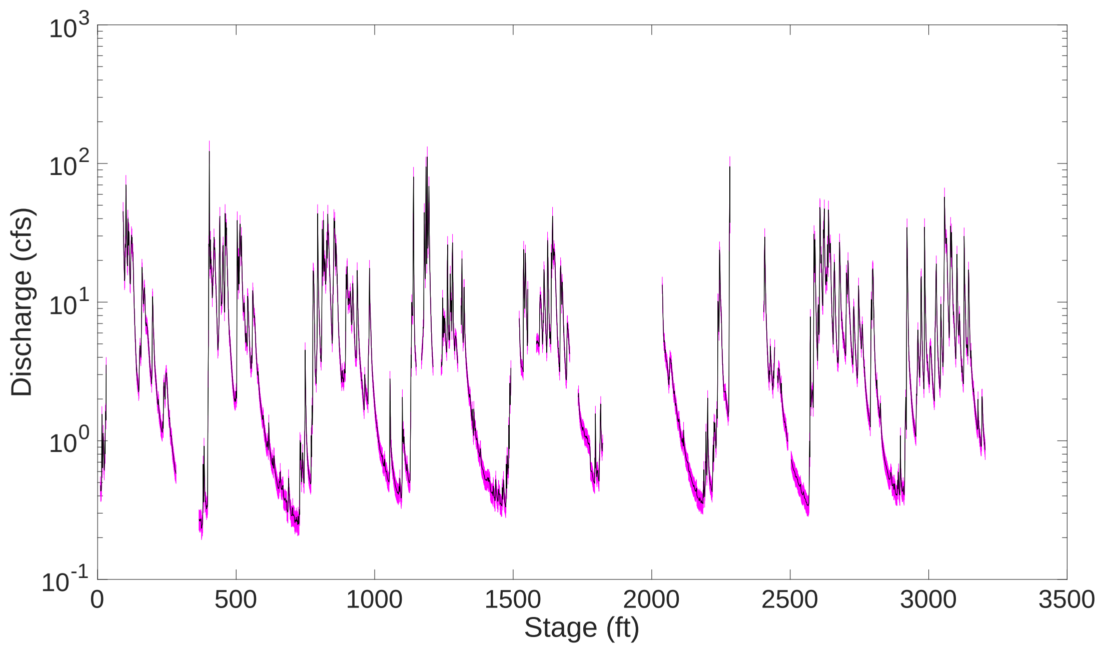


Fig. 3.8: Mean daily discharge with error bars for DCG between Oct 1, 2005 and 30 Sep 2015. Upper panel presents data in linear scale; lower panel presents

Table 3.2: Generated QA/QC time series of discharge for DCG.

Name	Description
DCG_10_Q_minute_data_2006-2015.txt	Date/time Raw uncorrected stage Raw uncorrected stage Stage corrected (equation 3.2) Discharge value calculated based on raw stage and rating curve Discharge value calculated based corrected stage and rating curve
DCG_daily_Q_data_2006-2015.txt	Date Raw uncorrected stage Stage corrected (equation 3.2) Discharge value calculated based on raw stage and rating curve Discharge value calculated based corrected stage and rating curve
DCG_daily_Q_data_2006-2015_with_error.txt	Date Discharge value calculated based on complex-corrected stage and rating curve error

3.1. Annual water yield

Annual water yield (Fig. 3.9) was calculated for DCG considering all data available from complete days only. Note the number of days with data available per year (Fig. 3.10). The runoff coefficient (Q/P) was calculated considering both the precipitation in the study area and the precipitation in Alsea FH (Fig.3.11).

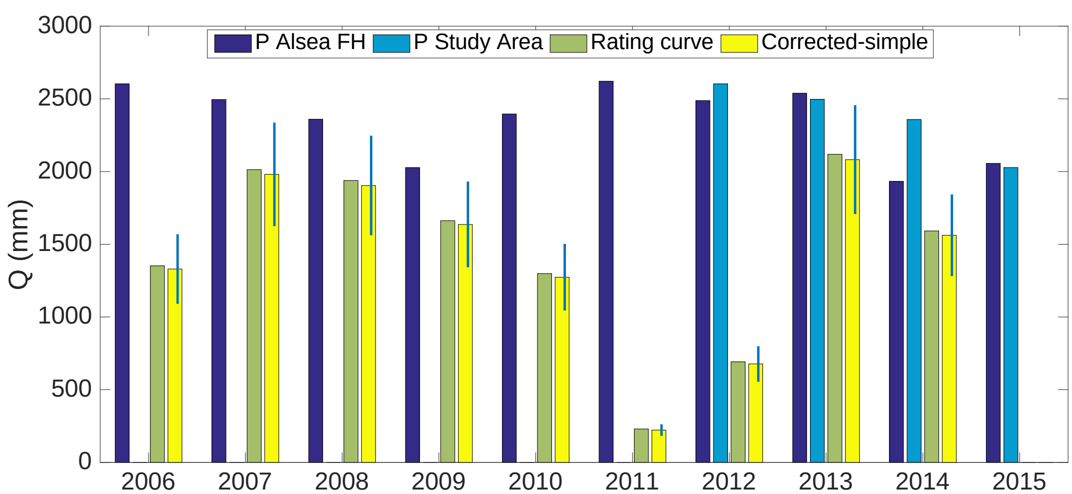


Fig. 3.9: Annual precipitation recorded at the Alsea FH station (No. 350145); annual precipitation computed combining precipitation data from 4 stations within the area of study (Appendix 1); annual water yield computed with 2 methods (raw rating curve and corrected stage (Equation 3.2). Error bars for the corrected water yield were calculated considering the mean combine uncertainty in Fig. 3.4).

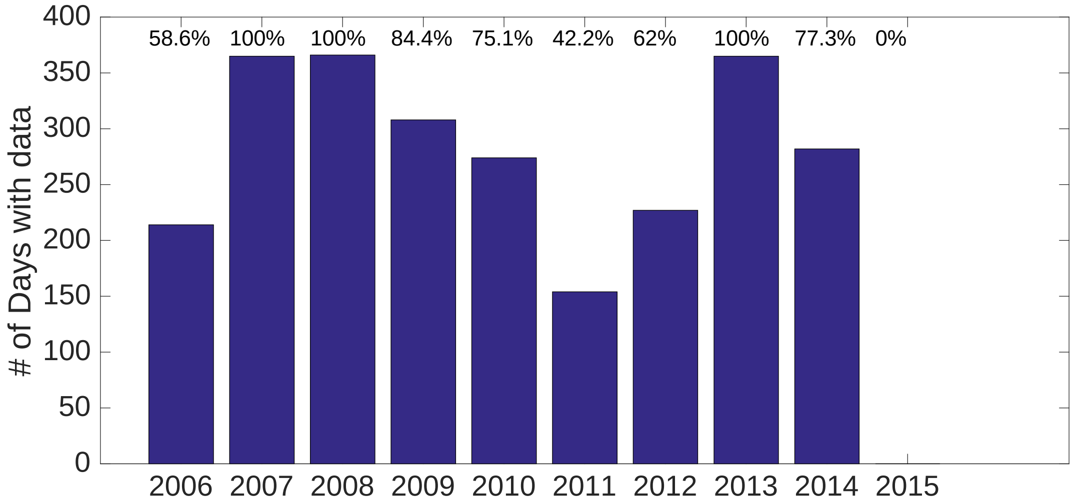


Fig. 3.10: Number of days per year with complete record for DCG. The percentage of the year with complete record is also indicated.

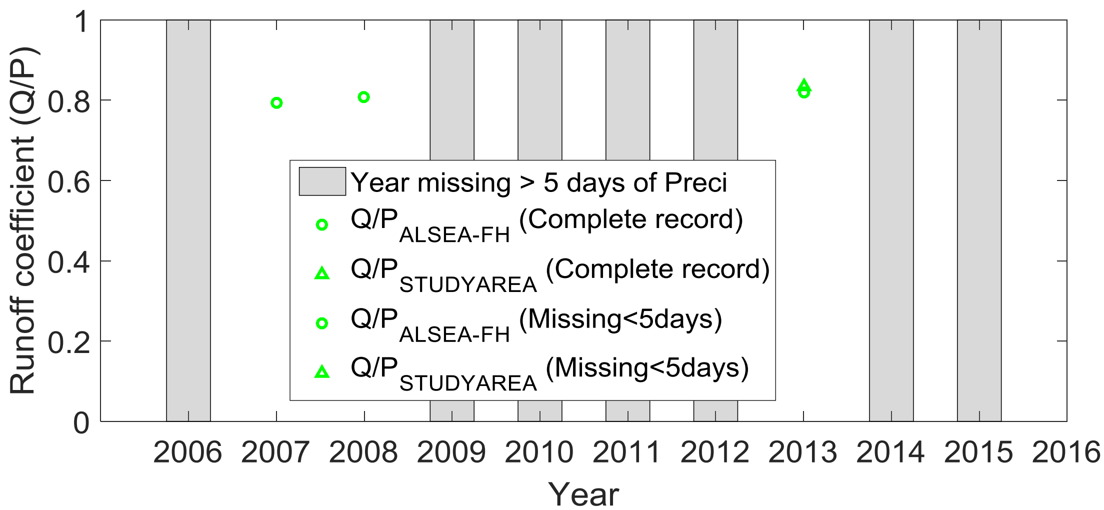
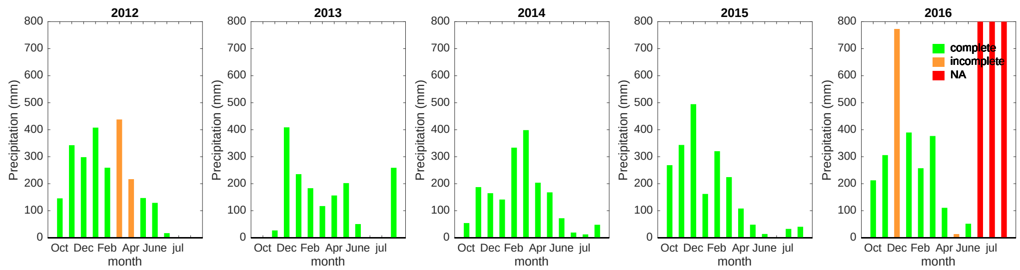


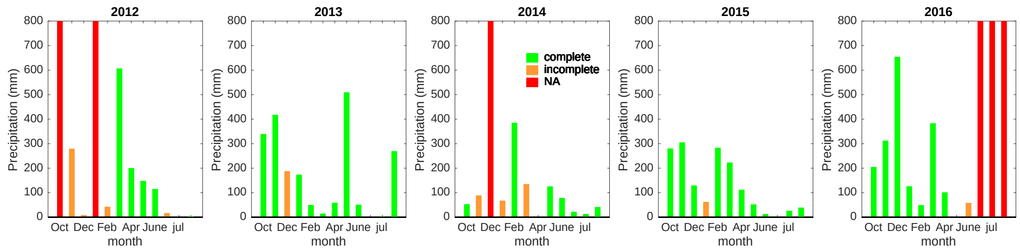
Fig. 1.14: Annual runoff coefficient (Q/P) in DCG based on discharge (Q) computed with the corrected stage data and precipitation (P) collected in the study area and the Alsea FH station. No calculation (grey bars) is presented for years missing more than 5 days of Q data

4. Appendix 1: Precipitation data: Compiled between Oct 1, 2011 and June 30, 2016

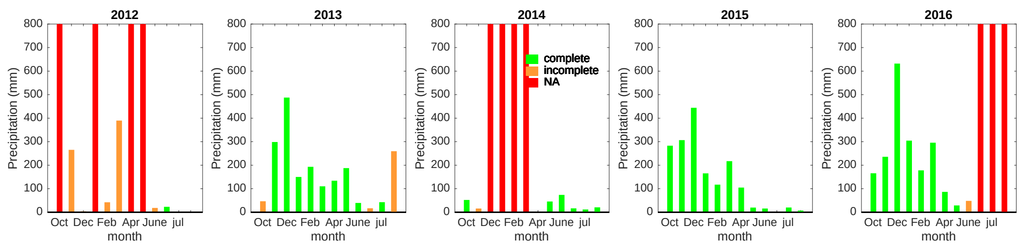
Met Station



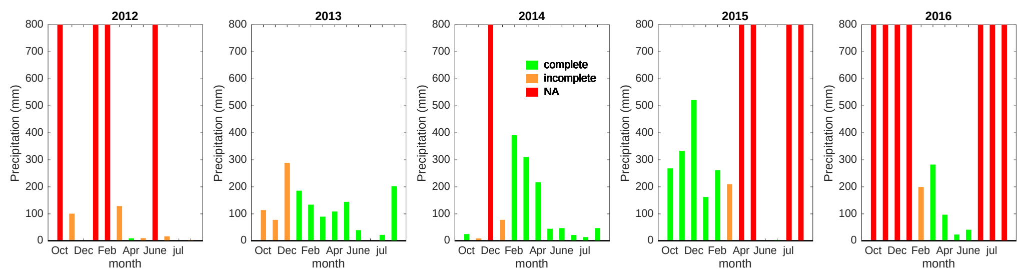
Flynn Creek



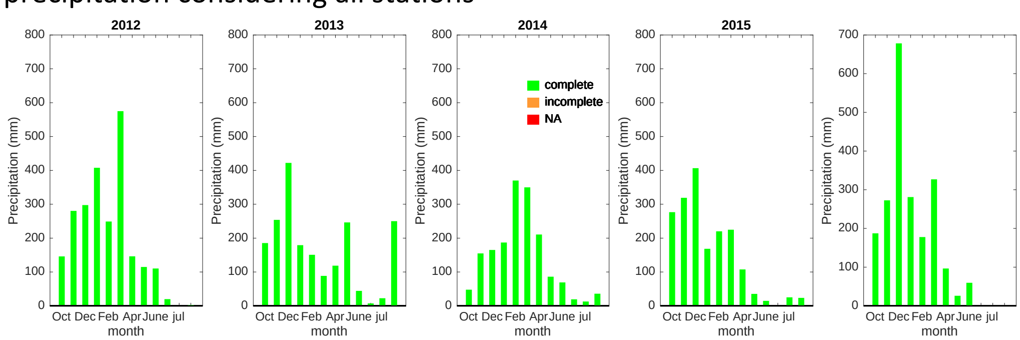
Deer Creek



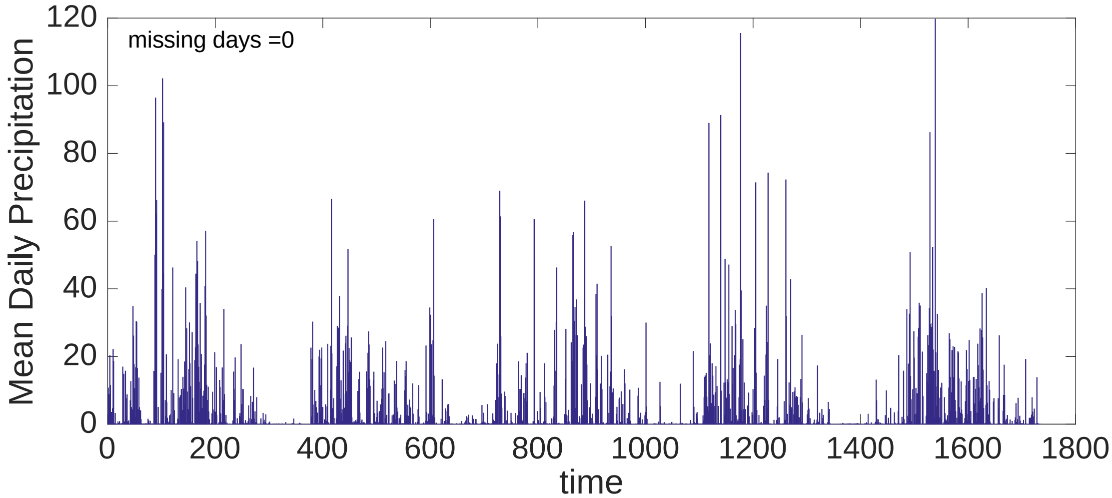
Needle Branch



Monthly precipitation considering all stations



Mean Daily Precipitation in the Alsea Pair Watershed Study



Precipitation files:

ALSEA_FISH_HATCHERY_2005-2016.txt
DATE
Precipitation (mm)
WY: Water year

RainGuageComparisonWY12016.txt
Date
MET Daily Precipitation (mm)
FCG Daily Precipitation (mm)
DCG Daily Precipitation (mm)
NBU Daily Precipitation (mm)

Combined_Daily Prec_APWS.txt

This includes the daily precipitation data between 10/01/2011 and 06/30/2016 computed for the Alsea Pair Watershed study.
Date
Prec (mm)

5. Appendix 2: File description Flynn Creek gauge QA/QC process

FCG_rating.txt
DATE: Date of collection
Q FILTERED: 1 (included); 0 (not included)
TIME: time of day
Stage1: Reference stage (ft)
Stage2: Electronic stage (ft)
Q: Discharge (cfs)

FCG_Stage.txt
Date/time
Stage (feet)

FCG_Stage_gauge-logger-pairs_2012_2015.txt

Date: Date of collection
Reference stage (ft)
Electronic Stage (ft)
Difference: Electronic Stage- Reference stage (ft)
WY: Water year
Shovel: 1: post sediment removal; 2: pre sediment removal; 3: instances when sediment was not removed.
Comments

FCG_relative_uncertainty.dat
Stage (feet)
Relative uncertainty

FCG_ Uncertainty_stage.txt
Stage (feet)
Relative uncertainty

FCG_Combined_Q_uncertainty.txt
Stage (feet)
Relative uncertainty

6. Appendix 3: File description Needle Branch Gauge Creek gauge QA/QC process

NBG_rating.txt
DATE: Date of collection
Q FILTERED: 1 (included); 0 (not included)
TIME: time of day
Stage1: Reference stage (ft)
Stage2: Electronic stage (ft)
Q: Discharge (cfs)

NBG_Stage.txt
Date/time
Stage (feet)

NBG_Stage_gauge-logger-pairs_2012_2015.txt

Date: Date of collection
Reference stage (ft)
Electronic Stage (ft)
Difference: Electronic Stage- Reference stage (ft)
WY: Water year
Shovel: 1: post sediment removal; 2: pre sediment removal; 3: instances when sediment was not removed.
Comments

NBG_uncertainty.dat
Stage (feet)
Relative uncertainty

NBG_Uncertainty_stage.txt
Stage (feet)
Relative uncertainty

NBG_Combined_Q_uncertainty.txt
Stage (feet)
Relative uncertainty

7. Appendix 3: File description Deer Creek Gauge Creek gauge QA/QC process

DCG_rating.txt
DATE: Date of collection
Q FILTERED: 1 (included); 0 (not included)
TIME: time of day
Stage1: Reference stage (ft)
Stage2: Electronic stage (ft)
Q: Discharge (cfs)

DCG_Stage.txt
Date/time
Stage (feet)

DCG_Stage_gauge-logger-pairs_2012_2015.txt

Date: Date of collection
Reference stage (ft)
Electronic Stage (ft)
Difference: Electronic Stage- Reference stage (ft)
WY: Water year
Shovel: 1: post sediment removal; 2: pre sediment removal; 3: instances when sediment was not removed.
Comments

DCG_relative_uncertainty.dat
Stage (feet)
Relative uncertainty

DCG_Uncertainty_stage.txt
Stage (feet)
Relative uncertainty

DCG_Combined_Q_uncertainty.txt
Stage (feet)
Relative uncertainty