CHAMP CREW VARIABILITY STUDY

INFLUENCE ON QUALITY OF TOPOGRAPHIC SURFACES & DERIVED METRICS

DRAFT REPORT TO ECO LOGICAL RESEARCH, INC. & COLUMBIA HABITAT MONITORING PROGRAM (CHAMP)

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EXECUTIVE SUMMARY

The Columbia Habitat Monitoring Program (CHaMP) relies heavily on topographic surveys to provide spatially-explicit maps and snap-shots of habitat conditions. Field crews are responsible for editing their raw topographic data and TINs to ensure that their derived maps (e.g. DEMs and water depths) are an accurate portrayal of what they saw in the field. This emphasis on the field crew's expertise and judgment is critical for two reasons. First, the field crew is in a much better position to assess the accuracy and representativeness of a habitat survey then someone who has never visited the site. Secondly, the field crews' involvement in the data analysis sets up an important positive feedback loop, which helps the crews refine and improve their implementation of the field surveys. Giving crews these 'extra' responsibilities instills in them more pride and ownership of the data, and also gives them a better appreciation for how the data will be used. One potential downside of this approach is that the variability in effort, skill and implementation of the protocol by each crew could make it: a) more difficult to understand the relative quality of the data, and b) limit our ability to detect changes through time in topography, habitat, and habitat attributes.

In order to better understand the influence of crew to crew variability and to what extent stream size influences this variability, an experiment was set up at six CHaMP sites within the Grande Ronde Basin, during the 2011 Pilot CHaMP season. Seven different crews were sent to six sites within a short-window of time over which it can be assumed no geomorphic changes took place. Accordingly, observed differences in surveys could be attributed to crew variability. Three of the sites were in small tributary streams (<8 m banfull width; second order stream), and three of the sites were on the mainstem Grand Ronde (> 14 m bankfull width; fifth order stream). In this section, we focus on the influence of crew variability on the quality of topographic data and derived products. We set out to resolve the following specific questions:

1. What are the magnitudes of inter-crew variability within sites and what proportion can be attributed to systematic surveying or processing errors and blunders?
2. Does the magnitude of inter-crew variability show consistency in different portions of the survey extent (e.g. greater on banks or floodplains and less in the in-channel habitat)?
3. Are individual crews consistent in their implementation of the protocol (e.g. sampling effort) across sites?
4. To what extent does crew variability limit our ability to reliably calculate DEM derived metrics such as water depth and detect and interpret geomorphic changes to physical habitat from time series data?

Analysis methods included both basic statistical and advanced spatial analysis approaches. Our statistical methods were geared towards summarizing differences in topographic survey metrics (e.g. total number of points collected, survey extent ,etc), while the spatial analysis approaches consisted of estimating spatially variable DEM errors in each DEM and various raster comparison methods of the interpolated topographic surfaces (e.g. TINs, DEMs) and their derivatives in ArcGIS.

The primary findings were

- **Crews are collecting topographic data of sufficient quality and consistency** that their DEMs and water depths show the same basic spatial patterns and their distributions and summary statistics are within acceptable levels of error. *Additional guidance on point densities and breakline data collection could help promote higher qualities and consistency*.
- The **largest observed differences between crews were attributed to a systematic error** by one crew (different crews across sites). Most systematic errors are easy to identify and remedy in the data editing or QA/QC process (e.g. TIN busts). *These errors are also easy to avoid with more targeted training and QA/QC procedures*.
- The **topographic data between crews is of adequate quality to support geomorphic change detection** for both obvious changes (reported) and subtle changes in the channel and along channel margins. However, crews were not given adequate guidance on how far to extend their survey extents out into areas that the channel could plausibly migrate into. *These floodplain areas can generally be surveyed with minimal effort to facilitate a more accurate portrayal of future geomorphic changes.*

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1: INTRODUCTION

The goal of the Columbia Habitat Monitoring Program (CHaMP) is to develop and implement fish habitat monitoring (status and trend) methods in up to 26 watersheds in the Columbia River basin (Bouwes et al., 2011). The CHaMP protocol incorporates both channel unit and total station topographic surveys from which Digital Elevation Models (DEMs) and water depths can be derived for every sample reach. CHaMP relies heavily on topographic surveys to provide spatially-explicit maps and snap-shots of habitat conditions. Field crews are responsible for editing their raw topographic data and TINs to ensure that their derived maps (e.g. DEMs and water depths) are an accurate portrayal of what they saw in the field. This emphasis on the field crew's expertise and judgment is critical for two reasons. First, the field crew is in a much better position to assess the accuracy and representativeness of a habitat survey then someone who has never visited the site. Secondly, the field crews' involvement in the data analysis sets up an important positive feedback loop, which helps the crews refine and improve their implementation of the field surveys. Giving crews these 'extra' responsibilities instills in them more pride and ownership of the data, and also gives them a better appreciation for how the data will be used. One potential downside of this approach is that the variability in effort, skill and implementation of the protocol by each crew could make it: a) more difficult to understand the relative quality of the data, and b) limit our ability to detect changes through time in topography, habitat, and habitat attributes.

The CHaMP program recently concluded its pilot field season where 12 crews sampled 325 unique sites. Like any monitoring campaign that might rely on different crews, either between years or between sites, CHaMP suffers from knowing whether calculated differences between surveyed and derived quantities are real or due to noise from discrepancies in how the different crews sampled. That noise may be due to the inherent precision limitations of the measurement methods, sampling differences, interpolation inaccuracies, and/or crew variability amongst other factors. To discern the extent of crew variability this study was conducted to intercompare topographic surfaces derived by different crews.

The objective of this report is to assess the magnitude and effect of variability in the topographic data collected by different crews. We seek to enumerate the extent to which variability in how crews sample topography limits the quality and reliability of data, the calculation of metrics derived from topography (e.g. water depth), and the ability to reliably make inter-comparisons between different sites and/or changes through time at one site (i.e. time series geomorphic change detection analysis). We are particularly interested in differentiating between background noise due to inherent acceptable variability in sampling, versus noise and errors due to systematic biases in the quality of data from crews. If there are consistently poor performing crews and consistently well-performing crews or if different crews make a consistent set of blunders or mistakes, this is encouraging as it suggests that with better training, better feedback and better QA/QC, the variability of performance between crews can be minimized.

2: UPPER GRANDE RONDE RIVER SAMPLE REACHES

Seven crews sampled the same six stream reaches in the Upper Grande Ronde River watershed (Figure 1) from June through August 2011. The Upper Grande Ronde River flows in a northeasterly direction and is a left-bank tributary to the Snake River. The basin encompasses 4238 km^2, has a mean elevation of 1267 m and has a mean annual precipitation of 719 mm. The six sample reaches selected include 3 smaller stream sites and 3 larger mainstem sites (Table 1). The smaller stream sites had average bankfull widths between 5.7 and 7.2 m and sampled reach lengths between 120 m and 160 m; whereas the larger streams had average bankfull widths between 14.8 and 16.1 m and sampled reach lengths between 320 m and 360 m. Reach slopes varied across all sites between 0.92% and 3.00%.

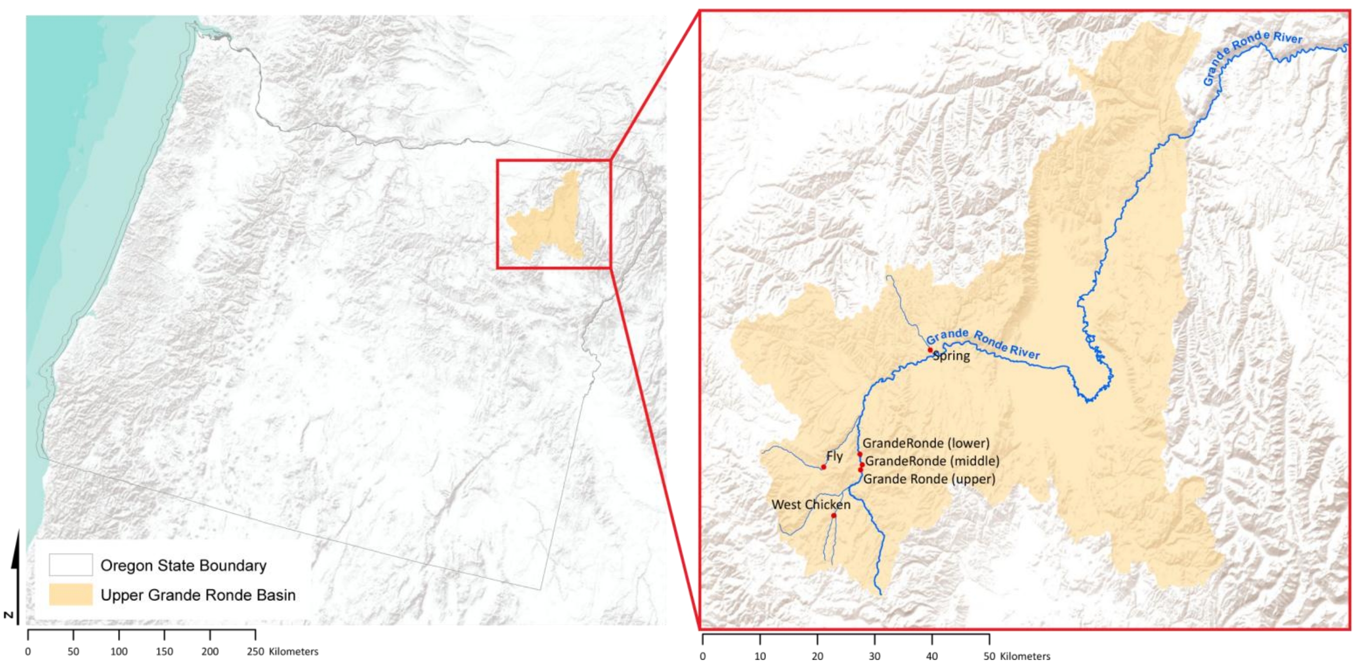

Figure 1. Upper Grande Ronde River crew variability sample reaches.

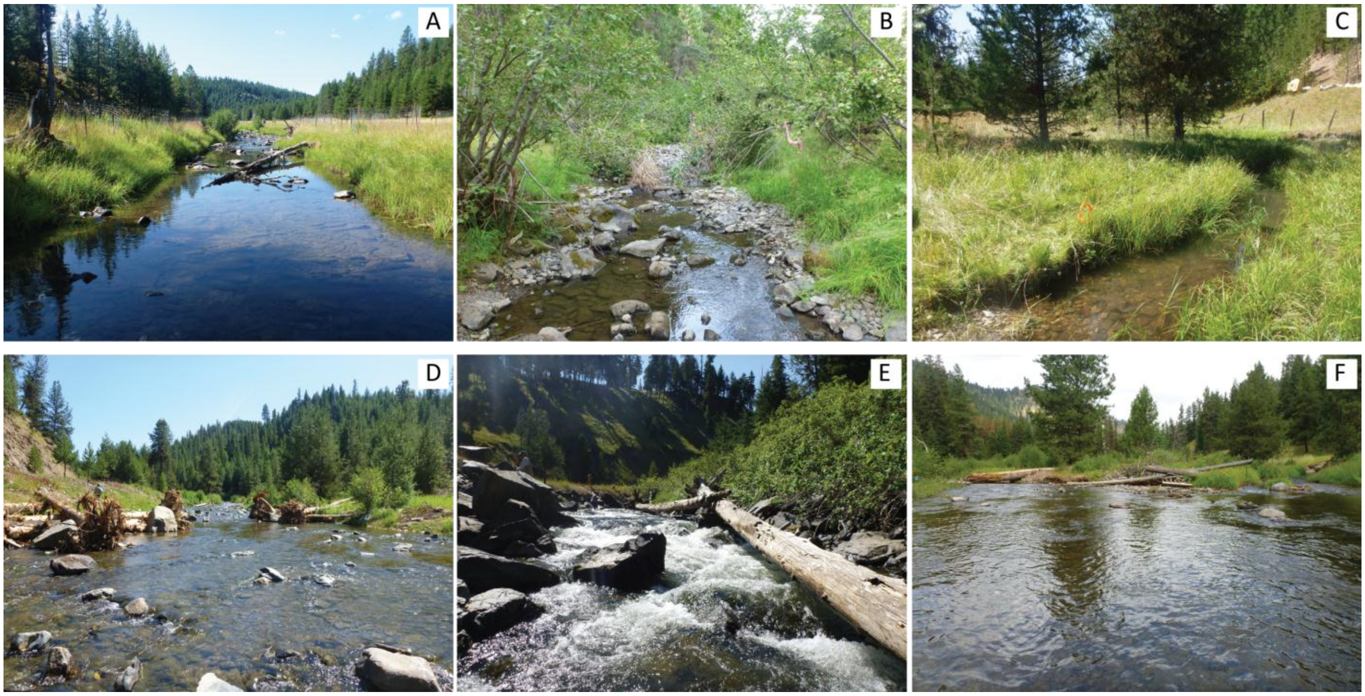

Figure 2 - Site photos of the 3 lower order sample reaches: A. Fly Creek, B. Spring Creek, C. West Chicken Creek and the three mainstem sample reaches: D. Grande Ronde River upper E. Grande Ronde River middle, F. Grande Ronde River lower.

	Site Characteristic				
Stream Name	Elevation (m)	Gradient (%)	Primary bedform class	Avergae bankfull width (m)	Site length (m)
A. Fly Creek	1311	0.92	Pool-Riffle	7.2	160
B. Spring Creek	953	1.92	Pool-Riffle	5.6	120
C. West Chicken Creek	1328	1.25	Pool-Riffle	5.7	120
D. Grande Ronde River (upper site)	1206	1.14	Plane-Bed	16.8	360
E. Grande Ronde River (middle site)	1187	3.00	Step-Pool	16.1	360
F. Grande Ronde River (lower site)	1155	1.00	Pool-Riffle	14.8	320

Table 1 - Site characteristics for six crew variability sample reaches.

3: STUDY DESIGN

The study was designed to analyze replicate topographic data collected by seven CHaMP crews at the six sites described in §2: and answer questions related to the magnitude and importance of variability between crews at individual sample reaches (inter-crew variability) as well as consistency within crews across sites. Specific questions we sought to resolve were:

1. What are the magnitudes of inter-crew variability within sites?
    a. What proportion of the inter-crew variability at specific sites can be attributed to systematic surveying or processing errors and blunders?

b. Does the magnitude of inter-crew variability show consistency in different portions of the survey extent (e.g. greater on banks or floodplains and less in the in-channel habitat)?

2. Are individual crews consistent in their implementation of the CHaMP protocol across sites?
3. To what extent does crew variability limit our ability to:
   a. Reliably calculate DEM derived metrics such as water depth?
   b. Detect and interpret geomorphic changes to physical habitat from time series data?

The study design called for seven crews to sample the same six stream reaches adhering to sampling methods in the CHaMP protocol (Bouwes et al., 2011). The first crew to sample the site established the appropriate site length, marked the bottom and top of site and established survey benchmarks. These site extents and benchmarks were used by subsequent survey crews to ensure that common coordinate systems were used, which would facilitate the direct comparison of surveys. In general, all crews sampled the same site within a narrow sampling window to minimize any variability in discharge and support the assumption that no physical changes took place between the crew visits (Table 2). The only exception is the ODFWUGR crew who surveyed and established the three lower order tributary sites early in the sampling season (June 14-16), whereas the other crews and three mainstem sites were all sampled in a roughly one month window in August (Figure 3). As some of the crew derived metrics are stage dependent (e.g. water extent, water depth) it was important to discern how stage dependent each crew's observation were. Table 2 compares sample dates and crew measured discharge whereas Figure 3 shows a hydrograph for the Grande Ronde River. Unfortunately, the sole USGS gauging station in the watershed is located over 150 km downstream in the town of Troy near the mouth of the Grande Ronde River. No continuous sampling of discharge or stage takes place at any of the CHaMP sample reaches, but we can use the Grande Ronde hydrograph as a crude proxy and the crew measurements of discharge to discern temporal trends in discharge. Here, in the hydrograph, it is apparent that during the ODFWUGR crew tributary surveys snowmelt runoff was influencing streamflow as evidenced by the spike in the hydrograph. As Figure 3 illustrates, 2011 was an exceptional year in terms of snow-pack with flows elevated above baseflows through July. As a result, the ODFWUGR crew derived water depth rasters were omitted from inter-comparisons at Fly, Spring and West Chicken Creek. The stabilization of streamflow fluctuations in the hydrograph in the month of August (Figure 3) gave us reason to include all other crews' water depth rasters in the intercomparison.

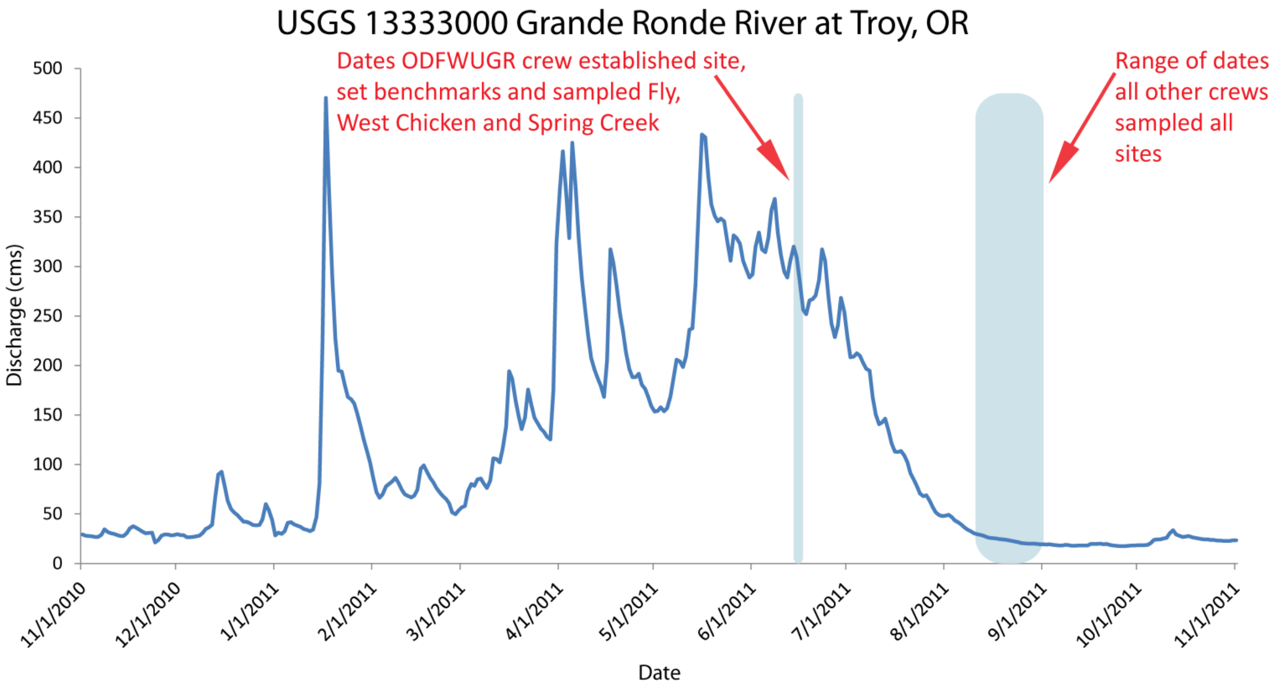

Figure 3 - Hydrograph from November 2010 to 2011 of the Grande Ronde River at USGS gauging station near the town of Troy, OR. The colored bars represent the range of survey dates crews sampled at each site.

		Crew						
Site		CRITFC	ELR	ODFWJD	ODFWUGR	QCI	Tetra	TQ
Fly Creek	Survey Date	Sep 1	Aug 23	Aug 31	June 14	Aug 25	Aug 22	Aug 30
	Crew measured Q (m^3/s)	0.018	0.005	0.009	0.705	0.022	0.009	0.013
Spring Creek	Survey Date	Aug 31	Aug 24	Aug 22	June 16	Aug 26	Aug 23	Aug 29
	Crew measured Q (m^3/s)	0.003	0.004	0.003	0.087	-	0.003	0.002
West Chicken Creek	Survey Date	Aug 31	Aug 23	Aug 25	June 15	Aug 24	Aug 28	Aug 27
	Crew measured Q (m^3/s)	0.006	0.007	0.006	0.221	-	-	0.006
Grande Ronde River (upper site)	Survey Date	Aug 11	Aug 21	Sep 1	Aug 16	Aug 27	Aug 24	Aug 28
	Crew measured Q (m^3/s)	0.799	0.727	0.585	0.820	0.608	0.595	0.656
Grande Ronde River (middle site)	Survey Date	Aug 15	Aug 19	Aug 29	Aug 17	Aug 28	Aug 25	Aug 31
	Crew measured Q (m^3/s)	0.677	0.761	0.447	1.091	0.787	0.696	0.715
Grande Ronde River (lower site)	Survey Date	Aug 11	Aug 17	Aug 23	Aug 15	Aug 29	Aug 27	Aug 26
	Crew measured Q (m^3/s)	0.785	0.753	0.543	0.982	0.512	0.700	0.689

Table 2 - Crew sample dates for each site and crew measured discharge. Null values are for discharge measurements that were too low to be discernible (e.g. approximately 0 m^3/s) or dates at which the stream depth was too shallow to collect accurate velocity measurements.

4: CREW VARIABILITY DEFINED

Figure 4 illustrates graphically some of the primary consequences and scope of crew variability. The figure shows how seven different crews characterized the exact same site (Fly Creek) over a temporal period when we can safely assume there have been no substantial geomorphic changes in the channel topography. If there was no variability in how crews sampled, all seven figures should be exactly the same. Even though many of the differences are subtle, we can identify variability in the in-channel features individual crews choose to capture. For instance, OFWUGR, QCI and TQ (Figure 4D,E,G inset) captured a small boulder or slump-block that other crews did not. Although it appears that all crews captured all major topographic concavities (i.e. pools) the definitive shapes differ (see Figure 4 insets) as a result of where crews chose to: a) emphasize collection of points characterizing the bedform, breaklines and b) make post-hoc edits in the construction of their TINs. Here we also see that differences in survey extents delineated by crews will have a direct effect on the range of elevation values measured (Table 3) with the ODFWUGR crew having the greatest survey extent and highest measured elevation on the floodplain. The exception is the ELR crew, whose DEM elevation range differs from other crews due to a survey blunder where they surveyed from a single control point and incorrectly added 1 meter to the total station base unit recorded height (see Appendix B). Overall we observed variability in the total number of habitat units delineated by different crews. Although 4 of the 7 crews delineated 8 or 9 habitat units at Fly Creek, the CRITFC crew delineated a total of 17 habitat units (Table 3). This reflects that some crews may tend to split habitat units (e.g. split a pool with a crosswise shallower intersection into 2 separate pools) while others may tend to lump habitat units (see Figure 4H). We also observed variability in the number of control points that crews chose to establish to survey a site (Table 4). Additional control points require greater effort to set, survey in and then relocate the total station base unit to occupy a different control point during the topographic survey. However, additional control points can be advantageous affording a more direct line of site between the base unit and survey prism permitting more rapid data point collection. At Fly Creek, a site with relatively little vegetation, crews set 2 to 3 control points (Figure 5). In contrast, at the relatively steeper and topographically more complex Grande Ronde River middle reach, crews established between 5 to 10 control points (Table 4). In the context of observed crew variability, the key question is how significant are both the subtle visible differences and the differences we can't discern visibly on the quality of the topographic representation and our ability to derive metrics from that data and detect changes?

		Crew						
Variable	Statistic	CRITFC	ELR	ODFWJD	ODFWUGR	QCI	Tetra	TQ
Water Depth (m)	Min	0	0	0	0	0	0	0
	Max	0.56	0.51	0.43	0.72	0.53	0.45	0.57
	Mean	0.11	0.11	0.11	0.26	0.12	0.12	0.11
	StdDev	0.08	0.07	0.07	0.13	0.07	0.07	0.08
DEM Elevation (m)	Min	1311.2	1312.1	1311.2	1311.2	1311.2	1311.2	1311.2
	Max	1314.5	1315.8	1314.7	1315.4	1314.4	1314.3	1314.7
	Mean	1312.3	1313.4	1312.3	1312.7	1312.3	1312.5	1312.3
	StdDev	0.54	0.57	0.57	0.69	0.52	0.56	0.54
Wetted Extent (m^2)		637.5	579.1	613.7	960.6	592	588.5	584.6
Survey Extent (m^2)		1496.8	1986.7	1593.8	3079	1434.3	2484.2	1478.6
No. Habitat Units		17	13	9	8	9	8	11

Table 3 - Summary of observed variability in water depth, DEM elevation values, survey extents and number of habitat units delineated by all seven crews at the Fly Creek sample reach.

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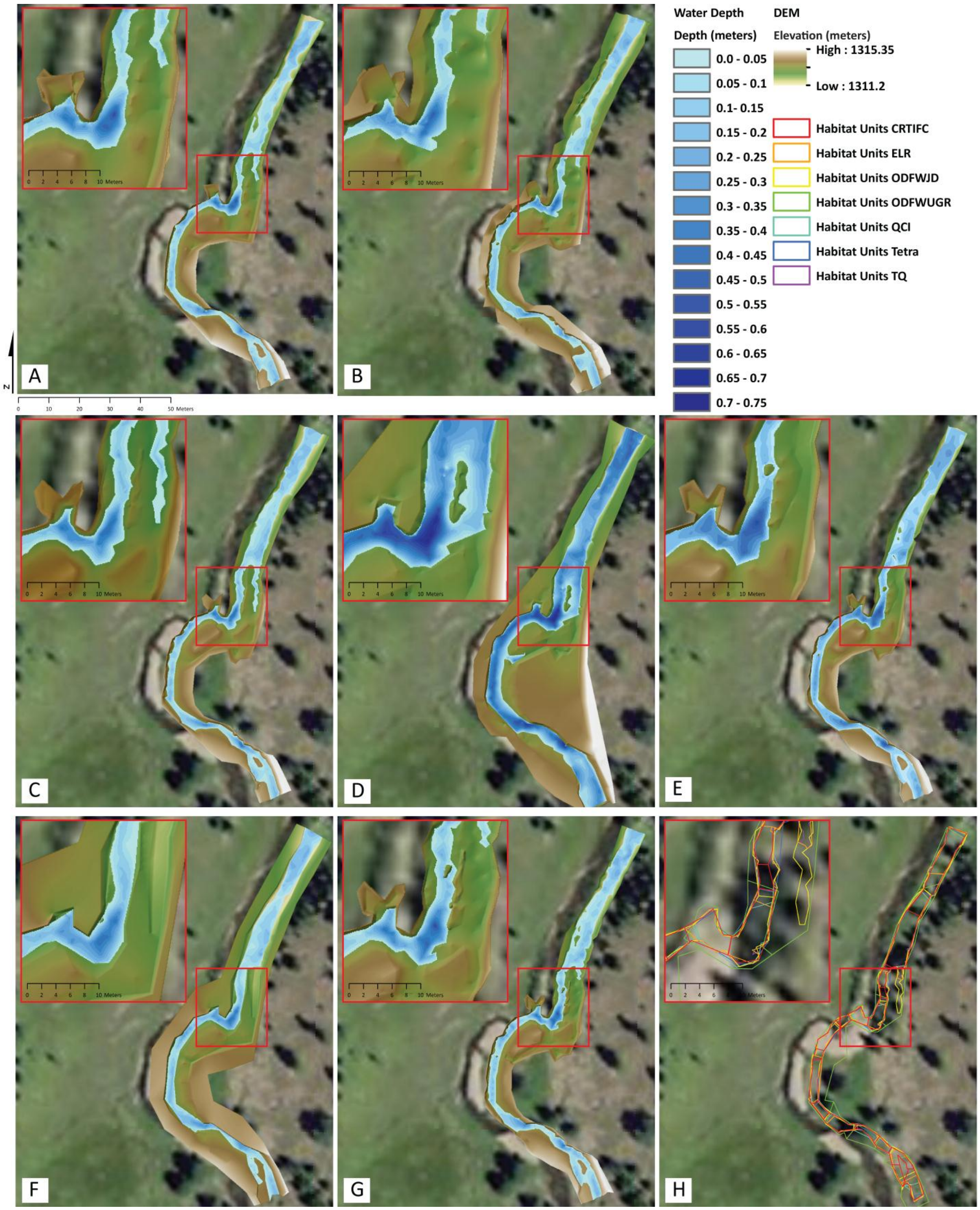


Figure 4 - DEMs and water depth maps of Fly Creek illustrating variable survey extents and water depths between crews: CRITFC (A), ELR (B), ODFWJD (C), ODFWUGR (D), QCI (E), Tetra (F) and TQ (G). Variability was also observed between crews in habitat unit delineation (H).

Figure 5 - Fly Creek control points established by all 7 crews. Benchmarks were established by the first crew to visit the sample reach (here ODFWUGR) and used by subsequent survey crews to ensure agreement between all topographic surveys.

		Crew						
Site		CRITFC	ELR	ODFWJD	ODFWUGR	QCI	Tetra	TQ
Fly Creek	Control points occupied	1	1	1	2	1	2	2
	Control points set	2	2	2	2	2	2	3
Spring Creek	Control points occupied	5	4	3	3	4	5	4
	Control points set	5	5	4	4	6	5	5
West Chicken Creek	Control points occupied	2	2	1	3	2	2	2
	Control points set	2	2	2	4	3	3	3
Grande Ronde River (upper site)	Control points occupied	4	3	2	5	3	3	5
	Control points set	5	4	3	7	5	3	3
Grande Ronde River (middle site)	Control points occupied	7	10	4	5	6	7	6
	Control points set	8	10	5	8	7	7	7
Grande Ronde River (lower site)	Control points occupied	5	6	3	3	6	6	7
	Control points set	6	7	4	4	6	6	7

Table 4 - Number of control points set and occupied by all crews at all sites.

5: METHODS

5.1: FIELD METHODS

Following the CHaMP protocol (Bouwes et al., 2011) crews used total stations to conduct topographically stratified surveys of the sample reach (Brasington et al., 2000). Following this method, the greatest emphasis was placed on sampling areas of more complex topography (e.g. pools) and breaks in slope with less effort expended in areas with homogeneous bedforms (e.g. riffles). Crews were encouraged to collect breaklines (top of bank, toe of bank, edge of water, thalweg, bankfull) to reduce the number of points and effort necessary to capture the channel and floodplain topography (Figure 6). CHaMP crews are given responsibility for editing their raw topographic data and TINs to ensure derived maps look like what they saw in the field. In addition to surveying topography crews: delineated habitat units, sampled invertebrate drift, measured substrate, canopy cover, amongst other habitat attributes. All sites were to be sampled within a single day with the exception of the Grande Ronde River middle and lower sites where 1.5 to 2 days were allocated due to the width and length of these reaches.

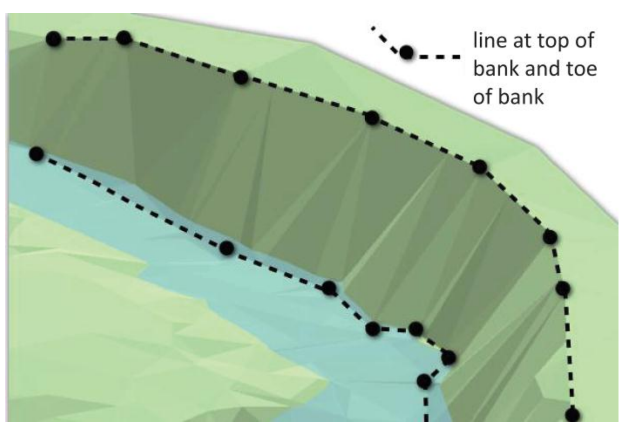


Figure 6 - Example from CHaMP protocol of appropriate use of toe and top of bank breaklines.

5.2: ANALYSIS METHODS

Analysis methods included spatial and statistical approaches. Spatial analysis was conducted in ArcGIS 10.0 and Matlab R2010a while statistical analysis was performed in SAS 9.3. All topographic survey data was downloaded from the CHaMP website (www.champmonitoring.org).

5.2.1: INTER-CREW VARIABILITY

5.2.1.1: SURVEY EFFORT

Intuitively, survey effort should be positively correlated with topographic surface quality. If a crew collects sufficient selective (i.e. smart) points and breaklines (e.g. Figure 6) to capture variations in the channel bedform, the resulting interpolated surface should be a good representation of the true topography. Here we assessed survey effort in the context of relative topographic survey thoroughness. Summary statistics were computed for what we characterized as survey effort metrics including: number of total station points collected, point density (pts/m^2), the total length (m) of breaklines collected in the field, the cumulative length of breaklines after crews processed and edited TINs, total edge of water points collected in the field, the crew delineated wetted survey extent (m^2) and the crew delineated entire survey extent (m^2). An obvious metric of effort would be time spent surveying each item, but the total station software was not set-up to record time-stamps with every point collected, and this information was not available this year. Survey effort metrics were summarized for each crew to permit inter-comparisons. Due to variations in the channel width and reach length between the six sites (Table 1), metrics were summarized across: a) the three tributary sites and b) the three mainstem sites. Variables were summarized by the range of values, the mean and the standard deviation. Here we assumed that if there was no variability between crews we would not observe any differences in survey effort metrics.

5.2.1.2: QUANTIFICATION OF VARIABILITY

5.2.1.2.1: MAX-MIN – FULL RANGE

To quantify the maximum range of variability between crews, DEMs interpolated from field collected total station point data were differenced across all seven crews at each site. The DEM differencing involved an ArcGIS cell statistics exercise where all 7 crew's DEMs are essentially stacked and, cell by cell, the maximum and minimum elevation values are extracted. This resulted in two DEMs: one which is comprised wholly of the minimum elevation value derived by any crew for each cell and one that is comprised wholly of the maximum elevation value derived by any crew for each cell. The difference of the maximum and minimum rasters (i.e. the DEM max-min difference raster) was calculated and constitutes the full range of elevation difference, cell by cell, across all crews.

It should be emphasized that this analysis highlights the worse-case scenario discrepancies, and is not a good indicator of average variability between crews.

DEM max-min difference rasters were spatially segregated to discern if observed variability was greatest in the wetted channel or on the margins and out of channel areas. Per the CHaMP protocol, crews were instructed to expend greater effort sampling within the wetted portion of the channel as this area constitutes primary fish habitat. As such, we would anticipate observed variability to be less in areas where greater sampling effort was concentrated (i.e. wetted channel). To determine if this assumption held true, each site was segregated into three survey area categories: wetted, dry, discrepant (Figure 7). These spatially segregated categories were developed in response to variation in the delineated survey and water extent boundaries between crews. What was marked as the water extent boundary by one crew did not fully match the water extent boundary marked by of any other crew. For the purpose of our analysis, we wanted to differentiate between the in-channel and out of channel portions of each sample reach. We delineated the across crew 'wetted' survey area as the intersection of the water extent polygons for all 7 crews. This is the area of the reach that we are highly certain is within the wetted channel since this area was contained within the water extent polygons of all crews. The 'discrepant' area is the union of all water extent polygons with the 'wetted' survey area clipped out. This resulting 'discrepant' area is the portion of the sample reach that some crews had included in their water extent and some crews surveyed as beyond the wetted perimeter. As we cannot be fully certain if this area is truly wet or truly dry (e.g. bank, floodplain) we consider it the discrepant portion of the survey area. Some of the discrepant areas may be due to minor flow fluctuations between the dates the crews surveyed a site, whereas some are due to differences in how the crew surveyed the water's edge and/or digitized the wetted area. The 'dry' survey area is the portion of the reach outside of all water extents surveyed by all crews as out of channel so we can have a high degree of certainty that this area constitutes the banks, floodplain and/or adjacent hillslopes.

Figure 7 - Fly Creek sample reach segregated into: wetted, dry and discrepant survey areas.

5.2.1.2.2: FIS ERROR

There is an inherent degree of error, or uncertainty, in DEMs derived from field collected topographic surveys with error tending to increase in areas with greater environmental complexity (Milan et al., 2011; Rayburg et al., 2009). This uncertainty can be attributed to individual point quality, overall survey point density, stream area complexity and interpolation method (Keim et al., 1999; Lane et al., 2003; Wheaton et al., 2010). As a consequence of uncertainty, the interpolated DEM surfaces crews derive will never be a wholly accurate representation of the stream and floodplain surveyed. As part of its analysis design, the CHaMP program has instituted using a Fuzzy Inference System (FIS) model to enumerate the uncertainty of individual DEMs generated for each stream reach sampling event. A DEM-based FIS approach is advantageous as it affords a practical method of estimating cell by cell spatially variable elevation uncertainty across an individual DEM. CHaMP estimates topographic surface elevation uncertainty using an FIS developed by Wheaton et al. (2010) that uses a rule set based on point density (a proxy for sampling effort) and DEM slope (a proxy for topographic complexity). An example of an FIS rule set (Table 5) is that, for a given DEM cell, if the slope of the cell is high and the point density is low, the elevation uncertainty for that given cell is extremely high. Conversely, if the slope of the cell is low and the point density is high, the elevation uncertainty is low. For the crew variability study, FIS elevation uncertainty rasters were generated for each individual crew's DEM at each sample site. Here higher uncertainty is assumed to indicate a lower quality topographic surface. An FIS inter-comparison was used to identify variability in the relatively quality (or elevation uncertainty) between crews at each site. This FIS elevation uncertainties were originally calibrated for total station point surveys, which did not include breakline surveys and have not been specifically calibrated for these CHaMP sites, nor sampling method. Accordingly, they currently represent a conservative approach to estimating elevation uncertainty.

Rule:	Inputs		Output
	Slope %	Pt. ρ m/pts^2	$\delta(z)$ m
1	Low	Low	Average
2	Low	Medium	Low
3	Low	High	Low
4	Medium	Low	High
5	Medium	Medium	High
6	Medium	High	Average
7	High	Low	Extreme
8	High	Medium	High
9	High	High	High

Table 5 - Example of a spatially variable Fuzzy Inference System rule set which has 9 rules based on two inputs: slope and point density.

5.2.2: INTRA-CREW VARIABILITY

5.2.2.1: CONSISTENCY

In the context of this study, we are interested in how consistently crews implement the CHaMP protocol, both in the field and their post-processing of the data into DEMs. We wanted to identify if some crews were consistent in their approach to collecting certain types of topographic data (e.g. breaklines) but were less consistent in others (e.g. water's edge points). Here we used the coefficient of variation (CV) as an estimate of individual crew consistency. CV normalizes measured variability. CV is a dimensionless number which is advantageous when comparing metrics or variables whose units may be on scales that differ by an order of magnitude or more (e.g. total number of edge of water points collected and total length of breaklines). The coefficient of variation is calculated as: ((Standard deviation) / (Mean)) * 100. A high CV value indicates greater variability and lower consistency. Several crew variability studies (Roper et al., 2010; Whitacre et al., 2007) have used CV to quantify habitat variable (e.g. residual pool depth) measurement precision between crews using different sampling protocols. Here we use CV to measure the consistency within crews implementing the same protocol. For the purposes of this analysis CV was computed for: mean DEM elevation uncertainty (i.e. mean FIS raster value), number of total station points collected, point density, number of breaklines collected in the field, total length of field collected breaklines, the total length of post-edited breaklines, number of edge of water points collected, mean water depth, survey extent and water extent. Here we used CV and summary data to measure intra-crew consistency and the magnitude of inter-crew variability. If CV values for a specific metric were similar across crews at a given site, this indicated inter-crew variability was low for that specific metric. That is, if all crews at Fly Creek had a mean water depth CV of close to 25%, we could assume they captured a similar range of depths and infer relatively low inter-crew variability in water depth measurements at Fly Creek. In the context of within crews, if a single crew had a low CV value for a given metric across all sample reaches we could discern the crew was consistent in measuring that metric across sites. For instance, if the CV for number of breaklines collected in the field was lower for CRITFC than any other crew, we could infer that CRITFC had the highest consistency (i.e. the least intra-crew variability) of any crew in the number of breaklines collected in the field.

5.2.2.2: IDENTIFICATION OF BLUNDERS & ERRORS

At each site the aforementioned DEM maximum-minimum raster was used to identify areas within the reach that had the highest variability (i.e. elevation range) between crews. Once the areas of greatest variability were isolated, we attempted to visually locate discrepancies between the different crews' DEMs to see if the significant difference could be attributed to a single crew. If one crew was identified as the source of the variability, we then used other evidence (e.g. TIN, raw point data, total station job file) to discern if the difference could be attributed to a systematic surveying error (e.g. incorrect rod height) or a post-processing error (e.g. TIN bust) as opposed to simply a lack of sampling effort in that locality. It is important to differentiate crew variability that is due to mistakes versus inadequate or inconsistent sampling effort. Both can be potentially minimized with more targeted training and QA/QC measures. However, only variability due to mistakes has the potential to be rectified post-hoc (during for example QA/QC checks). Not all mistakes can be repaired, but some are relatively straightforward to discern from the total station's *.raw survey file and field notes and can be easily repaired (e.g. certain rod-height busts).

5.2.3: EFFECT OF VARIABILITY

5.2.3.1: ABILITY TO DERIVE METRICS

Several habitat and geomorphic metrics are derived from CHaMP survey crew interpolated surfaces, including water depth maps. As a requisite of the CHaMP total station topographic survey, crews collect coded XYZ edge of water points. During the data post-processing these points are interpolated into a water surface DEM. The water surface DEM is subtracted from the topographic DEM (i.e. the interpolated surface characterizing the channel bed, banks and floodplain points and breaklines) which results in a water depth raster. Here we sought to elucidate to what extent variability in how and where different crews collect and edit total station data affects DEM-derived metrics such as water depth. To answer this question, we took two separate approaches. The first approach consisted of calculating the summary statistics of water depth rasters produced by each crew at each site including: minimum, maximum, mean, standard deviation and CV. The second approach followed the maximum-minimum differencing methodology applied to the DEM full range of variability analysis. Here the differencing involved an ArcGIS cell statistics exercise where, at each site, all crew's water depth rasters were stacked and, cell by cell, the maximum and minimum water depth values were extracted. This resulted in two rasters: one which is comprised wholly of the minimum derived water depth value for each cell and a second raster comprised wholly of the maximum derived water depth for each cell. The difference of the maximum and minimum water depth rasters was calculated and, as in the DEM maximum-minimum differencing, constitutes the full range of derived water depths, cell by cell, across all crews. This was subsequently used to identify the degree and source of water depth discrepancies between crews. Similar to the DEM maximum-minimum differencing, this analysis highlights the absolute worst case scenario discrepancies across all crews.

5.2.3.2: ABILITY TO DETECT GEOMORPHIC CHANGE

Of the many metrics CHaMP data can be used to estimate, geomorphic change detection is potentially one of the most sensitive to crew variability and the quality of the topographic data. The reason is geomorphic changes are calculated by doing a cell-by-cell subtraction of elevation values to create a DEM of difference (DoD; see Figure 8 for illustration of concept). Accordingly, the DoD calculation is very sensitive to the positional accuracy, and sampling pattern of survey points, as well as the interpolation of the TIN. As this is only the first year of data collection in CHaMP, repeat topographic surveys were not available that captured real geomorphic changes[1] (De Meurichy et al., 2011). As such, we created artificial DEMs that represented plausible future states of the channel for two scenarios – a subtle change and an obvious change scenario. Potential geomorphic change occurring between the pilot year DEM and each of these future scenario DEM was modeled at the Fly Creek site to assess how crew variability effects the ability to capture topographic alteration.

The magnitude of modeled change was measured using DEM-based Geomorphic Change Detection (GCD 5: http://gcd.joewheaotn.org) software developed by Wheaton & ESSA Technologies. For this analysis, we used a simple minimum level of detection approach to account for DEM uncertainties in the total station surveys and thresholded the DoDs at +/- 6 cm to differentiate those changes assumed to represent hypothetical geomorphic change versus those indistinguishable from noise. Volumetric estimates of erosion and deposition as well as volumetric uncertainty estimates are reported in the GCD software. For each scenario, the individual crew's DEM was used as old DEM in the calculation shown in Figure 8, and the scenario DEM was used as the new DEM. To assess how well each crew performed, they were compared both to each other and to the ODFWUGR crew's DEM, which we treated as 'truth'. The reason we treated the ODFWUGR crew as truth was two-fold. First, the ODFWUGR had the greatest spatial coverage in their survey extents for Fly Creek (see Appendix A). Secondly, we used the topographic data from the ODFWUGR to create the scenarios and simply substituted new data where we wanted to represent geomorphic changes.

[1] Although this is true for the CHaMP protocol, it should be noted that there ISEMP sites (e.g. Bridge Creek, OR), which have been resurveyed successfully using similar topographic sampling methods and have been shown to reliably track geomorphic changes even after accounting for uncertainty DeMeurichy et al. (2011).

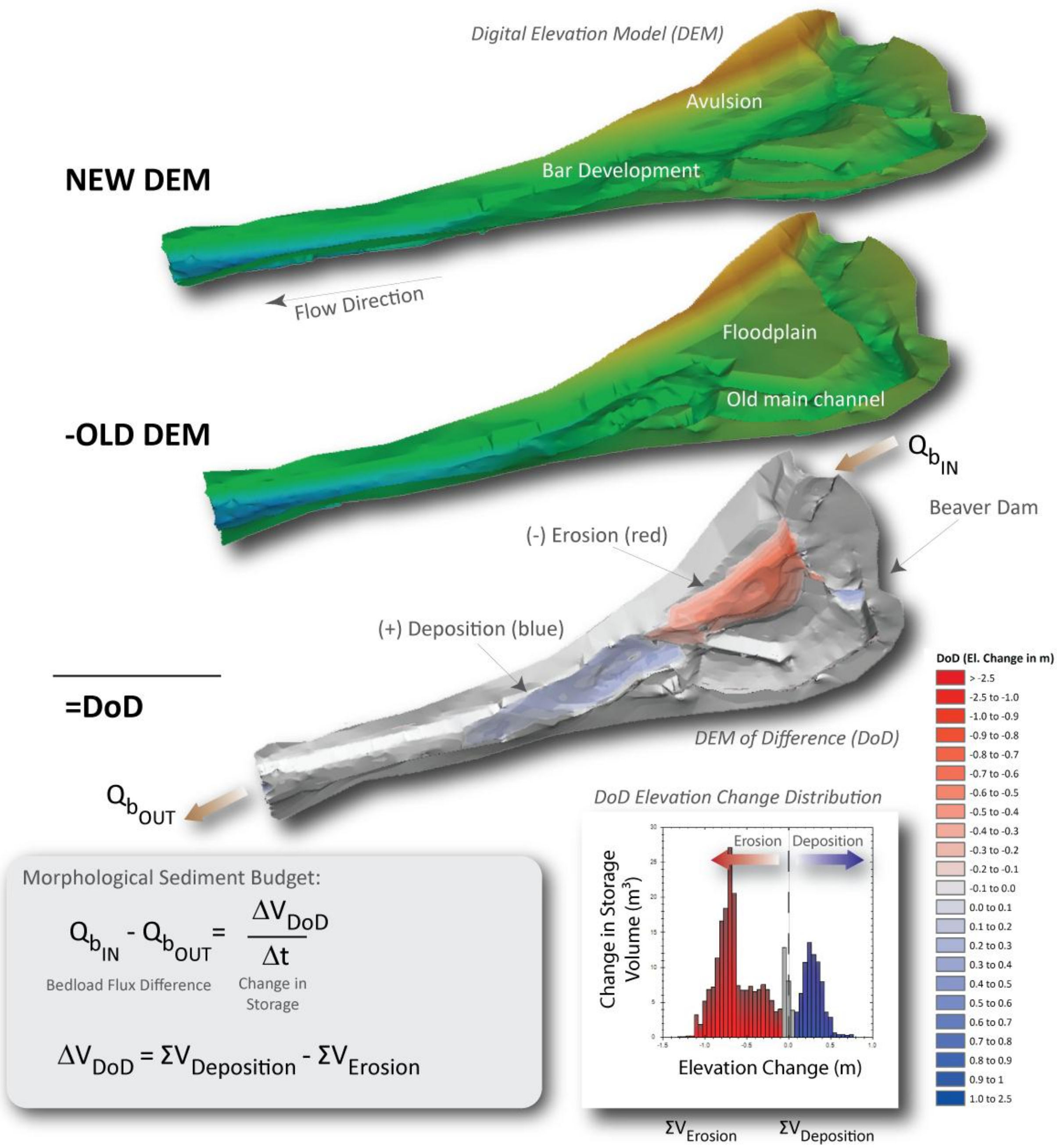


Figure 8 – Concept of DEM Differencing for Morphological Sediment Budgeting. As CHaMP repeat monitoring takes place into the future, pairwise comparisons of more recent DEMs (New DEM) and previous year's DEMs (Old DEM) can be made by doing a simple cell-by-cell subtraction of elevation values. This results in a distribution of negative (red) and positive (blue) DoD values, which correspond to erosion and deposition respectively. These elevation change values can be multiplied by cell size and summed to estimate the total volume of erosion and deposition respectively.

The two scenarios of geomorphic change we modeled were a 'subtle change' scenario that could plausibly take place in any given year, and a more dramatic 'obvious change' scenario that could plausibly have taken place following a large flood. The 'subtle change' scenario was created by modifying the topography on several outside bends to reflect minor bank erosion (on the order of 10-30 cm laterally) and modest pool scour. Additionally some point-bars and central bars were re-shaped to represent minor growth and deposition on these surfaces. We designed this scenario so that the changes would be right on the edge of what is detectable change limits given the DEM cell resolution (10 cm) and the total station survey precision. We hypothesized that if crew variability were insignificant, that the 'subtle change' scenario would barely be detectable.

By contrast, for the 'obvious change scenario', we imagined a scenario in which a beaver built a large channel-spanning dam in the upper portions of the meander bend with a crest elevation matching the adjacent floodplain on the inside bend. The likely result of this would have been a decrease in stream-flow through the main channel and the diversion of flow across the floodplain on the inside of the meander bend. We then envisioned that the reach experienced a large flood(s), which captured the preferential flow across the floodplain and caused a major avulsion in the form of a meander neck cutoff. The geomorphic change we modeled associated with this included: i) the topography of the beaver dam itself (assumed to have remained in-tact through the flood), ii) the carving of a new main channel across the floodplain, iii) and the deposition of a significant proportion of this eroded material on and downstream of an existing central bar in the downstream meander bend. We hypothesized that all crews should be able to detect this change, regardless of crew variability because the magnitude of the signal so exceeded likely DEM uncertainties.

6: RESULTS

6.1: INTER-CREW VARIABILITY

6.1.1: SURVEY EFFORT

Analysis of data from the three tributary samples reaches (Table 6) reveals some degree of inter-crew variability in all survey effort metrics. If there were no or minimal variability between crews, the metric range and mean would be the same or very similar, while the standard deviation and CV would be equal to or close to 0. The mean number of total station points collected by each crew ranged between 575.0 and 987.3 points (CV range: 7.64 – 30.82%). Point density averages varied from 0.19 to 0.78 pts./m^2 (CV range: 68.42 – 117.5%). On average, QCI collected the least number of points while TQ collected the highest number of points. However, while TQ had the highest average point density ODFWUGR had the lowest average point density (owing to the fact ODFWUGR generally surveyed a greater extent laterally away from the channel, capturing more context across floodplains, but at generally low point density). The total length of field collected breaklines averaged from 587.3 m to 1073.8 m (CV range: 9.62 – 36.54%) while the total length of post-edited breaklines averaged from 712.9 to 1343.8 m (CV range: 8.58 - 36.54%). While on average TQ collected the least length of breaklines in the field and Tetra the most, the average length of post-edited breaklines was highest for Tetra and lowest for CRITFC. That TQ collected less breaklines in the field but did not have the minimal total length of breaklines following edits indicates that their crew placed a greater emphasis on inserting breaklines post-hoc during TIN edit sessions whereas other crews focused on collecting these breaklines in the field. The average number of edge of water points collected by crews had close to a three-fold difference ranging from 80 to 212.3 points (CV range: 12.77 – 50.55%). Survey area extent also varied between crews, ranging on average from 1039.4 to 3206.1 m^2 (CV range: 25.31 – 52.38%).

		Crew						
Variable	Statistic	CRITFC	ELR	ODFWJD	ODFWUGR	QCI	Tetra	TQ
Total station points	Min	621	576	595	680	509	509	906
	Max	883	803	865	800	648	846	1055
	Mean	731.7	713	686.7	724.7	575	624	987.3
	StdDev	135.7	120.6	154.5	65.6	69.8	192.3	75.4
	CV(%)	18.55	16.91	22.50	9.05	12.14	30.82	7.64
Point density (pts/m^2)	Min	0.08	0.07	0.11	0.06	0.06	0.06	0.11
	Max	1.12	0.98	0.98	0.31	0.87	0.94	1.63
	Mean	0.52	0.47	0.47	0.19	0.41	0.4	0.78
	StdDev	0.54	0.46	0.45	0.13	0.41	0.47	0.78
	CV(%)	103.85	97.87	95.74	68.42	100.00	117.50	100.00
Total length (m) of field collected breaklines	Min	648.8	791.3	437.5	743.9	830.8	937.7	456.3
	Max	786.6	1110.7	941.3	1430.8	1102.6	1339.9	704.3
	Mean	716.4	928	753.7	1029.2	980.8	1073.8	587.3
	StdDev	68.9	164.6	275.4	357.9	138.1	230.4	124.6
	CV(%)	9.62	17.74	36.54	34.77	14.08	21.46	21.22
Total length (m) of post-edits breaklines	Min	648.8	788.2	437.5	913	829.3	1144	632.3
	Max	780.2	1100.8	941.3	1055.7	1092.5	1687.2	971.7
	Mean	712.9	922.2	753.7	960.6	977	1343.8	791.3
	StdDev	65.8	161	275.4	82.4	134.5	234.4	170.7
	CV(%)	9.23	17.46	36.54	8.58	13.77	17.44	21.57
Edge of water points	Min	84	86	150	59	92	61	185
	Max	149	164	190	103	168	144	257
	Mean	114.3	126.0	166	80	121.7	91	212.3
	StdDev	32.7	39.0	21.2	22.1	40.6	46	39
	CV(%)	28.61	30.95	12.77	27.63	33.36	50.55	18.37
Survey extent (m^2)	Min	706.1	707.9	523.1	2465.7	599.6	844.5	560.5
	Max	1496.8	1986.7	1593.8	4073.7	1434.3	2484.2	1478.6
	Mean	1132.7	1350.1	1079	3206.1	1153.8	1586.2	1039.4
	StdDev	399	639.4	536.5	811.5	480	830.9	460.3
	CV(%)	35.23	47.36	49.72	25.31	41.60	52.38	44.29

Table 6 - Survey effort metrics summarized across all 3 tributary sites (Fly, Spring, West Chicken Creek).

As seen in the three tributary sites, analysis of the three mainstem Grande Ronde River sample reaches (Table 7) reveal substantial inter-crew variability in all survey effort metrics. The mean number of total station points collected by each crew ranged between 759.7 and 1298.0 points (CV range: 3.12 – 35.70%). This higher total number of points is consistent with the extra effort required to survey a larger site (nearly twice as wide and twice as long). Point density averages were quite similar and only varied from 0.09 to 0.15 pts./m^2 (CV range: 10.00 – 38.46%). On average, QCI collected the least number of points while ODFWJD collected the highest number of points. ODFWJD had the highest average point density ODFWUGR and QCI had the lowest point density. There was almost a two-fold difference between the minimum and maximum values of the mean total length of both field collected and post-edited breaklines. The total length of field collected breaklines averaged from 1387.0 m to 2827.5 m (CV range: 14.23 – 35.08%) while the total length of post-edited breaklines averaged from 1876.7 to 3598 m (CV range: 12.92 - 35.08%). While, on average, TQ collected the least length of breaklines in the field and QCI the most, the average length of post-edited breaklines was again highest for Tetra and lowest for CRITFC. This finding, as seen across the three lower order sites, highlights variability between crews where some crews placed a greater emphasis on inserting breaklines post-hoc during TIN edit sessions than others. The average number of edge of water points collected by crews ranged from 112.3 to 285 points (CV range: 12.00 – 32.27%). Survey area extent also varied between crews underscoring the extent to which crews elect to survey the floodplain. Mean survey area extent ranged from 8129.8 to 11966.5 m^2 (CV range: 25.91 – 46.77%).

		Crew						
Variable	Statistic	CRITFC	ELR	ODFWJD	ODFWUGR	QCI	Tetra	TQ
Total station points	Min	745	894	1091	854	740	724	994
	Max	1099	1458	1493	1107	786	1502	1524
	Mean	959	1130.3	1298	1007.3	759.7	1093.7	1293.7
	StdDev	188.2	292.9	201.3	134.8	23.7	390.4	271.7
	CV(%)	19.62	25.91	15.51	13.38	3.12	35.70	21.00
Point density (pts/m^2)	Min	0.08	0.09	0.12	0.07	0.06	0.09	0.11
	Max	0.16	0.11	0.2	0.11	0.11	0.18	0.19
	Mean	0.11	0.1	0.15	0.09	0.09	0.13	0.14
	StdDev	0.04	0.01	0.04	0.02	0.03	0.05	0.04
	CV(%)	36.36	10.00	26.67	22.22	33.33	38.46	28.57
Total length (m) of field collected breaklines	Min	1577	1914.3	1838.8	2237	2527.8	2468.8	1118.3
	Max	2377.4	3562.3	3176.3	2888.7	3402.9	3263.2	1881.9
	Mean	1884.6	2541.7	2346.7	2483.9	2827.5	2779.1	1387
	StdDev	431.2	891.6	724.4	353.4	466.2	424.7	429.1
	CV(%)	22.88	35.08	30.87	14.23	16.49	15.28	30.94
Total length (m) of post-edits breaklines	Min	1553.3	1914.3	1838.8	2237	2520.7	3192.1	1629.8
	Max	2377.4	3562.3	3176.3	2888.7	3384.6	4308.8	2732.1
	Mean	1876.7	2541.7	2346.7	2513.8	2845.7	3598	2003.4
	StdDev	439.7	891.6	724.4	324.7	470	617.6	631.1
	CV(%)	23.43	35.08	30.87	12.92	16.52	17.17	31.50
Edge of water points	Min	115	120	231	115	133	94	213
	Max	162	222	321	180	165	131	285
	Mean	143.0	163.3	285	149.7	145	112.3	258.3
	StdDev	24.8	52.7	47.6	32.7	17.4	18.5	39.5
	CV(%)	17.34	32.27	16.70	21.84	12.00	16.47	15.29
Survey extent (m^2)	Min	5856	8431	6315.4	9889.9	6199.7	5584.1	6803.2
	Max	13135.8	14940	11349.7	15530.6	11955.4	12968.8	12097.8
	Mean	8543.7	10884.5	8265.4	11966.5	8129.8	8566.6	8593.4
	StdDev	3996.1	3537.9	2702	3100.7	3313.1	3891.7	3035.1
	CV(%)	46.77	32.50	32.69	25.91	40.75	45.43	35.32

Table 7 - Survey effort metrics summarized across all 3 mainstem Grande Ronde River sites.

6.1.2: QUANTIFICATION OF VARIABILITY

6.1.2.1: MAX-MIN – FULL RANGE

The full range of elevation variability between crews was not equitable across the six sample reaches (Table 8). Despite observed localized large maximum elevation differences, on average elevation differences were relatively low at two of the three tributary sites: Spring Creek (mean=0.10 m; max=10.05 m; StdDev=0.23 m), West Chicken Creek (mean=0.05 m; max=0.84 m; StdDev=0.09 m). Mean maximum elevation variability was relatively moderate at the Grande Ronde River upper (mean=0.21 m; max=4.68 m; StdDev=0.43 m) and the Grande Ronde River lower (mean=0.23 m; max=3.46 m; StdDev=0.20 m) sample reaches. The observed mean elevation difference was greatest at the Grande Ronde River middle site (mean=0.39 m; max=4.61 m; StdDev=0.47 m) and Fly Creek (mean=0.67 m; max=1.92 m; StdDev=0.50 m).

		Site					
	Statistic	Fly Creek	Spring Creek	West Chicken Creek	Grande Ronde River (upper)	Grande Ronde River (middle)	Grande Ronde River (lower)
DEM maximum-minimum difference (m)	Min	0	0	0	0	0	0
	Max	1.92	10.05	0.84	4.68	4.61	3.46
	Mean	0.67	0.1	0.05	0.21	0.39	0.23
	StdDev	0.5	0.29	0.09	0.43	0.47	0.2

Table 8 - DEM maximum-minimum difference by site.

Spatially segregating the maximum-minimum elevation differences reveals that, in comparison with the combined dry and discrepant areas (i.e. channel margins and floodplain), the percentage of total volumetric differences was least within the wetted portion of the survey area (Figure 9). This relationship held true for all six sample reaches. Summary statistics of the DEM maximum-minimum difference spatial segregation (Table 9) show the maximum difference was consistently least in the wetted portion of the survey area across 5 of 6 sites (range: 0.365 – 2.256 m) in comparison with results in the discrepant (range: 0.838 – 4.057 m) and dry (range: 0.703 – 10.045 m) survey areas. At the three tributary sites and the Grande Ronde River lower site the mean DEM maximum-minimum difference was least in the dry, wetted and discrepant survey areas respectively. At both the Grande Ronde River upper and middle sites the mean DEM maximum-minimum difference subsequently increased in the wetted, dry and discrepant survey areas. Results of both the total percentage volumetric analysis and summary statistics reveal the proportion of elevation variability was least in the wetted channel (i.e. the primary fish habitat) and greatest in the off channel habitat (e.g. channel margins and in the floodplains).

		DEM Maximum-Minimum Difference			
Site	Survey Area Segretaion	Min (m)	Max (m)	Mean (m)	StdDev (m)
Fly Creek*	Wetted	0.006	0.939	0.093	0.064
	Dry	0	0.913	0.088	0.114
	Discrepant	0	0.987	0.161	0.139
Spring Creek	Wetted	0.018	0.365	0.158	0.058
	Dry	0	10.045	0.081	0.312
	Discrepant	0	2.152	0.199	0.098
West Chicken Creek	Wetted	0.011	0.536	0.105	0.060
	Dry	0	0.703	0.034	0.077
	Discrepant	0	0.838	0.158	0.106
Grande Ronde River (upper site)	Wetted	0.007	1.138	0.173	0.094
	Dry	0	4.681	0.239	0.612
	Discrepant	0	4.057	0.252	0.163
Grande Ronde River (middle site)	Wetted	0.025	2.256	0.318	0.143
	Dry	0	4.607	0.359	0.527
	Discrepant	0	3.989	0.677	0.556
Grande Ronde River (lower site)**	Wetted	0.008	1.088	0.219	0.115
	Dry	0	2.430	0.144	0.178
	Discrepant	0	2.544	0.273	0.150

* with ELR crew removed due to survey blunder

** with QCI crew removed due to survey blunder

Table 9 - Summary statistics of DEM maximum-minimum difference across crews spatially segregated by wetted, dry and discrepant survey area.

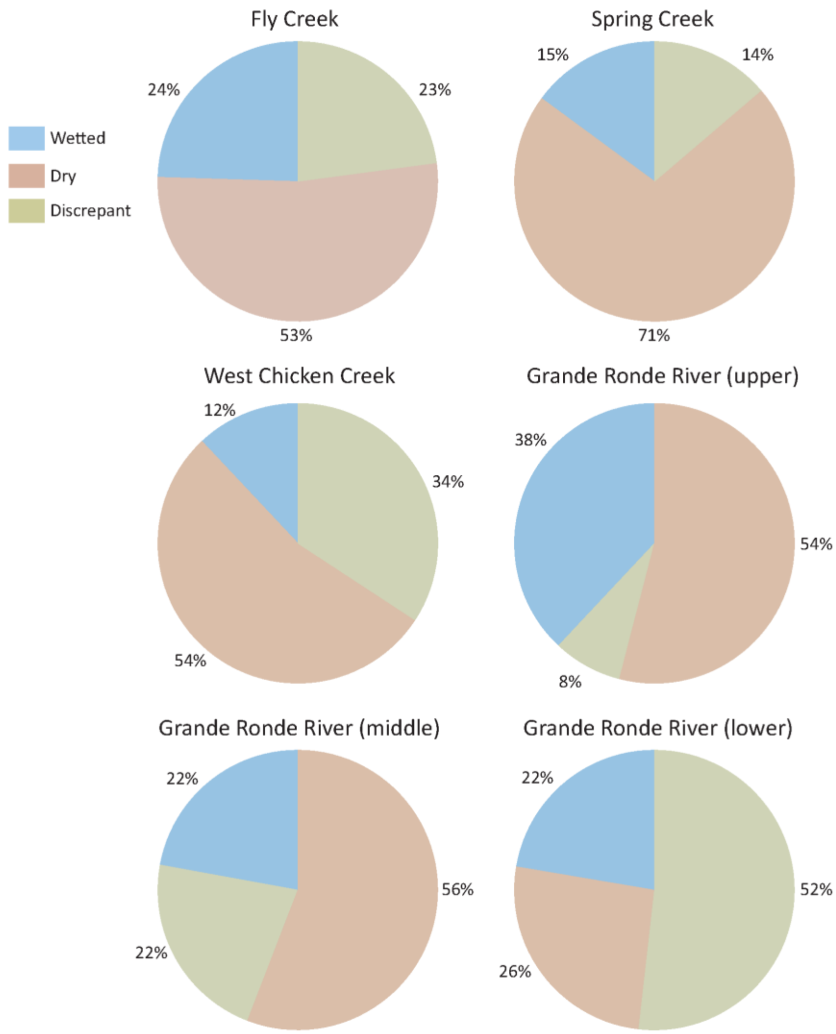


Figure 9 - Percentage of total volumetric DEM maximum-minimum difference across crews spatially segregated by wetted, dry and discrepant survey area.

6.1.2.2: FIS ERROR

Spatially variable elevation uncertainty rasters (Figure 10) were produced for each DEM using an FIS rule set based on 2 inputs: DEM cell slope (a proxy for topographic complexity) and total station point density (a proxy for sampling). Results of the FIS error raster analysis (Table 10) reveal that across all sites ODFWUGR had the highest mean elevation uncertainty (mean=0.31 m; StdDev=0.14 m; CV=45.16%) while TQ's interpolated surfaces had the lowest mean elevation uncertainty (mean=0.18 m; StdDev=0.13 m; CV=72.22%). This is largely a reflection of the dramatically greater extent of the ODFWUGR survey areas, which provided helpful context out on to the floodplain and surrounding slopes. Appropriately, ODFWUGR had minimal point density in these areas, which is assigned a higher elevation uncertainty in the FIS used. Across the mainstem Grande Ronde River sites, ELR produced the highest mean error raster values (mean=0.35 m; StdDev=0.14 m; CV=40.00%) while Tetra had the lowest (mean=0.26 m; StdDev=0.08 m; CV=30.77%). Examining lower-order sites, as was observed across all sites, ODFWUGR produced surfaces with the highest mean elevation uncertainty (mean=0.28 m; StdDev=0.19 m; CV=67.86%) while TQ had the lowest mean elevation uncertainty (mean=0.08 m; StdDev=0.03 m; CV=37.50%). Elevation uncertainty was lower at the tributary sites (mean=0.16 m) and higher at the mainstem Grande Ronde River sample reaches (mean=0.31 m).

Error rasters were spatially segregated at two sites (Grande Ronde River middle and lower) to determine if uncertainty was consistently higher within the wetted portion of the channel or on the banks and floodplain. Spatially segregating by wet, dry and discrepant area at both sites (Table 11) indicated uncertainty was lowest within the wetted channel. At the Grande Ronde River middle site elevation uncertainty across all crews was highest for the dry survey area (mean range: 0.49 to 0.73 m), moderate for the discrepant (mean range: 0.33 to 0.44 m) and lowest for the wetted portions of the channel (mean range: 0.15 to 0.34 m). This pattern is also reflected at the Grande Ronde lower site where elevation uncertainty across all crews was highest in the dry portion of the sample reach (mean range: 0.27 to 0.49 m), moderate in the discrepant area (mean range: 0.19 to 0.26 m) and lowest within the wetted perimeter (mean range: 0.13 to 0.17 m).

Figure 10 – Example of FIS-derived elevation uncertainty. Fly Creek FIS estimated elevation error rasters for CRITFC (A) and ELR (B). See Appendix A for other sites.

Site	Statistic	CREW CRITFC	ELR	ODFWJD	ODFWUGR	QCI	Tetra	TQ
All Sites	Min	0.05	0.07	0.1	0.14	0.14	0.06	0.05
	Max	0.41	0.5	0.4	0.5	0.47	0.35	0.39
	Mean	0.22	0.25	0.23	0.31	0.25	0.2	0.18
	StdDev	0.12	0.15	0.11	0.14	0.12	0.1	0.13
	CV(%)	54.55	60.00	47.83	45.16	48.00	50.00	72.22
Lower Order Sites	Min	0.05	0.07	0.1	0.14	0.14	0.06	0.05
	Max	0.2	0.19	0.24	0.5	0.21	0.18	0.11
	Mean	0.13	0.14	0.16	0.28	0.18	0.14	0.08
	StdDev	0.07	0.07	0.07	0.19	0.04	0.07	0.03
	CV(%)	53.85	50.00	43.75	67.86	22.22	50.00	37.50
Mainstem Sites	Min	0.23	0.23	0.2	0.24	0.24	0.19	0.21
	Max	0.41	0.5	0.4	0.45	0.47	0.35	0.39
	Mean	0.31	0.35	0.3	0.34	0.32	0.26	0.28
	StdDev	0.1	0.14	0.1	0.11	0.13	0.08	0.1
	CV(%)	32.26	40.00	33.33	32.35	40.63	30.77	35.71

Table 10 - DEM elevation uncertainty summarized across all crews by: all sites, the 3 lower order sites (Fly, Spring, West Chicken Creek) and the 3 mainstem Grande Ronde River sites.

Site	Survey Area Segretaion	Statistic	Crew CRITFC	ELR	ODFWJD	ODFWUGR	QCI	Tetra	TQ
Grande Ronde River (middle site)	Entire Site	Min	0.05	0.05	0.05	0.05	0.05	0.02	0.03
		Max	0.86	0.86	0.86	0.86	0.86	0.86	0.86
		Mean	0.41	0.5	0.4	0.45	0.47	0.35	0.39
		StdDev	0.34	0.35	0.35	0.35	0.35	0.32	0.33
	Wetted	Min	0.05	0.05	0.05	0.05	-	0.02	0.03
		Max	0.86	0.86	0.86	0.86	-	0.86	0.86
		Mean	0.21	0.34	0.15	0.19	-	0.19	0.18
		StdDev	0.21	0.32	0.18	0.2	-	0.2	0.19
	Dry	Min	0.05	0.05	0.05	0.05	-	0.05	0.05
		Max	0.86	0.86	0.86	0.86	-	0.86	0.96
		Mean	0.73	0.49	0.73	0.59	-	0.59	0.64
		StdDev	0.25	0.35	0.25	0.33	-	0.32	0.3
	Discrepant	Min	0.05	0.05	0.05	0.05	-	0.03	0.04
		Max	0.86	0.86	0.86	0.86	-	0.86	0.86
		Mean	0.42	0.44	0.35	0.39	-	0.41	0.33
		StdDev	0.33	0.35	0.32	0.33	-	0.33	0.3
Grande Ronde River (lower site)	Entire Site	Min	0.05	0.02	0.04	0.05	0.05	0.02	0.04
		Max	0.86	0.86	0.86	0.86	0.86	0.86	0.86
		Mean	0.23	0.23	0.2	0.24	0.24	0.19	0.21
		StdDev	0.23	0.23	0.2	0.24	0.24	0.19	0.21
	Wetted	Min	0.05	0.05	0.04	0.05	0.05	0.02	0.03
		Max	0.86	0.86	0.86	0.86	0.86	0.86	0.86
		Mean	0.15	0.16	0.16	0.16	0.17	0.13	0.14
		StdDev	0.13	0.16	0.18	0.13	0.15	0.13	0.12
	Dry	Min	0.05	0.04	0.05	0.05	0.05	0.04	0.04
		Max	0.86	0.86	0.86	0.86	0.86	0.86	0.86
		Mean	0.38	0.33	0.34	0.34	0.49	0.27	0.29
		StdDev	0.32	0.31	0.3	0.31	0.34	0.26	0.27
	Discrepant	Min	0.05	0.02	0.04	0.05	0.05	0.02	0.04
		Max	0.86	0.86	0.86	0.86	0.86	0.86	0.86
		Mean	0.21	0.19	0.2	0.2	0.21	0.19	0.26
		StdDev	0.19	0.17	0.18	0.18	0.2	0.17	0.25

Table 11- Values of DEM error rasters generated by the RBT using a FIS based on point density and slope. Here error raster values are summarized for the Grande Ronde River middle and the Grande Ronde River lower sites by crew. Values are reported for the entire site and then spatially segregated by wetted, dry, or discrepant survey area. The QCI crew was omitted from survey area segregation analysis at the Grande Ronde River middle site due to a projection shift that resulted in misalignment with all other crews' interpolated surfaces.

6.2: INTRA-CREW VARIABILITY

6.2.1: CONSISTENCY

While some crews stood out as consistent across all sites for particular variables, no single crew appears to have a universally consistent or inconsistent performance for all metrics across all sites (Table 12). In other words, crews were variable across all surveys in terms of how they performed relative to their peers. The total number of points surveyed by each crew (see Appendix A Tables 1-3) reveals that TQ consistently collected the highest number of points across all sites (mean=1140.5 pts.; StdDev=244.9 pts.; CV=21.47%) and across the three lower order sites (mean=981.3 pts.; StdDev=75.4 pts.; CV=7.64%). The QCI crew collected the lowest number of points across all sites (mean=667.3 pts.; StdDev=111.4 pts.; CV=16.69%), the three mainstem Grande Ronde River sties (mean=759.7 pts.; StdDev=23.7 pts.; CV=3.12%) and across all three lower order sites (mean=575 pts.; StdDev=69.8 pts.; CV=12.14%). It should be noted that collecting a low or high number of points does not necessarily translate into a lower or high point density. While a crew may have a lower overall number of points, those points may be topographically stratified and concentrated in areas of high concavity or topographic complexity. Similarly, crews had highly variable survey extents, which dramatically influences point density. Thus, even a low number of points may result in an overall moderate mean point density when combined with a smaller survey extent. The TQ crew consistently collected the smallest total length of field collected breaklines across all sites (mean=987.1 m; StdDev=521.3 m; CV=52.8%), across the mainstem sites (mean=1387.0 m; StdDev=429.1 m; CV=30.94%) and lower-order sites (mean=587.3.0 m; StdDev=124.6 m; CV=21.22%). However the CRITFC crew consistently had the lowest total length of post-edited breaklines across all sites (mean=1300.5 m; StdDev=696.9 m; CV=53.59%), all mainstem sites (mean=1876.7 m; StdDev=439.7 m; CV=23.43%) and all lower-order sites (mean=712.3 m; StdDev=65.8 m; CV=9.23%). In contrast the Tetra crew consistently had the largest total length of post-edited breaklines across all sites (mean=2470.9.0 m; StdDev=1308.7 m; CV=52.96%), across the mainstem sites (mean=3598.0 m; StdDev=617.6 m; CV=17.17%) and the lower order sites (mean=1343.8 m; StdDev=234.4 m; CV=17.44%). The ODFWUGR crew consistently surveyed the largest extent across all sites (mean=7586.3 m^2; StdDev=5208.8 m^2; CV=68.66%), mainstem sites (mean=11966.5 m^2; StdDev=3100.7 m^2; CV=25.91%) and lower order sites (mean=3206.1 m^2; StdDev=811.5 m^2; CV=25.31%).

Overall the ODFWUGR crew was the most consistent (i.e. had the lowest CV value) in the total length of post-edit breaklines, survey extent and water extent across all sites, the three mainstem sites and three lower order sites (Table 12). The Tetra crew consistently had the greatest amount of variability (i.e. highest CV value) for the number of total station points collected and mean point density across all sites, the three mainstem sites and the three lower order sites.

We did not see any distinct patterns of increased or decreased intra-crew variability across the three mainstem sites versus across the three tributary sites (see Appendix A Tables 2-3). Here we used the CV value to determine the degree of variability with higher CV values indicating increased variability for a given metric. Intra-crew variability in the total number of total station points decreased from mainstem to lower order sites with the exception of the ODFWJD and QCI crews. This means 5 of 7 crews were more consistent in the total number of points collected at tributary sample reaches and were less consistent in the number of points they collected across the mainstem sites. This apparent inconsistency is not indicative of poor sampling as more complex reaches such as the Grande Ronde River middle site will require more points to capture the varying topography than a site such as the Grande Ronde River upper site. While observed point densities were higher at lower order sites, the within crew variability in mean point density was greater at lower sites for all crews in comparison to the mainstem sample reaches. Similarly, with the exception of the QCI crew, mean DEM elevation uncertainty values were lower at the three tributary sites, but intra-crew variability was higher than at the mainstem sites. Variability in the total length of field collected breaklines was greater at lower order sites for ODFWJD, ODFWUGR and Tetra. Additionally, variability in the total length of post-edited breaklines was higher at lower order sites for ODFFWJD and Tetra. Survey extent variability decreased at higher order sites for CRITFC and ODFWUGR.

Variable		Mean		CV(%)	
		Smallest	Largest	Smallest	Largest
Total station points	All sites	Tetra	TQ	QCI	Tetra
	Mainstem sites	QCI	ODFWJD	QCI	Tetra
	Lower-order sites	QCI	TQ	TQ	Tetra
Point density (pts/m^2)	All sites	ODFWUGR	TQ	ODFWUGR	Tetra
	Mainstem sites	ODFWUGR/QCI	ODFWJD	ELR	Tetra
	Lower-order sites	ODFWUGR	TQ	ODWUGR	Tetra
Mean DEM elevation uncertainty (m)	All sites	TQ	ODFWUGR	ODFWUGR	TQ
	Mainstem sites	Tetra	ELR	Tetra	QCI
	Lower-order sites	TQ	ODFWUGR	QCI	ODFWUGR
Number of breaklines collected in field	All sites	Tetra	ELR	TQ	ELR
	Mainstem sites	Tetra	ELR	CRITFC	ELR
	Lower-order sites	Tetra	QCI	ODFWUGR	CRITFC
Total length (m) of field collected breaklines	All sites	TQ	QCI	ODFWUGR	ODFWJD
	Mainstem sites	TQ	QCI	ODFWUGR	ELR
	Lower-order sites	TQ	Tetra	CRITFC	ODFWJD
Total length (m) of post-edits breaklines	All sites	CRITFC	Tetra	ODFWUGR	ODFWJD
	Mainstem sites	CRITFC	Tetra	ODFWUGR	ELR
	Lower-order sites	CRITFC	Tetra	ODFWUGR	ODFWJD
Edge of water points	All sites	Tetra	TQ	ELR	ODFWUGR
	Mainstem sites	Tetra	ODFWJD	QCI	ELR
	Lower-order sites	ODFWUGR	TQ	ODFWJD	Tetra
Mean water depth (m)	All sites	ODFWJD/QCI/TQ	ODFWUGR	ODFWUGR	Tetra
	Mainstem sites	QCI	CRITFC	Tetra	ELR
	Lower-order sites	ELR	ODFWUGR	ODFWJD/TQ	CRITFC/QCI
Survey extent (m^2)	All sites	QCI	ODFWUGR	ODFWUGR	CRITFC
	Mainstem sites	QCI	ODFWUGR	ODFWUGR	CRITFC
	Lower-order sites	TQ	ODFWUGR	ODFWUGR	Tetra
Water extent (m^2)	All sites	TQ	Tetra	ODFWUGR	ELR
	Mainstem sites	TQ	Tetra	ODFWUGR	ELR
	Lower-order sites	ELR	Tetra	ODFWUGR	CRITFC

Table 12 - Crews with the smallest and largest mean and CV summarized across all sites by topographic 'quality' variables. The crews with largest CV have the greatest variability per variable across all sites. The crews with the smallest CV have the smallest variability per variable across sites. A low CV values can be used to infer consistent performance.

6.2.2: IDENTIFICATION OF BLUNDERS & ERRORS

Here we found that, on the whole, observed DEM elevation variability between crews could be attributed to either systematic survey or post-processing blunders (Table 13). It should be noted that, due to logistical constraints, we did not attempt to trace the root of every observed difference but focused primarily on the most obvious or greatest differences. The most common blunders were TIN busts not caught by crews when editing TINs. These were typically associated with incorrect rod heights. TIN busts located in the wetted portion of the channel can propagate through to DEM-derived metrics such as water depth maps (Figure 11). Most observed errors are easy to fix post-hoc (e.g. TIN bust). However some are difficult or nearly impossible to remedy post-hoc and could compromise an entire survey (e.g. excessive error in backsight check). Overall, all observed blunders are easy to avoid with clear guidance and training. Blunders and survey comments are further detailed in Appendix B.

			Crew							
			CRITFC	ELR	ODFWJD	ODFWUGR	QCI	Tetra	TQ	Total
Survey Problems	Red Flags	Benchmarks in wetted channel	-	-	-	1	-	-	-	1
		Control points in wetted channel	1	1	1	1	1	1	1	7
		Excessive error in BS check	-	-	-	-	2	-	-	2
	Blunders	Incorrect rod height	-	-	2	1	-	-	-	3
		Incorrect Total Station base height	-	1	-	-	-	-	-	1
Post-processing Problems	Blunders	Mistakes when connecting EW points	-	-	-	1	1	-	-	2
		Missed large TIN busts in edits	-	-	2	1	-	-	-	3
	Weaknesses	Did not clip out islands > BF	-	1	-	-	1	1	-	3

Easy to Remedy (green)
Difficult/Impossible to Remedy (red)

Table 13 - Summary of observed survey and post-processing issues.

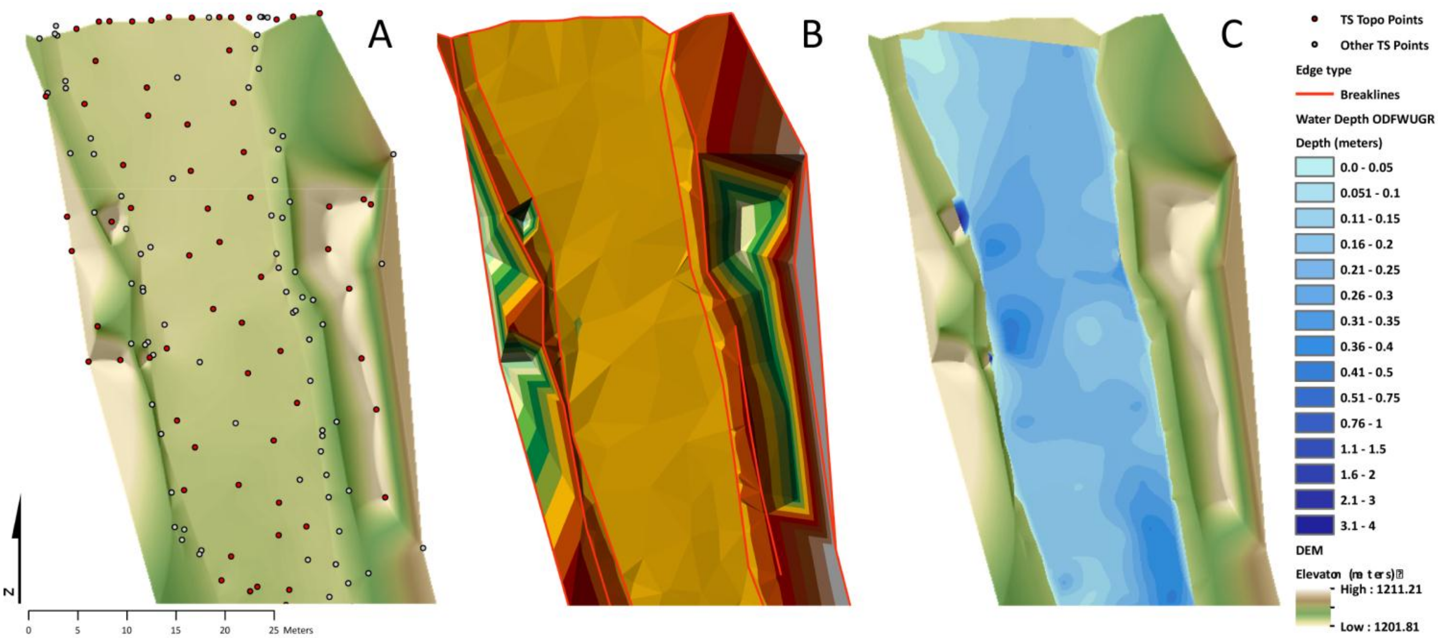


Figure 11 - Example of a survey blunder by a crew at the Grande Ronde River upper site. Here, we inferred that while collecting Topo coded points the crew incorrectly recorded the total station rod height (A). This led to TIN busts (B) that were not caught or corrected by the crew member who post-processed and edited the TIN. One of the RL TIN busts fell within the wetted channel and resulted in a localized anomalous 3.5 meter water depth (C) in the derived bathymetric raster.

6.3: IMPORTANCE OF VARIABILITY

6.3.1: ABILITY TO DERIVE METRICS

Analysis of water depth rasters derived from topographic data collected by each crew at each site indicate minimal discrepancies in mean water depths (Table 14). The ODFWUGR crew water depth data was omitted from crew intercomparisons at the three tributary sites due to the fact they sampled these streams roughly two months earlier at discharges roughly one to two orders of magnitude higher than the base flows other crews surveyed at.

At both lower order and mainstem sites the mean water depths between crews differed by only a few centimeters (Fly Creek mean range=0.11–0.12 m; Spring Creek mean range=0.06–0.07 m; West Chicken Creek mean range = 0.14–0.17 m; Grande Ronde River upper mean range=0.17–0.21 m; Grande Ronde River middle mean range=0.29–0.33 m; Grande Ronde River lower mean range=0.17–0.21 m). This inter-crew agreement is reflected not only in the mean water depths, but across the whole distributions of water depth as shown in the volumetric water depth histograms which show similar shaped and magnitude distributions for crews at each site (Figure 12). Given the relative roughness (ratio of water depth to bed roughness elements) in some of these streams (Figure 2), it is very reassuring how little crew variability influenced water depth values and distributions – a key fish habitat variable. As is illustrated in the volumetric distribution tails and captured in the data summary table, we observed that maximum values have a greater range of inter-crew variability (Fly Creek max range=0.43–0.57 m; Spring Creek max range=0.27–0.41 m; West Chicken Creek max range=0.61–0.63 m; Grande Ronde River upper max range=0.49–3.62 m; Grande Ronde River middle max range=1.66–2.05 m; Grande Ronde River lower max range=0.66–0.93 m). The difference in this extreme end member may be attributed to either systematic blunders or more likely that not all crews successfully located and surveyed the maximum pool depth of the deepest pool in the reach.

The largest observed discrepancy in maximum water depth between crews at a site was observed at the Grande Ronde River upper site. Here, the ODFWUGR crew's derived water depth had a maximum value of 3.62 m while all other crews' maximum water depth ranged between 0.48 and 0.60 m (Table 14). The next largest inter-crew maximum water depth discrepancy at any site was on the order of 39 cm. It should be noted the ODRWUGR crew anomalous near water's edge depth is not reflected in the water depth raster maximum-minimum difference at this site (Table 15) as no other crew had delineated this area as within the wetted perimeter. As a result, for this raster cell, ODFWUGR had both the maximum and minimum cell value.

Results of the cell by cell maximum-minimum water depth raster difference reveal the maximum range in depth at any site for a single cell was 1.83 m (Table 15). This was observed at the Grande Ronde River middle site. Even though there was a local large difference in water depth values, a distribution of the cell by cell maximum-minimum water depth range (Figure 13) reveals the majority of the volumetric difference is contributed by cells with a discrepancy of 10 to 30 cm (mean= 0.17 m). Thus, maximum variability in water depth between all crews is less than maximum DEM elevation variability.

		WATER DEPTH RASTERS							
		Crew							
Site	Statistic	CRITFC	ELR	ODFWJD	ODFWUGR	QCI	Tetra	TQ	Mean
Fly Creek	Min (m)	0	0	0	0	0	0	0	0
	Max (m)	0.56	0.51	0.43	0.72	0.53	0.45	0.57	0.51
	Mean (m)	0.11	0.11	0.11	0.26	0.12	0.12	0.11	0.11
	StdDev (m)	0.08	0.07	0.07	0.13	0.07	0.07	0.08	0.07
	CV(%)	71.56	63.30	65.74	50.00	57.85	61.74	69.72	64.99
Spring Creek	Min (m)	0	0	0	0	0	0	0	0
	Max (m)	0.38	0.39	0.40	0.33	0.34	0.27	0.41	0.37
	Mean (m)	0.06	0.06	0.07	0.10	0.06	0.07	0.06	0.06
	StdDev (m)	0.04	0.04	0.05	0.06	0.04	0.05	0.04	0.04
	CV(%)	66.67	66.67	71.43	60.00	66.67	71.43	66.67	68.25
West Chicken Creek	Min (m)	0	0	0	0	0	0	0	0
	Max (m)	0.62	0.61	0.61	0.80	0.61	0.61	0.63	0.61
	Mean (m)	0.16	0.15	0.14	0.25	0.16	0.17	0.15	0.15
	StdDev (m)	0.12	0.11	0.12	0.15	0.12	0.12	0.13	0.12
	CV(%)	77.42	75.86	83.92	59.29	74.07	71.86	89.04	78.69
Grande Ronde River (upper site)	Min (m)	0	0	0	0	0	0	0	0
	Max (m)	0.53	0.48	0.50	3.62	0.60	0.52	0.49	0.96
	Mean (m)	0.21	0.17	0.18	0.20	0.18	0.18	0.18	0.19
	StdDev (m)	0.09	0.08	0.09	0.09	0.08	0.08	0.09	0.09
	CV(%)	41.46	47.06	46.70	45.00	47.43	45.65	49.44	46.11
Grande Ronde River (middle site)	Min (m)	0	0	0	0	0	0	0	0
	Max (m)	2.05	1.66	1.92	1.92	1.67	2.00	1.99	1.89
	Mean (m)	0.33	0.33	0.30	0.31	0.29	0.30	0.30	0.31
	StdDev (m)	0.23	0.21	0.21	0.21	0.21	0.21	0.21	0.21
	CV(%)	69.67	62.35	70.76	68.93	71.43	70.76	69.36	69.04
Grande Ronde River (lower site)	Min (m)	0	0	0	0	0	0	0	0
	Max (m)	0.82	0.66	0.88	0.93	0.88	0.84	0.74	0.82
	Mean (m)	0.21	0.19	0.17	0.19	0.17	0.20	0.19	0.19
	StdDev (m)	0.11	0.11	0.11	0.11	0.09	0.11	0.11	0.11
	CV(%)	53.05	55.67	62.07	57.29	56.36	53.85	58.55	56.69
Three lower order sites	Min	0	0	0	0	0	0	0	0
	Max	0.62	0.61	0.61	0.80	0.61	0.61	0.63	0.61
	Mean	0.11	0.10	0.11	0.21	0.11	0.12	0.11	0.11
	StdDev	0.05	0.04	0.04	0.09	0.05	0.05	0.04	0.04
	CV(%)	0.44	0.41	0.34	0.44	0.45	0.41	0.41	0.41
Three mainstem Grande Ronde River sites	Min	0	0	0	0	0	0	0	0
	Max	2.05	1.66	1.92	3.62	1.67	2.00	1.99	1.89
	Mean	0.25	0.23	0.22	0.23	0.21	0.23	0.22	0.23
	StdDev	0.07	0.09	0.07	0.07	0.07	0.06	0.06	0.07
	CV(%)	0.29	0.38	0.32	0.28	0.34	0.29	0.29	0.31

Table 14 - Summary of DEM derived water depth raster for each crew at each site, summarized across all crews at each site and for the three tributary and mainstem sites. Values shaded in grey indicate reaches the ODFWUGR crew sampled approximately 1 month prior to other crews. These values were not included in crew inter-comparisons due to the stage dependency of water depth measurements. At the lower order sites, omitting ODFWUGR, average water depths vary by a maximum of 3 cm while maximum water depth varies by 14 cm. At the mainstem sites, average water depths vary by a maximum of 4 cm while maximum water depth varies by up to 3.14 m. CV values are relatively similar between crews at all sites indicating crews measured comparable variation of depths.

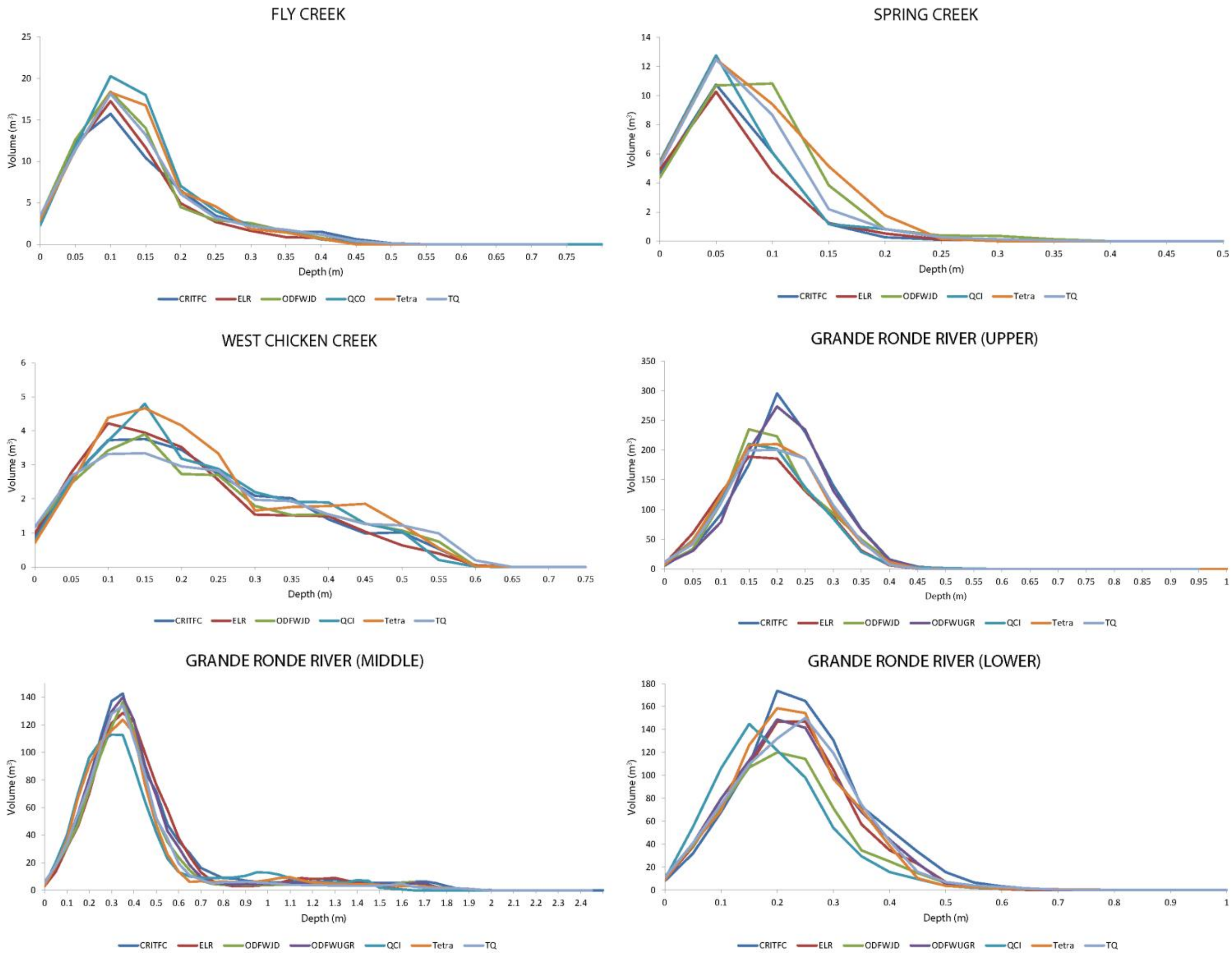
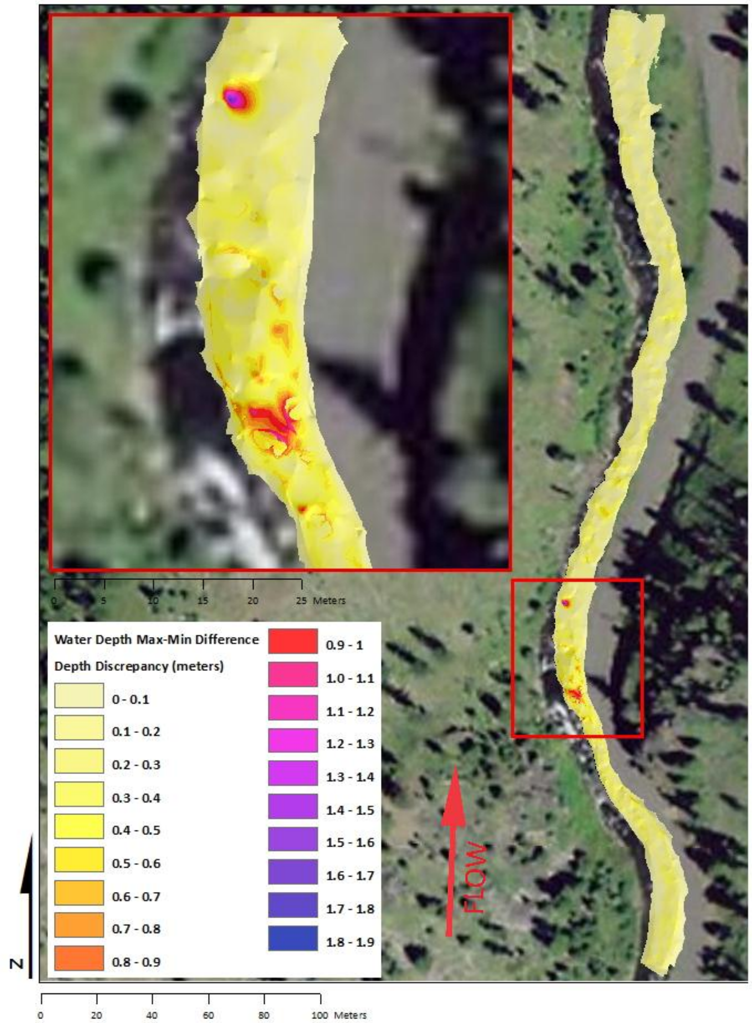


Figure 12 - Water depth volumetric distribution for all crews by site. The area under each curve denotes the total volume of water within the reach as estimated by the difference between each crew's water surface survey and topographic survey.

	Water Depth Max-Min Difference				
Site	Min (m)	Max (m)	Mean (m)	StdDev (m)	CV (%)
Fly Creek *	0	0.397	0.064	0.041	64.06
Spring Creek *	0	0.374	0.056	0.04	71.43
West Chicken Creek *	0	0.574	0.079	0.058	73.42
Grande Ronde River (upper site)	0	1.543	0.091	0.05	54.95
Grande Ronde River (middle site)	0	1.831	0.172	0.133	77.33
Grande Ronde River (lower site)	0	0.679	0.107	0.063	58.88

* Did not include ODFWUGR crew at Fly, West Chicken or Spring Creek as they sampled 2 months prior to all other crews

Table 15- Minimum-maximum water depth raster differences by site.



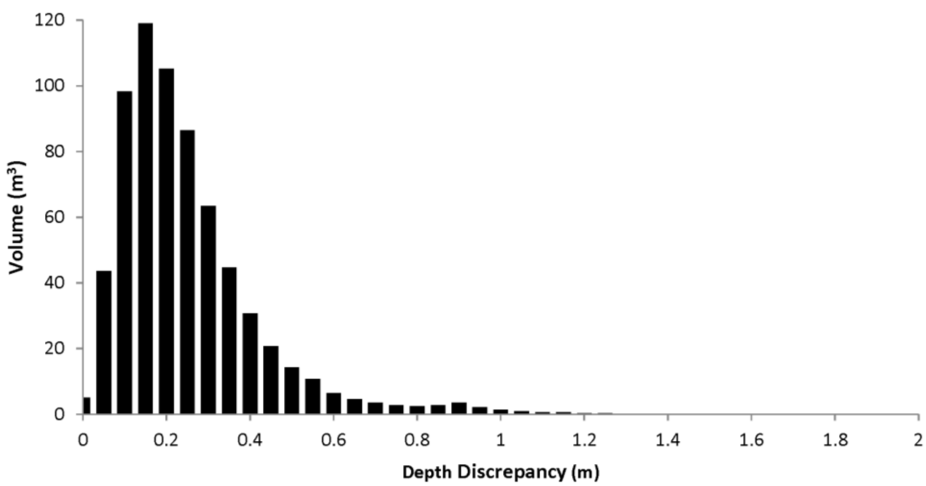


Figure 13 - Grande Ronde River middle site water depth maximum-minimum difference raster. Inset map highlights the portion of the reach with the greatest difference in water depth between all crews. Note the small spatial extent of the observed large water depth discrepancy. Histogram shows gross volumetric depth discrepancy.

6.3.2: ABILITY TO DETECT GEOMORPHIC CHANGE

Results of the subtle change scenario indicate four of six crews had a sediment budget result with magnitudes of net change and interpretations consistent with the 'truth' (Table 16). Net change is the deposition volume minus the erosion volume, and when positive is interpreted as a net aggradational period, when negative is interpreted as a net degradational period, when zero is interpreted as an equilibrium period, and when the signal is less than the volumetric uncertainty the budget is considered indeterminate. The 'true' geomorphic change modeled for this subtle change scenario from the ODFWUGR crew DEMs detected 5±1.7 m^3 of erosion (river right pool scour, river left bank erosion) and 5±2.9 m^3 of deposition (river left and mid channel bar development) for a net difference of 0±3.4 m^3. This means the 'true' net thresholded subtle geomorphic change resulted in an indeterminate budget where we could not definitively conclude if the net budget was erosional or depositional. Visually, it is apparent that most crews captured spatially elements of both the erosional and depositional signal (Figure 14) between Time 1 (i.e. each crew's 2011 DEM) and Time 2 (i.e. time step 2 modeled from ODFWUGR 2011 DEM). As well, histograms of the gross volumetric differences have a similar magnitude and pattern across most crews (Figure 14). Exceptions are the TQ crew whose budget resulted in a very slight net aggradational signal of 7±4.3 m^3 and the ELR crew whose modeled change detection resulted in a hugely discrepant degradational budget of -153±9.7 m^3.

	Unthresholded (m^3)			Thresholded (m^3)			
Crew	Erosion	Deposition	Net	Erosion	Deposition	Net	Budget Result
ODFWUGR (Truth)	6	7	1	5 ± 1.7	5 ± 2.9	0 ± 3.4	Indeterminant
CRITFC	4	9	5	3 ± 1.6	6 ± 3.	3 ± 3.7	Indeterminant
ELR	153	0	-153	153 ± 9.7	0 ± 0.0	-153 ± 9.7	Systematic Erorr
ODFWJD	7	6	-1	6 ± 2.4	5 ± 2.6	-1 ± 3.5	Indeterminant
Tetra	6	9	3	5 ± 1.5	8 ± 3.5	3 ± 3.8	Indeterminant
TQ	3	11	8	3 ± 1.2	10 ± 4.1	7 ±4.3	Net Aggradational
QCI	5	8	3	4 ± 1.6	7 ± 3.0	3 ± 3.4	Indeterminant
Average	26	7	-19	26 ± 2.8	6 ± 2.8	-20 ± 4.6	NA
Averge w/o ELR	5	8	3	4 ± 1.7	7 ± 3.3	2.5 ± 3.7	Indeterminant

Table 16 - Results of modeled 'subtle' geomorphic change by crew. New DEM and Old DEM surfaces were both un-thresholded (straight DEM of difference) and thresholded with uniform error of 0.06 cm.

The obvious change scenario modeled the geomorphic consequences of the construction of a channel spanning beaver dam between the crews 2011 survey and a hypothetical future point in time (Figure 15). The 'true' effect of the dam was -188±26.0 m^3 of erosion (active floodplain avulsion) and 74±15.8 m^3 of deposition (subsequent bar development from avulsed material) producing a net degradational signal of -114±30.4 m^3. All six crews failed to detect the 'true' sediment budget result modeled in the obvious change scenario (Table 15). From the DEMs of difference (i.e. New DEM – Old DEM) it is evident that five of the six crews correctly detected bar development in the DS half of the wetted channel but failed to capture the massive channel avulsion event across the floodplain

(Figure 15). Consequently, their effective control volumes differ and this skews the overall budget representation towards a net aggradational signal (Table 17).

Crew	Unthresholded (m^3)			Thresholded (m^3)			Budget Result
	Erosion	Deposition	Net	Erosion	Deposition	Net	
ODFWUGR (Truth)	201	85	-116	188 ± 26.0	74 ± 15.8	-114 ± 30.4	Net Degradational
CRITFC	44	126	82	38 ± 14.2	105 ± 24.9	67 ± 28.6	Net Aggradational
ELR	1884	0	-1884	1884 ± 119.8	0 ± 0.0	-1884 ± 119.8	Systematic Error
ODFWJD	86	22	36	78 ± 31.1	105 ± 25.3	27 ± 40.1	Net Aggradational
Tetra	139	164	25	131 ± 28.7	126 ± 33.8	-5 ± 44.4	Indeterminant
TQ	38	142	104	32 ± 12.1	118 ± 26.5	86 ±29.1	Net Aggradational
QCI	42	127	85	36 ± 12.5	106 ± 25.3	70 ± 28.2	Net Aggradational
Average	348	109	-238	341 ± 34.9	91 ± 21.7	-250 ± 45.8	NA
Averge w/o ELR	92	128	36	84 ± 20.8	106 ± 25.3	21.8 ± 33.5	Net Aggradational

Table 17 - Results of modeled 'obvious' geomorphic change by crew. New DEM and Old DEM surfaces were both un-thresholded (straight DEM of difference) and thresholded with uniform error of 0.06 cm.

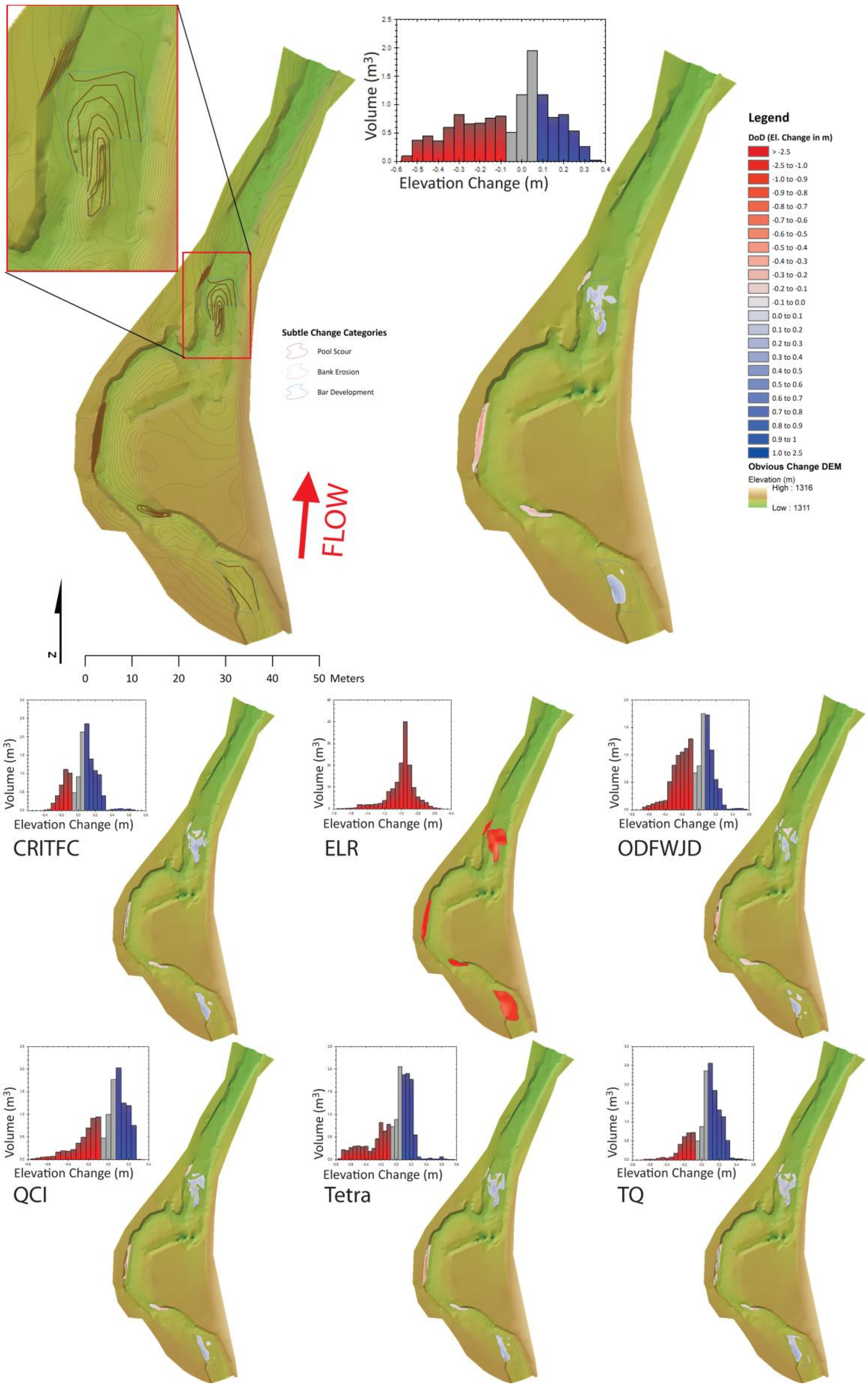


Figure 14- Results of modeled 'subtle' geomorphic change of Time 2 – Time 1. Here the ODFWUGR crew represents 'true' change. Areas in blue represent deposition while areas in red represent erosions. Histograms represent gross volumetric differences (m^3).

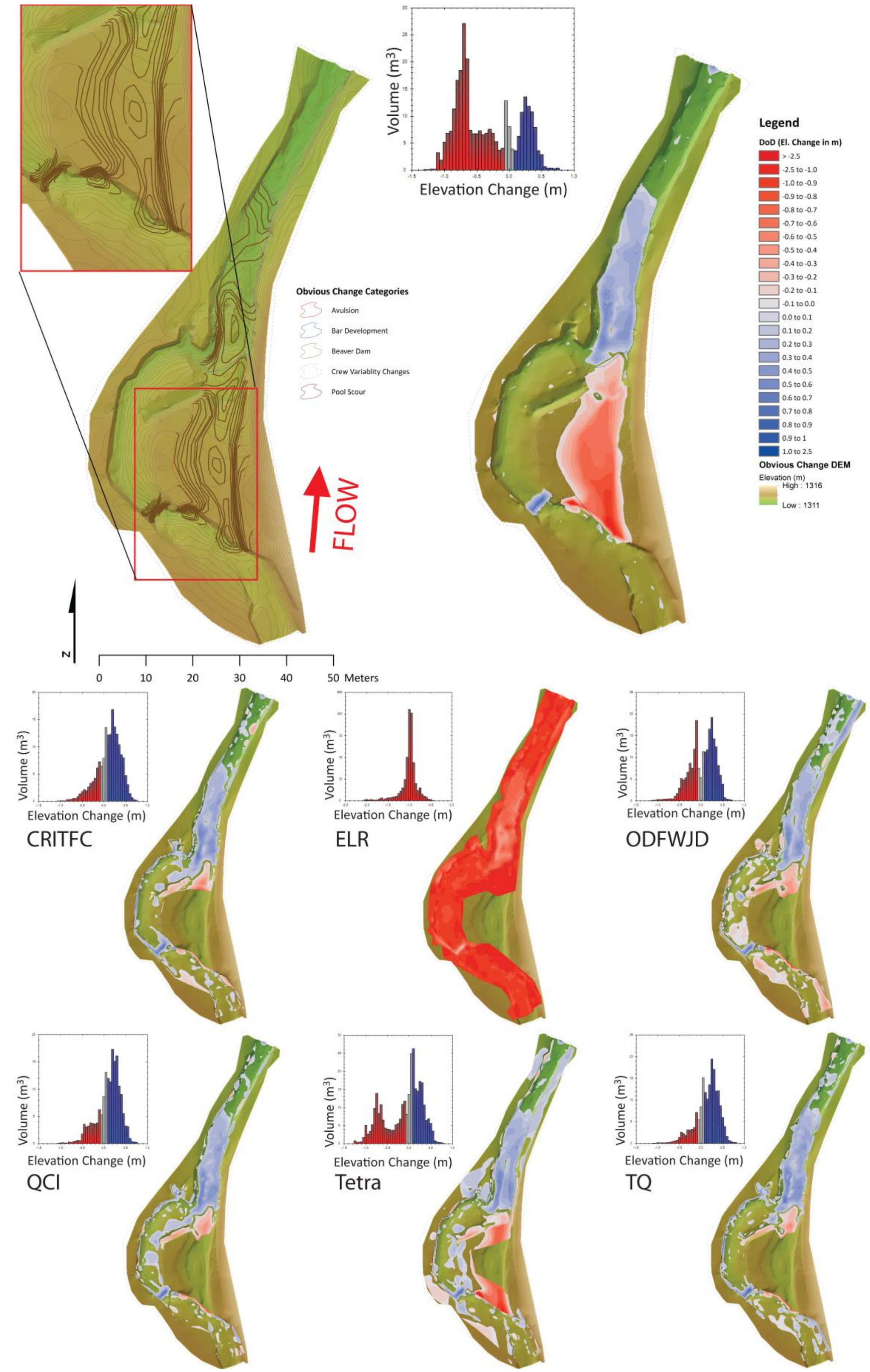


Figure 15 - Results of modeled 'obvious' geomorphic change of Time 2 – Time 1. Here the ODFWUGR crew represents 'true' change. Areas in blue represent deposition while areas in red represent erosion. Histograms represent gross volumetric differences (m^3).

7: DISCUSSION

7.1: INTER-CREW VARIABILITY

7.1.1: SURVEY EFFORT

Different crews develop habits and sampling strategies based on their implementation of the protocol. Certain crews may focus their effort surveying as many points as possible while others may prefer to capture most breaks in slope with breaklines. Across all sites TQ collected the greatest number of total station points but the least length of breaklines. Conversely, QCI collected the least number of total station points but the second greatest length in breaklines. The inter-crew variability observed in survey effort variables was a result of these different sampling strategies. At tributary sites we saw an almost two-fold difference in the mean number of total station points collected, total length of field collected breaklines, total length of post-edited breaklines and a three-fold difference in survey area extent. Results were of a similar magnitude across mainstem sites. Of significant interest in the context of detecting potential future geomorphic change was the relatively substantial variability survey extent. Delineating a larger survey extent in areas of active alluvial floodplain that might experience lateral migration can certainly increase sampling effort, yet adequately surveying the active floodplain is integral in studies trying to capture geomorphic changes through time. Clearer guidance could be provided in the protocol and in training to the crews on target variable point densities in channel areas, bank areas versus overbank areas, as well as breakline delineation (field is better than office). Similarly, scouts could be used to flag or delineate on a map approximate target survey extents for crews. The survey effort should always be focused on the in-channel habitat, but in many cases it is relatively easily to grab on the order of 15 to 30 additional context points on floodplains and or hillslopes to provide topographic context and facilitate potential future change detection. Moreover, scouts could be trained to reasonably infer areas that are likely to experience future lateral migration versus those that are less likely to experience such change.

An interesting component of the survey effort analysis would be to inter-compare the amount of time different crews spent establishing control points and surveying the reach. Time effort rasters, where each cell represents how long it took to survey a location (e.g. 5 seconds/pt.), would allow for spatial intercomparisons of effort throughout the entire survey area. Unfortunately the total station units used in the study were not configured to include timestamps for each individual point. This should be investigated as a potential addition, if possible, in the future.

7.1.2: MAX-MIN – FULL RANGE

In general, large observed maximum-minimum differences were explained by survey or post-processing blunders attributable to a single crew. While some blunders (e.g. incorrect total station base unit height) resulted in substantial reach wide discrepancies between crews, other errors (e.g. incorrect survey rod height) propagated to large magnitude elevation differences in relatively small, localized areas (e.g. range of a few pixels to several m^2). For example, at Fly Creek the large, site-wide mean elevation difference was attributed to a simple and easily correctable survey blunder made by the ELR crew. Here the ELR crew surveyed the entire reach from a single control point and erroneously added 1 meter to the recorded total station base instrument height. As a consequence each Z value in the survey was recorded as 1 meter greater than the true elevation. This resulted in an observed maximum-minimum difference across all crews with a maximum value of 1.92 m and a relatively high mean of 0.67 m (Table 18). Omitting the ELR crew from the crew intercomparison (Figure 16) drastically reduced the mean observed variability from 0.67 m to 0.10 m (Table 18). This adjusted difference is on par with the full range of elevation variability observed at the other two tributary sites. The large observed difference at Spring Creek (max=10.05 m) was attributed to an apparent survey blunder by the ODFWJD who recorded an incorrect rod height while surveying a few points on the RR bank (see Appendix B). While the sampling error made by the ODFWJD crew led to large localized discrepancies when analyzed across all crews, the mean observed difference was only on the order of 10 cm. While not every raster cell with a substantial maximum-minimum difference was accounted for in our analysis, we were able to identify the sources of several of the large differences which will aid in limiting crew-derived sources of error (see Appendix B). Being able to attribute large sources of variability to systematic sampling errors will facilitate efforts (e.g. improved training and QA/QC practices) to limit crew-derived sources of error. We strongly recommend that these examples be emphasized in crew training to help crews avoid such mistakes, and identify them when they are made. We also recommend that QA/QC guidance be expanded not just to identify such blunders, but to provide specific guidance to crews on if and how such things can be rectified post hoc. For example, many crews experienced simple rod-height busts. If the protocol recommends that crews only adjust rod heights in whole 25 cm increments (for example), rod height busts are much easier to correct post-hoc as the bust is likely off by some multiple of 25 cm. Similarly, crews could be encouraged to routinely (say every 25-50 points) call out rod heights by the gunner stating what the rod height is currently set at in the instrument and the rodman copying and confirming this height back to the gunner. This will instill a greater consciousness of the importance of correct rod heights, and save significant effort and time in the crew's post-processing of the data.

Another notable area where crew blunders arose and clearer guidance is needed is in basic survey practice and troubleshooting procedures. For example, the *.raw survey files revealed that on multiple occasions crews accepted a backsight check either during the instrument setup or during a routine backsight check that was outside the specified tolerance in the CHaMP protocol. In some cases, this was likely an oversight, but in other instances you can see that the crew checked multiple times and still got a result outside tolerance, but just proceeded with the survey anyway. This indicates that although crews knew a backsight check out of tolerance was not good, they were not equipped to trouble shoot effectively to fix it. Clearer survey troubleshooting guidance can be provided in the protocol and training to help crews both avoid such problems and effectively cope with it when they encounter it.

Spatially segregating the maximum-minimum difference raster by survey area revealed the largest volumetric discrepancies between crews occurred beyond the wetted channel boundary. The CHaMP protocol emphasizes concentrating survey effort in the wetted channel to accurately capture that quantity and quality of available fish habitat. If the observed full range of inter-crew variability were greater within the wetted channel in comparison with the channel margins and floodplain we would have cause for concern pertaining to how crews sampled, edited their data and/or the protocol in its present form. That the observed range of variability is greater on the floodplain is consistent with how crews are instructed to sample the local topography.

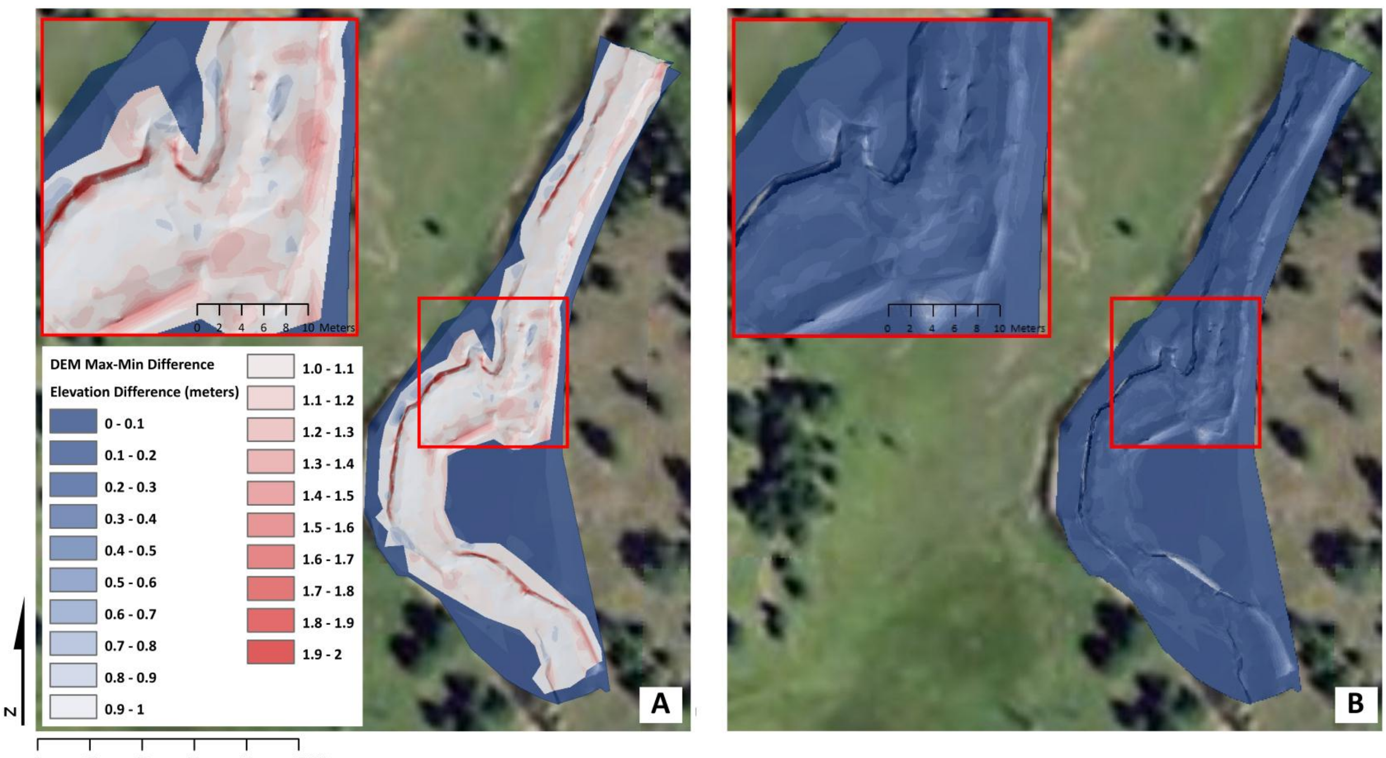


Figure 16 - Fly Creek DEM maximum-minimum difference raster with (A) and without ELR crew (B) who made survey blunder of adding 1 meter to total station instrument height.

	DEM Maximum-Minimum Difference			
Site	Min	Max	Mean	StdDev
Fly Creek	0	1.92	0.67	0.50
Fly Creek*	0	0.99	0.10	0.11

* without ELR

Table 18 - Summary statistics of Fly Creek DEM maximum-minimum difference raster with and without ELR crew.

7.1.3: FIS ERROR

The FIS error model outputs of elevation uncertainty used in this study was uncalibrated to the specific conditions of CHaMP. Accordingly, the estimates are reasonable in highlighting relative spatial differences but are likely overly conservative in most places. Observed mean elevation uncertainty was lower across all three tributary sites in comparison with the three Grande Ronde River sites. Average point density across the tributary sites was 0.47 pts./m^2 and 0.12 pts./m^2 across the mainstem reaches (note > 0.3 pts./m2 is considered high for stream surveys). The lower overall point density across mainstem reaches may be a result of these sites being approximately 3 times longer than the tributary sites yet crews were only allocated ½ to 1 day longer to sample. However, the exception is the Spring Creek reach which had the lowest observed mean point density of any site. This is due impart to channel spanning vegetation which drastically limited the line of sight between the total station base unit and survey rod prism and thus impaired the crews' ability to comprehensively sample within the survey extent. Within the lower order sites, mean FIS error raster values were highest for Spring Creek, and within mainstem sites, at the Grande Ronde River middle site (Appendix A Table 4). That these two sites had the highest elevation uncertainty is most certainly a reflection of how increased complexity at these two sample reaches presents greater surveying challenges. As aforementioned the Fly Creek reach had extremely dense deciduous vegetation along both banks while the Grande Ronde River middle site had the greatest topographic and hydraulic complexity of all sample reaches with large boulders, steeper gradient and high velocity flow convergences. The increased difficulty of sampling such sites with total station equipment may indicate that, in order to accurately capture topography, either: a) more time and effort should be allocated to sampling sites with greater complexity, or b) a secondary sampling method and/or protocol that does not necessitate total stations should be developed.

Inter-crew comparisons did not indicate a single crew consistently produced topographic surfaces with the greatest or least elevation uncertainty across both tributary and mainstem reaches. However, averaged across all sites and tributary sites, the ODFWUGR crew had the highest mean FIS and lowest mean point density values while TQ had the lowest mean FIS values and the highest mean point density. Across the three mainstem sites, Tetra had the lowest mean FIS values while ELR had the highest. Yet at the Grande Ronde River sites these crews did not also produce the highest and lowest observed mean point densities. ODFWJD had the highest mean point density while ODFWUGR and QCI had the lowest mean point density. Although, from results averaged across all sites, it would appear there is an explicit relationship between elevation uncertainty and point density that may not hold true as implicated by results across the 3 mainstem reaches. An issue in interpreting the elevation uncertainty raster results lies in the current FIS rule set which does not incorporate breaklines. As breakline collection was emphasized by the CHaMP program as a means to reduce the number of points necessary to represent topography in a reach, the FIS error raster may be biased towards crews that place greater emphasis in collecting points versus those that have lower total number of points but a greater total length of breaklines. Additionally, the numerical values set in the FIS point density rule membership function (i.e. low, medium, high) may be artificially high as they have not been calibrated. The max-min relationships reported here as well as variance cell statistics, bed roughness and maximum bank heights could all be used to calibrate FIS elevation uncertainty outputs. The membership function values were initially set in the context of a crew devoting an entire day or more to surveying the topography of a reach. Here, the CHaMP crews have several other tasks they need to complete at a survey site, one of which is surveying topography. Therefore, for a given day of sampling, a CHaMP crew will have lower point density per square meter than a crew who devoted 100% of their sampling effort to collecting topography.

While the current form of the FIS rule set may impede our ability to definitively quantify the elevation uncertainty of individual DEMs we can still use the error raster output to make relative proportional intercomparisons between crews and across sites. Encouragingly, for both the Grande Ronde River lower and middle sites, mean elevation uncertainty is lowest within the wetted channel, moderate in the discrepant area and highest in the dry portion of the reach (Table 10). This reflects that, per the CHaMP protocol, crews expended the greatest effort sampling within the wetted channel resulting in a higher point density and decreased elevation uncertainty. Conversely, crews expended less effort collecting point data in the floodplain, therefore the point density is lower and elevation uncertainty higher in the dry portions of the reach. This reveals some consistency in spatial distribution of sampling effort between crews and across sites.

Interestingly, across all sites, CRTIFC, Tetra and TQ had the lowest mean elevation uncertainty. These three groups had experienced surveyors as crew members while all other crews solely had experienced habitat technicians. The crews with professional surveying experience had fewer observed survey and post-processing problems (Table 13). Having professional surveying experience likely improves survey efficiency and minimizes errors due to knowledge of how to troubleshoot total station equipment. It would be interesting to compare precision in topographic surfaces with precisions in habitat based-metrics (e.g. habitat unit type, embeddedness, etc.) between crews with and without professional surveying experience. In future years, many of the site layout and surveying judgment issues could be dealt with and anticipated ahead of time by a scout who is well versed and trained in surveying practice. If scouts outlined site control, a recommended survey workflow (e.g. occupy BM2 first, backsight to BM1, then traverse to CP1, etc.), a site survey boundary, and suggested areas that warranted higher survey effort; variability in performance could be significantly minimized. However, it important to reiterate that even with the variability quantified here from a relatively frantic pilot season, most topographic metrics were well inside the range of acceptable quality and coherent change detection was still possible. Any improvements in training, guidance and QA/QC are likely to only further improve the quality of CHaMP surveys.

7.2: INTRA-CREW VARIABILITY

7.2.1: CONSISTENCY

Some crews were identified as having relatively low or high variability in relation to a single or multiple variables yet, in terms of within crew consistency, no one crew was identified as universally consistent or inconsistent for all variables across all sites. Compared with their peers, the ODFWUGR crew was the most consistent across all sites for several, but not all, metrics (Table 12). Yet consistency, or for that matter inconsistency, is not necessarily synonymous with quality. As mentioned earlier, we expected a priori that some crews may consistently perform well while others may consistently perform poorly. Here we observed that ODFWUGR had the lowest CV for mean DEM elevation uncertainty across all sites, but had the highest mean elevation uncertainty value. This allows us to infer that ODFWUGR consistently produced DEMs with some of the highest mean elevation uncertainty values of any crew. This is likely attributed to evidence they consistently delineated the largest survey extent, but did not proportionally collect more points (Table 6 & Table 7). This is particularly evident at the three lower order sample reaches (Table 6). A larger survey extent without proportionally increasing point sampling effort results in a lower overall point density in comparison with other crews and thus a greater elevation uncertainty in the resulting interpolated surface (i.e. DEM). A fairer comparison would be to look just at in-channel elevation uncertainty.

That no single crew was identified as having 'the best' or 'worst' performance may be encouraging as it indicates many of the crews are relatively equitable in the context of the overall survey. However, there is something that can be gained from understanding how different crews develop habits and sampling strategies for specific metrics based on their implementation of the protocol. The process of crews building their own DEMs is an important feedback mechanism on them refining their survey methods to facilitate production of better DEMs. However, if a crew starts a habitat that either the protocol, crew leads or their post-processing has no negative feedback on, a crew will continue with that practice. For example, the Tetra crew consistently had the greatest length of post-edited breaklines. However consistent this practice was, post-edited breaklines require more subjectivity and user-judgment than simply surveying the breaklines adequately in the field. This is an example of where summary metrics and approximate targets that CHaMP may judge to be indicative of quality can be shared with the crews in post-processing to help them assess their own work. In this sense, CHaMP can continue to develop its protocol based on techniques that produce higher quality topographic surfaces.

7.3: EFFECT OF VARIABILITY

7.3.1: ABILITY TO DERIVE METRICS

As seen in the full range of DEM variability analysis, several of the larger water depth maximum-minimum differences can be attributed to survey blunders made by an individual crew at a single site. Here, we consider survey blunders to be potentially correctible (post-hoc) or avoidable mistakes made by crews, such as an incorrectly recorded survey rod height. An example is the anomalous ODFWUGR crew derived maximum water depth observed at the Grande Ronde River upper site. Here, from the point data and crew edited TIN we deduced the crew made a survey blunder and recorded an incorrect rod height for several surveyed out of channel topo (tp) points. The incorrect rod height lead to several TIN busts and incorrect DEM elevations which were then propagated through to the derived water depth map (Figure 10). The river left in-channel bust resulted in an observed maximum depth of 3.62 meters while other crews observed a maximum depth equal to or less than 0.6 meters (mean max depth=0.52 m, StdDev=0.04 m). Here our recommendation is that: a) crews need to use more caution when changing rod heights throughout a survey and b) crews need to use more caution when editing TINs as these busts are quite obvious and could have been detected by the crew member visually inspecting and editing the data. In general, it is promising that the largest observed variability in interpolated topographic surfaces between crews could be attributed to systematic blunders. This indicates that with improved training, the development of total station troubleshooting protocols and better QA/QC measures, blunders and errors may be substantially reduced.

Despite observed variability in both DEM maximum-minimum difference rasters and FIS elevation uncertainty rasters across crews at sample reaches, the overall shape and magnitude of DEM-derived water depth volumetric distributions are quite similar (Figure 12). At the lower order sites (Table 14), average water depths varied by a maximum of 3 cm (West Chicken Creek) while maximum water depth varied by up to 14 cm (Spring Creek). At the mainstem sites, average derived water depths varied between crews by a maximum of 4 cm (lower site) while maximum water depth varied by up to 3.14 m (upper site). CV values were relatively similar between crews at all sites indicating crews measured comparable variation of depths. This may indicate that large differences due to sampling blunders, such as with the ODFWUGR crew at the Grande Ronde River upper site, tend to be highly localized. That is, large differences tend to observed at the scale of only a few meters of the total survey area. While the aim of sampling programs utilizing survey-grade technologies should be to minimize all differences, albeit large scale or localized, it may be that for some metrics, such as water depth, distributions of values are not highly influenced by small spatial scale differences. Further analysis should be conducted to ascertain if the limited effect of localized differences on frequency distributions holds true for other topographically derived habitat metrics such as width to depth ratio or residual pool depths.

7.3.2: ABILITY TO DETECT GEOMORPHIC CHANGE

The subtle change scenario revealed that, despite observed localized variability between crews, most crews detected net changes consistent with the 'true' indeterminate budget and produced results with reasonably consistent spatial patterns of erosion and deposition. (Figure 14). The exceptions in this scenario were the large net erosional signal detected by ELR and the very slight net aggradational signal detected by TQ. The TQ discrepancy was minor and within the range of plausible subtle detectable change, and a more realistic error model (i.e. with spatially variable DEM errors reflecting higher errors in the banks) would likely have made their net thresholded budget result indeterminate as well. The ELR crew discrepancy was simply due to a datum offset blunder in all their elevations (note that their water depth maps are consistent with all other crews for this site and the relative spatial patterns of their DEM match that of the other crews). Findings here indicate that, while large crew variability on the order of a few cells in a DEM may not affect the ability to detect geomorphic change, un-checked large-scale systematic error resulting from one simple small blunder such as that conducted by ELR can have serious consequences when comparing time series data.

In the obvious geomorphic change scenario all crews missed the 'true' net degradational signal contributed by out of channel change in the form of floodplain erosion (Table 17). This was a simple consequence of crews fairly consistently not extending their surveys far enough out on the floodplain. Tetra was the sole crew to find an indeterminate budget, closer to the actual net degradational signal and this was simply because their survey extended further into the floodplain, but did not capture the whole floodplain. It should be noted that the extra area that ODFWUGR surveyed in the wide open floodplain spanned roughly an extra 500 m^2 of area but only consisted of 15-20 extra survey points and a minimal amount of extra survey effort. However, in this case it made the difference between being able to capture a very plausible and significant geomorphic event in its entirety versus only detecting the in-channel change.

8: RECCOMENDATIONS

A large majority of observed inter and intra-crew variability was attributed to specific sources of error in collecting and/or post-processing survey data. Based on our findings from this study, we have prepared recommendations on how to reduce the incidence of these problems. Our set of recommendations includes protocol clarifications, points to emphasize in crew training and additional QA/QC measures. We would also like to emphasize how vital it is that the crew who sampled a reach edits the data and do so in a timely manner. An integral component to CHaMP is that crews use their on the ground knowledge of the site to validate that the topographic data adequately represents the sample reach. While we acknowledge the temptation to increase efficiency by conducting post-processing and or defer QA/QC outside of the field environment, we believe field crew edits are necessary to identify anomalies ensuring the most representative DEMs. Also, the vast majority of problems that may take hours to days to fix back in the office can be easily rectified in a matter of minutes while still in the field.

8.1: PROTOCOL CLARIFICATIONS

Benchmarks. Clearer guidance in both the protocol and crew training should be provided on placement of benchmarks. In the crew variability study a benchmark was placed in the middle of the wetted channel at Spring Creek. From what we can infer from topography and aerial imagery, this was not placed on a vegetated island or a stable boulder. Benchmarks should always be placed outside of the active flood zone in stable area. Losing a benchmark compromises alignment with future topographic surveys and time series change detection. We recommend that a series of in-the-field, post-processing, and independent (i.e. CM.org) QA/QC checks be developed to highlight potential problems with benchmarks and provide clearer guidance and feedback to crews. Some of the judgment required by crews, could be minimized by shifting the responsibility of establishing benchmarks and laying out control for a site to a scout who visits the site ahead of the crew and is well versed in survey practice.

Control Points. Placing control points in the wetted channel, rather than on the bank, introduces higher risk of the total station becoming unlevel as channel bed substrate is prone to shifting. Emphasis should be placed in the protocol and in crew training on the potential downsides and risks of setting up in the channel, and how to mitigate for these (e.g. frequent backsight checks and exercising extra caution when turning the instrument). This year crews were advised to remove their control points after surveying. We strongly recommend that any control points placed in semi-stable areas (i.e. not on an active bar or in the water, but perhaps on a bank) be set as rebar and caps and left for potential relocation by a scout and reoccupation by a crew in subsequent years. This builds more redundancy in the control network, increasing the probability of being able to reoccupy the established control and perform change detection from subsequent revisits. We also recommend that the numbering system for control points and benchmarks be modified to reflect when a benchmark was established (e.g. BM100 - BM10x or CP100-CP10x for points established in the first visit to a site, whereas BM200- BM20x or CP200-20x would be used in control established in subsequent years. Clearer guidance should also be provided for what to do when control and benchmarks are not recovered, or when they are recovered their quality is compromised to the point that they need to be retired.

Backsight Check Error Troubleshooting. We observed two incidences where crews accepted backlight check error in excess of that permitted by the CHaMP protocol. Section 7 Step 3(vi) of the protocol instructs crews to, *"make sure the error is not greater than .030 for horizontal error and .015 for vertical error. Repeat procedure if backsight error is unacceptable"*. Yet in its present form the CHaMP protocol does not provide crews with any instruction about what to do if repeating shots of the backsight result in unacceptable errors. It is imperative that crews know how to correct this in the field as such shifts in the surveys will undoubtedly confound the ability to conduct time series geomorphic change detection analysis. Both the protocol and training could emphasize how to retrace one's steps back to the last successful setup and re-establish occupation of the control network to within acceptable tolerances. If this involves the recheck and ultimate retirement of a control point and reestablishment of a new control point, that gives the crew flexibility in how they cope with such problems.

8.2: CREW TRAINING

Communication. The most common error we encountered were TIN busts. The majority of these were the result of incorrectly recorded survey rod heights. When surveying 500 to 1500 points a day the rod man will inevitably change the rod height several times. Crews should be equipped with radios and develop good communication habits whereby the rodman tells the gunner what the new height is and the gunner verifies this by repeating the new height to the rodman. Crews could also regularly (say every 25-50 points), reiterate and confirm rod heights even when the rod height has not changed.

Recording the Total Station Base Info. Whenever crews occupy a new control point they should write down the instrument height and station coordinate values in a field notebook. At Fly Creek the effect of ELR incorrectly recording the total station instrument base height led to survey wide elevation discrepancies. Requiring crews to physically write down this information will hopefully encourage crews to double-check the instrument height and avoid unwarranted errors. Pocket-size rite-in-the rain field books with pro forma encouraging consistency in the information recorded will emphasize to the crews good survey practice and provide a level of redundancy to help crews and CHaMP staff troubleshoot problems that were not revealed during a field survey. Field notebooks should be scanned regularly and a digital backup saved with every survey on champmonitorin.org.

TIN Editing. When a crew spends an entire day at a site they should be able to detect survey point blunders that result in large TIN busts or ambiguously steep elevation rises. Crews should be encouraged to take more care when editing TINs and shown how busts can propagate through to anomalous DEM-derived water depths. To make such busts easier to detect crews should increase the number of classes in the TIN elevation symbology to a minimum of 15 classes.

Delineating Water Extent Polygons. We found two incidents of crews incorrectly connecting edge of water points. Such an error is difficult for QA/QC personnel who did not survey the reach to catch later on in the office. Crews should be reminded to turn on point code 'rw' and 'lw' labels in ArcGIS when creating water extent polygons and zoom in to a sufficient scale.

8.3: ADDITIONAL QA/QC MEASURES

Checking the Total Station Base Info. As part of the Foresight QA/QC instrument heights and control point recorded in the field notebook should be checked against what was recorded on the total station job file. This will have been checked and recorded in the field, but this is an easy thing to check in the office before exporting the data to a *.dxf.

9: CONCLUSIONS

Monitoring programs that aim to track ecosystem changes through time will inevitably rely on different crews between sites and across years. As a result, programs such as CHaMP are vulnerable to variability in effort, skill and implementation of the protocol by each crew making it: a) more difficult to understand the relative quality of the data, and b) limiting the ability to detect changes through time in topography, habitat, and habitat attributes. While a level of inherent noise may be tolerable, differences attributed to poor training, subjective sampling, and/or inaccurate techniques should always be minimized. Here our objective was to assess the magnitude and significance of inter-crew variability in topographic data collected by crews during CHaMPs pilot field season. In our analysis we did not discover any crew that consistently outperformed or underperformed relative to their peers, but instead found that most crews appear to develop sampling habits and strategies in their effort to implement methodologies in the protocol. While we observed instances of substantial reach wide and localized inter-crew elevation differences these did not appear to effect the overall distribution of DEM-derived metrics such as water depths. As well, we were able to attribute the largest magnitude elevation and water depth discrepancies to survey and/or post-processing blunders made by a single crew. The primary findings were:

- **Crews are collecting topographic data of sufficient quality and consistency** that their DEMs and water depths show the same basic spatial patterns and their distributions and summary statistics are within acceptable levels of error. *Additional guidance on point densities and breakline data collection could help promote higher qualities and consistency*.
- The **largest observed differences between crews were attributed to a systematic error** by one crew (different crews across sites). Most such systematic errors are easy to identify and remedy in the data editing or QA/QC process (e.g. TIN busts). *These errors are also easy to avoid with more targeted training and QA/QC procedures*.
- The **topographic data between crews is of adequate quality to support geomorphic change detection** for both obvious changes (reported) and subtle changes in the channel and along channel margins. However, crews were not given adequate guidance on how far to extend their survey extents out into areas that the channel could plausibly migrate into. *These floodplain areas can generally be surveyed with minimal effort to facilitate a more accurate portrayal of future geomorphic changes.*

In the context of CHaMP this is encouraging as it implies that with protocol adjustments, improved training, and enhanced QA/QC measures, crew derived sources of error can be minimized in the future.

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APPENDIX A – CREW VARIABILITY DATA SUMMARY

BACKGROUND

This appendix is a summary of the crew variability data. Most of the data and figures presented in the appendix were not included in the report and are provided here as supplementary material. Appendix A includes data summarized across sites by crew as well as across crews by sites. For each site compiled figures include: water extents, an example water depth map, water depth maximum-minimum difference raster, an example FIS uncertainty raster, an example DEM, DEM maximum-minimum difference raster and a survey area segregation map. Data summarized in tabular form is presented first followed by figures organized by site.

SUMMARY EFFORT STATISTICS

Variable	Statistic	Crew CRITFC	ELR	ODFWJD	ODFWUGR	QCI	Tetra	TQ
Total station points	Min	621	576	595	680	509	509	906
	Max	1099	1458	1493	1107	786	1502	1524
	Mean	845.3	921.7	992.3	866	667.3	858.8	1140.5
	StdDev	192.5	303.9	371.3	181.5	111.4	376.8	244.9
	CV(%)	22.77	32.97	37.42	20.96	16.69	43.88	21.47
Point density (pts/m^2)	Min	0.08	0.07	0.11	0.06	0.06	0.06	0.11
	Max	1.12	0.98	0.98	0.31	0.87	0.94	1.63
	Mean	0.32	0.29	0.31	0.14	0.26	0.26	0.46
	StdDev	0.41	0.36	0.34	0.1	0.32	0.34	0.6
	CV(%)	128.13	124.14	109.68	71.43	123.08	130.77	130.43
Mean DEM elevation uncertainty (m)	Min	0.05	0.07	0.1	0.14	0.14	0.06	0.05
	Max	0.41	0.5	0.4	0.5	0.47	0.35	0.39
	Mean	0.22	0.25	0.23	0.31	0.25	0.2	0.18
	StdDev	0.12	0.15	0.11	0.14	0.12	0.1	0.13
	CV(%)	54.55	60.00	47.83	45.16	48.00	50.00	72.22
Number of breaklines collected in field	Min	10	18	25	18	27	7	30
	Max	30	234	75	40	96	33	61
	Mean	23.7	70.3	39.3	25.8	61.2	18.7	40.8
	StdDev	7.4	83.7	19.8	7.9	29.9	9	10.9
	CV(%)	31.22	119.06	50.38	30.62	48.86	48.13	26.72
Total length (m) of field collected breaklines	Min	648.8	791.3	437.5	743.9	830.8	937.7	456.3
	Max	2377.4	3562.3	3176.3	2888.7	3402.9	3263.2	1881.9
	Mean	1300.5	1734.9	1550.2	1756.6	1926.7	1926.5	987.1
	StdDev	696.9	1053.6	1000.8	857.9	1080.8	982.8	521.3
	CV(%)	53.59	60.73	64.56	48.84	56.10	51.01	52.81
Total length (m) of post-edits breaklines	Min	648.8	788.2	437.5	913	829	1144	632.3
	Max	2377.4	3562.3	3176.3	2888.7	3384.6	4308.8	2732.1
	Mean	1300.5	1732	1550.2	1737.2	1911.3	2470.9	1397.3
	StdDev	696.9	1056.01	1000.8	876.7	1069.2	1308.7	782.2
	CV(%)	53.59	60.97	64.56	50.47	55.94	52.96	55.98
Edge of water points	Min	84	86	150	59	92	61	185
	Max	162	222	321	180	168	144	285
	Mean	128.7	144.7	225.5	114.8	133.3	101.7	235.3
	StdDev	30.3	16.2	73	45.6	30.8	33.5	43.2
	CV(%)	23.54	11.20	32.37	39.72	23.11	32.94	18.36
Mean water depth (m)	Min	0.06	0.06	0.07	0.1	0.06	0.07	0.06
	Max	0.33	0.33	0.3	0.31	0.29	0.3	0.3
	Mean	0.18	0.17	0.16	0.22	0.16	0.17	0.16
	StdDev	0.1	0.09	0.08	0.07	0.08	0.08	0.08
	CV(%)	55.56	52.94	50.00	31.82	50.00	47.06	50.00
Survey extent (m^2)	Min	706.1	707.9	523.1	2465.7	599.6	844.5	560.5
	Max	13135.8	14940	11349.7	15530.6	11955.4	12968.8	12097.8
	Mean	4838.2	6117.3	4672.2	7586.3	4641.8	5076.4	4816.4
	StdDev	4788.3	5695.8	4304.51	5208.8	4368.3	4577.3	4570.4
	CV(%)	98.97	93.11	92.13	68.66	94.11	90.17	94.89
Water extent (m^2)	Min	176.9	178.3	187.5	383.6	175.7	176.7	182.6
	Max	5274.8	9843.7	5172.2	5328.1	9622.1	9876.4	5153.5
	Mean	2387.2	3243.7	2360	2539.7	3219.3	3291.3	2342.9
	StdDev	2227.2	3777.6	2176	2168.1	3694	3781.2	2179.6
	CV(%)	93.30	116.46	92.20	85.37	114.75	114.88	93.03

Table 1. Summary of crew variability data across all sites.

Variable	Statistic	Crew						
		CRITFC	ELR	ODFWJD	ODFWUGR	QCI	Tetra	TQ
Total station points	Min	621	576	595	680	509	509	906
	Max	883	803	865	800	648	846	1055
	Mean	731.7	713	686.7	724.7	575	624	987.3
	StdDev	135.7	120.6	154.5	65.6	69.8	192.3	75.4
	CV(%)	18.55	16.91	22.50	9.05	12.14	30.82	7.64
Point density (pts/m^2)	Min	0.08	0.07	0.11	0.06	0.06	0.06	0.11
	Max	1.12	0.98	0.98	0.31	0.87	0.94	1.63
	Mean	0.52	0.47	0.47	0.19	0.41	0.4	0.78
	StdDev	0.54	0.46	0.45	0.13	0.41	0.47	0.78
	CV(%)	103.85	97.87	95.74	68.42	100.00	117.50	100.00
Mean DEM elevation uncertainty (m)	Min	0.05	0.07	0.1	0.14	0.14	0.06	0.05
	Max	0.2	0.19	0.24	0.5	0.21	0.18	0.11
	Mean	0.13	0.14	0.16	0.28	0.18	0.14	0.08
	StdDev	0.07	0.07	0.07	0.19	0.04	0.07	0.03
	CV(%)	53.85	50.00	43.75	67.86	22.22	50.00	37.50
Number of breaklines collected in field	Min	10	18	25	20	27	7	30
	Max	28	40	33	25	52	18	39
	Mean	19.7	29.3	28.7	22.7	36	14	35.3
	StdDev	9.1	11.1	4	2.5	13.9	6.1	4.7
	CV(%)	46.19	37.88	13.94	11.01	38.61	43.57	13.31
Total length (m) of field collected breaklines	Min	648.8	791.3	437.5	743.9	830.8	937.7	456.3
	Max	786.6	1110.7	941.3	1430.8	1102.6	1339.9	704.3
	Mean	716.4	928	753.7	1029.2	980.8	1073.8	587.3
	StdDev	68.9	164.6	275.4	357.9	138.1	230.4	124.6
	CV(%)	9.62	17.74	36.54	34.77	14.08	21.46	21.22
Total length (m) of post-edits breaklines	Min	648.8	788.2	437.5	913	829.3	1144	632.3
	Max	780.2	1100.8	941.3	1055.7	1092.5	1687.2	971.7
	Mean	712.9	922.2	753.7	960.6	977	1343.8	791.3
	StdDev	65.8	161	275.4	82.4	134.5	234.4	170.7
	CV(%)	9.23	17.46	36.54	8.58	13.77	17.44	21.57
Edge of water points	Min	84	86	150	59	92	61	185
	Max	149	164	190	103	168	144	257
	Mean	114.3	126.0	166	80	121.7	91	212.3
	StdDev	32.7	39.0	21.2	22.1	40.6	46	39
	CV(%)	28.61	30.95	12.77	27.63	33.36	50.55	18.37
Mean water depth (m)	Min	0.06	0.06	0.07	0.1	0.06	0.07	0.06
	Max	0.16	0.15	0.14	0.26	0.16	0.17	0.15
	Mean	0.11	0.1	0.11	0.21	0.11	0.12	0.11
	StdDev	0.05	0.04	0.04	0.09	0.05	0.05	0.04
	CV(%)	45.45	40.00	36.36	42.86	45.45	41.67	36.36
Survey extent (m^2)	Min	706.1	707.9	523.1	2465.7	599.6	844.5	560.5
	Max	1496.8	1986.7	1593.8	4073.7	1434.3	2484.2	1478.6
	Mean	1132.7	1350.1	1079	3206.1	1153.8	1586.2	1039.4
	StdDev	399	639.4	536.5	811.5	480	830.9	460.3
	CV(%)	35.23	47.36	49.72	25.31	41.60	52.38	44.29
Water extent (m^2)	Min	176.9	178.3	187.5	383.6	175.7	176.7	182.6
	Max	637.5	579.1	613.7	960.6	592	588.5	584.6
	Mean	428.6	404	440.9	628.8	426.8	436	422
	StdDev	233.3	205.1	224.2	298.1	221	225.7	211.7
	CV(%)	54.43	50.77	50.85	47.41	51.78	51.77	50.17

Table 2. Summary of crew variability data across the 3 lower order sites (Fly, Spring, West Chicken Creek).

Variable	Statistic	Crew CRITFC	ELR	ODFWJD	ODFWUGR	QCI	Tetra	TQ
Total station points	Min	745	894	1091	854	740	724	994
	Max	1099	1458	1493	1107	786	1502	1524
	Mean	959	1130.3	1298	1007.3	759.7	1093.7	1293.7
	StdDev	188.2	292.9	201.3	134.8	23.7	390.4	271.7
	CV(%)	19.62	25.91	15.51	13.38	3.12	35.70	21.00
Point density (pts/m^2)	Min	0.08	0.09	0.12	0.07	0.06	0.09	0.11
	Max	0.16	0.11	0.2	0.11	0.11	0.18	0.19
	Mean	0.11	0.1	0.15	0.09	0.09	0.13	0.14
	StdDev	0.04	0.01	0.04	0.02	0.03	0.05	0.04
	CV(%)	36.36	10.00	26.67	22.22	33.33	38.46	28.57
Mean DEM elevation uncertainty (m)	Min	0.23	0.23	0.2	0.24	0.24	0.19	0.21
	Max	0.41	0.5	0.4	0.45	0.47	0.35	0.39
	Mean	0.31	0.35	0.3	0.34	0.32	0.26	0.28
	StdDev	0.1	0.14	0.1	0.11	0.13	0.08	0.1
	CV(%)	32.26	40.00	33.33	32.35	40.63	30.77	35.71
Number of breaklines collected in field	Min	25	20	25	18	73	13	34
	Max	30	234	75	40	96	33	61
	Mean	27.7	112.3	50	29	86.3	23.3	46.3
	StdDev	2.5	110	25	11	11.9	10	13.7
	CV(%)	9.03	97.95	50.00	37.93	13.79	42.92	29.59
Total length (m) of field collected breaklines	Min	1577	1914.3	1838.8	2237	2527.8	2468.8	1118.3
	Max	2377.4	3562.3	3176.3	2888.7	3402.9	3263.2	1881.9
	Mean	1884.6	2541.7	2346.7	2483.9	2827.5	2779.1	1387
	StdDev	431.2	891.6	724.4	353.4	466.2	424.7	429.1
	CV(%)	22.88	35.08	30.87	14.23	16.49	15.28	30.94
Total length (m) of post-edits breaklines	Min	1553.3	1914.3	1838.8	2237	2520.7	3192.1	1629.8
	Max	2377.4	3562.3	3176.3	2888.7	3384.6	4308.8	2732.1
	Mean	1876.7	2541.7	2346.7	2513.8	2845.7	3598	2003.4
	StdDev	439.7	891.6	724.4	324.7	470	617.6	631.1
	CV(%)	23.43	35.08	30.87	12.92	16.52	17.17	31.50
Edge of water points	Min	115	120	231	115	133	94	213
	Max	162	222	321	180	165	131	285
	Mean	143.0	163.3	285	149.7	145	112.3	258.3
	StdDev	24.8	52.7	47.6	32.7	17.4	18.5	39.5
	CV(%)	17.34	32.27	16.70	21.84	12.00	16.47	15.29
Mean water depth (m)	Min	0.21	0.17	0.17	0.19	0.17	0.18	0.18
	Max	0.33	0.33	0.3	0.31	0.29	0.3	0.3
	Mean	0.25	0.23	0.22	0.23	0.21	0.23	0.22
	StdDev	0.07	0.09	0.07	0.07	0.07	0.06	0.06
	CV(%)	28.00	39.13	31.82	30.43	33.33	26.09	27.27
Survey extent (m^2)	Min	5856	8431	6315.4	9889.9	6199.7	5584.1	6803.2
	Max	13135.8	14940	11349.7	15530.6	11955.4	12968.8	12097.8
	Mean	8543.7	10884.5	8265.4	11966.5	8129.8	8566.6	8593.4
	StdDev	3996.1	3537.9	2702	3100.7	3313.1	3891.7	3035.1
	CV(%)	46.77	32.50	32.69	25.91	40.75	45.43	35.32
Water extent (m^2)	Min	3443.8	3288	3459	3650.6	3363.6	3384.3	3408.3
	Max	5274.8	9843.7	5172.2	5328.1	9662.1	9876.4	5153.5
	Mean	4345.8	6083.4	4279.2	4450.7	6011.9	6146.1	4263.7
	StdDev	915.8	3382.7	858.9	841.4	3266.6	3352.5	873.1
	CV(%)	21.07	55.61	20.07	18.90	54.34	54.55	20.48

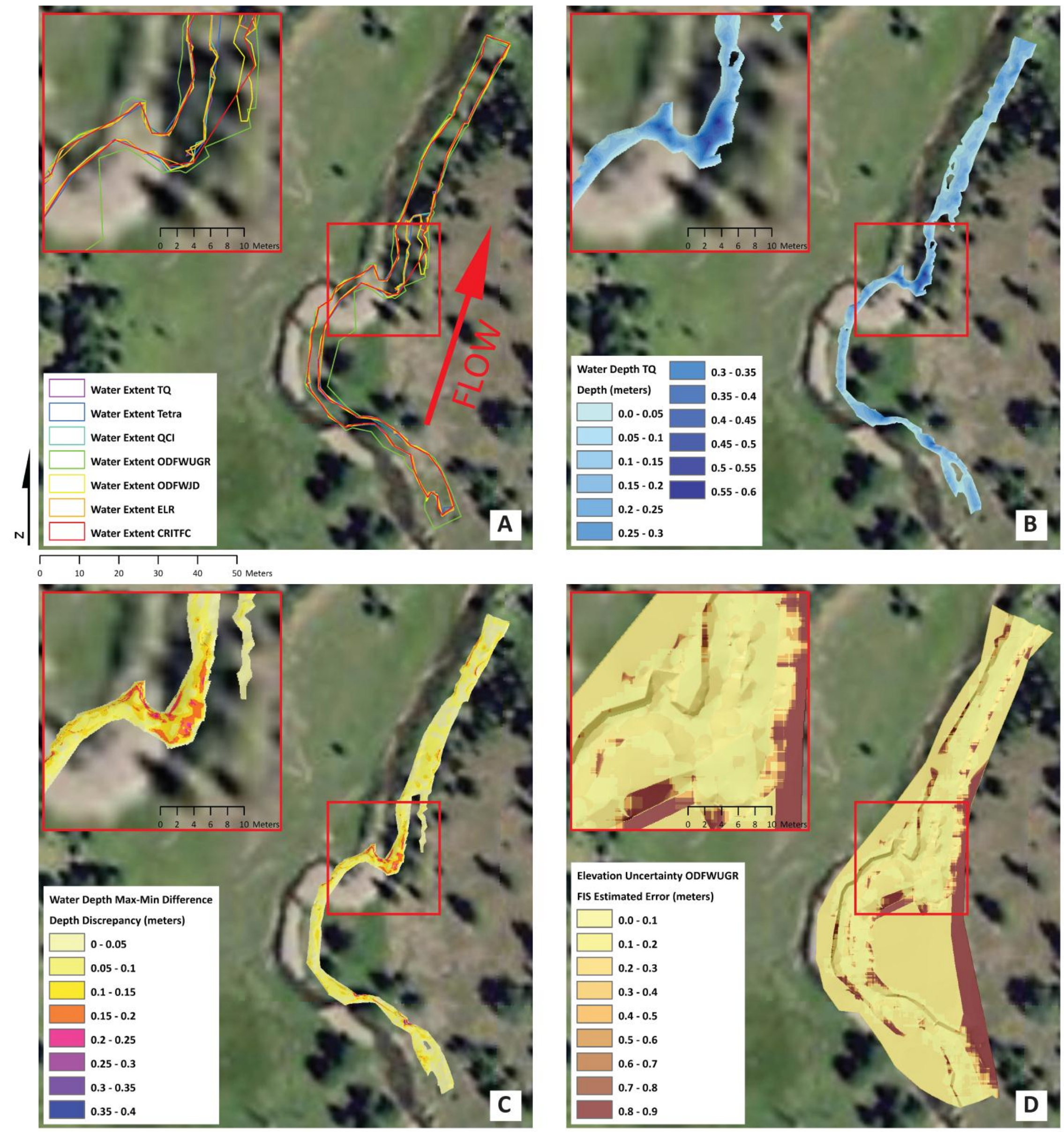
Table3. Summary of crew variability data across the 3 mainstem Grande Ronde River sites.

Variable	Statistic	Site: Fly Creek	Spring Creek	West Chicken Creek	Grande Rond River (upper)	Grande Ronde River (middle)	Grande Ronde River (lower)
Total station points	Min	517	509	600	724	740	786
	Max	1001	906	1055	1091	1363	1524
	Mean	685.6	676.6	798.9	885.7	1071.7	1274.7
	StdDev	167.3	160.5	152.1	153.8	218.4	291.7
	CV(%)	24.40	23.72	19.04	17.36	20.38	22.88
Point density (pts/m^2)	Min	0.2	0.06	0.31	0.08	0.1	0.06
	Max	0.58	0.11	1.63	0.14	0.2	0.12
	Mean	0.34	0.08	0.98	0.11	0.15	0.09
	StdDev	0.13	0.02	0.39	0.02	0.04	0.02
	CV(%)	38.24	25.00	39.80	18.18	26.67	22.22
Mean DEM elevation uncertainty (m)	Min	0.11	0.1	0.05	0.24	0.35	0.19
	Max	0.24	0.5	0.14	0.34	0.5	0.24
	Mean	0.19	0.21	0.08	0.29	0.43	0.22
	StdDev	0.04	0.13	0.04	0.04	0.05	0.02
	CV(%)	21.05	61.90	50.00	13.79	11.63	9.09
DEM maximum - minimum difference (m)	Min	0	0	0	0	0	0
	Max	1.92	10.05	0.84	4.68	4.61	3.46
	Mean	0.67	0.10	0.05	0.21	0.39	0.23
	StdDev	0.50	0.29	0.09	0.43	0.47	0.20
	CV(%)	NA	NA	NA	NA	NA	NA
Number of breaklines collected in field	Min	10	7	17	13	24	30
	Max	40	52	37	90	96	234
	Mean	26.6	28.6	24	32.6	53.7	74.4
	StdDev	10.8	13.4	7.1	26.2	30.3	72
	CV(%)	40.60	46.85	29.58	80.37	56.42	96.77
Total length (m) of field collected breaklines	Min	648.8	456.3	437.5	1118.3	1160.8	1881.9
	Max	1339.9	1430.8	943.9	2686.7	2527.8	3562.3
	Mean	933.2	910.2	757.8	2074.3	2039.4	2936.1
	StdDev	257.3	296.6	179.4	539.5	516.3	605.6
	CV(%)	27.57	32.59	23.67	26.01	25.32	20.63
Total length (m) of post-edits breaklines	Min	648.8	632.3	437.5	1629.8	1648.3	2377.4
	Max	1687.2	1200.2	1144	3293.2	3192.1	4308.8
	Mean	1062.7	897.6	808.9	2250.6	2240.1	3204.3
	StdDev	317.4	188.1	209.9	575.7	567.4	630.8
	CV(%)	29.87	20.96	25.95	25.58	25.33	19.69
Edge of water points	Min	68	61	59	94	120	112
	Max	195	185	257	303	321	285
	Mean	119.0	110.0	161.6	160.1	189.7	188.7
	StdDev	43.0	45.2	59.1	73.6	78.3	59.4
	CV(%)	36.13	41.09	36.57	45.97	41.28	31.48
Mean water depth (m) *	Min	0.11	0.06	0.14	0.17	0.29	0.17
	Max	0.12	0.07	0.17	0.21	0.33	0.21
	Mean	0.11	0.06	0.15	0.19	0.31	0.19
	StdDev	0.01	0.01	0.01	0.01	0.02	0.02
	CV(%)	9.09	16.67	6.67	5.26	6.45	10.53
Survey extent (m^2)	Min	1434.3	1079.2	523.1	6199.7	5584.1	11349.7
	Max	3079	4073.7	2465.7	10478.9	9889.9	15530.6
	Mean	1936.2	1668.8	915.3	7679.6	7016.3	13139.7
	StdDev	629.9	1070	692.2	1576	1570.8	1564.1
	CV(%)	32.53	64.12	75.63	20.52	22.39	11.90
Water extent (m^2) *	Min	579.1	454.6	175.7	5009.9	3288	4206.3
	Max	637.5	542.7	187.5	5328.1	3650.6	9876.4
	Mean	599.2	500.3	179.6	5176.3	3428.3	6644.3
	StdDev	22.2	32.6	4.6	103.5	113.1	2947.6
	CV(%)	3.70	6.52	2.56	2.00	3.30	44.36

* Did not include ODFWUGR crew at Fly, West Chicken or Spring Creek since sampled 2 months prior to other crews

Table 4. Summary of crew variability data across crews by site.

FLY CREEK SUMMARY



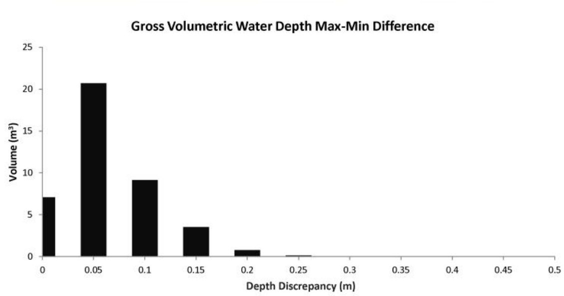
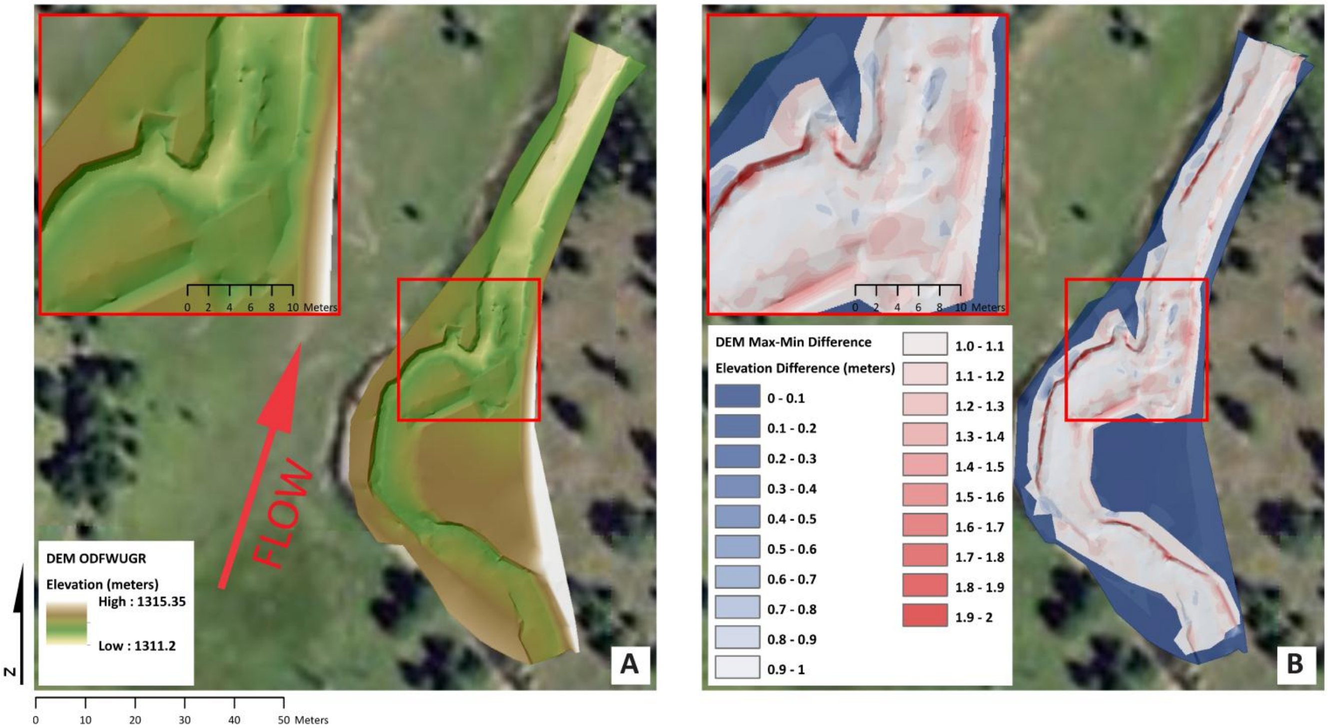
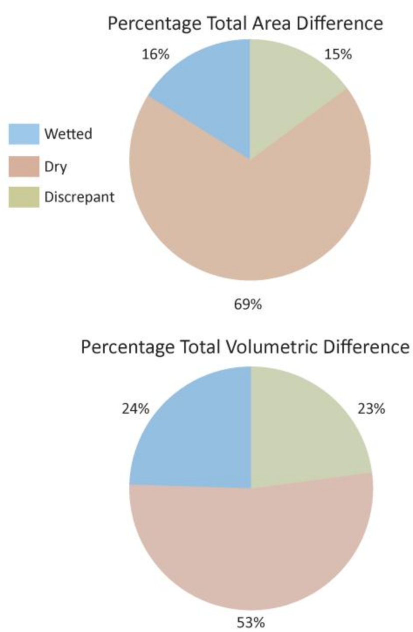


Figure 1A. CHaMP crew variability data for Fly Creek. Water extents (A) delineated by the 7 different crews. Water depth maps derived from total station topography and edge of water boundary collected by TQ (B) and the water depth maximum-minimum difference, cell by cell, for all crews (C). Gross volumetric water depth max-min difference histogram highlights the majority of volumetric differency is attributed to water depth discrepancy of only 5 cm. Results of spatially variable elevation uncertainty analysis for the ODFWUGR crew DEM (D) which was derived using a Fuzzy Inference System (FIS) ruleset based on membership functions for point density (proxy for sampling) and slope (proxy for topographic complexity).

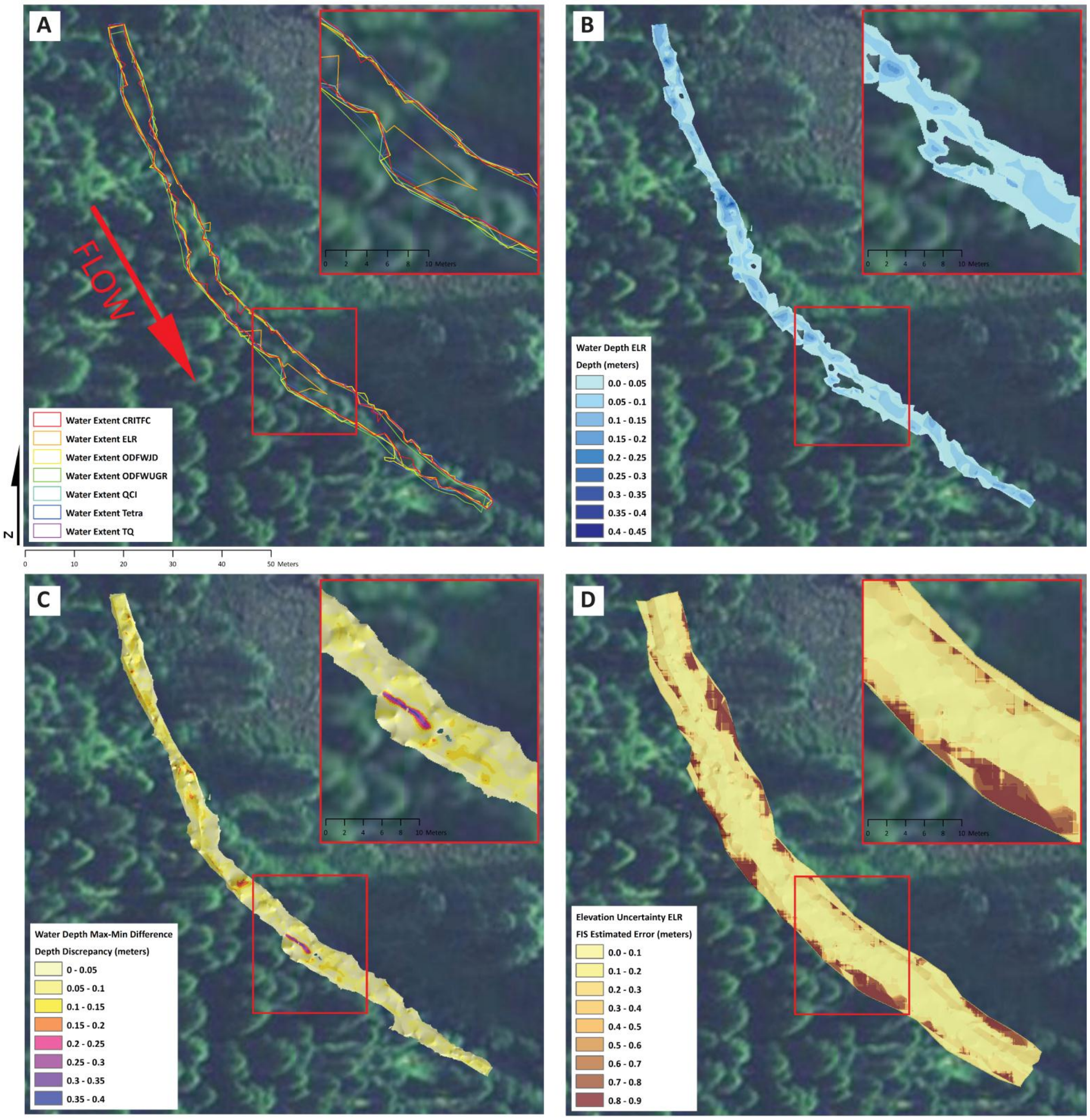




	DEM Maximum-Minimum Difference		
Survey Area Segretaion	Area (m^2)	Volume (m^3)	Volume (m^3) / Area (m^2)
Wetted	509	517	1.01
Dry	2186	1108	0.51
Discrepant	469	482	1.03

Figure 1B. CHaMP crew variability data for Fly Creek. Digital elevation model (DEM) generated from total station point data collected by ODFWUGR (A). The results of differencing the DEM maximum and minimum values, cell by cell, across all crews (B). Survey area segrgation (wetted, dry, discrepant) where wetted includes area that all crews surveyed as within the wetted channel, dry as the area that all crews surveyed outside of the wetted channel, and discrepant as the area that some crews surveyed as wet and some as dry. The pie chart shows these volumetric DEM max-min differences segregated by survey area (wetted, dry, discrepant). The table shows DEM maximum-minimum gross area, volume and normalized differences. Here, the normalized differences indicate the relatively substantial in-channel differences. These are a result of an incorrect total station instrument heigth recorded by one of the sampling crews.

SPRING CREEK SUMMARY



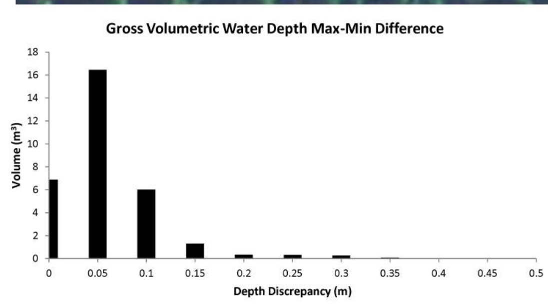
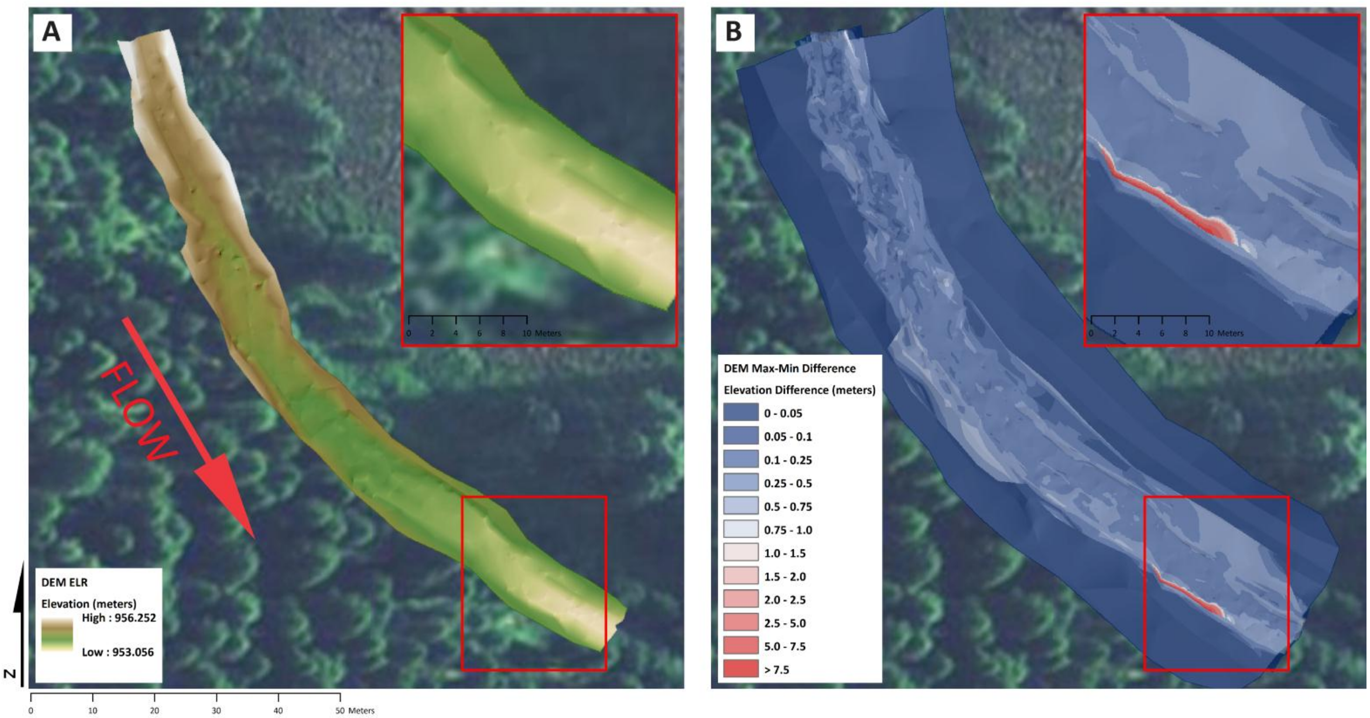
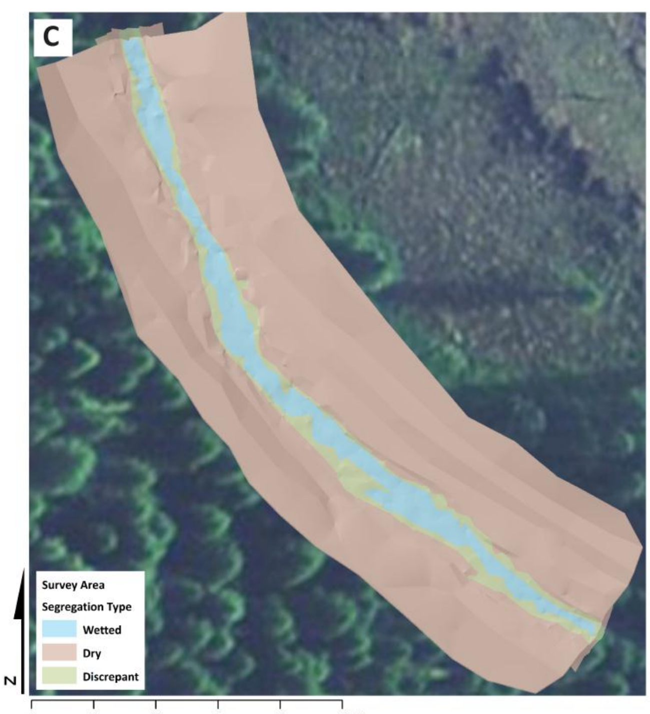
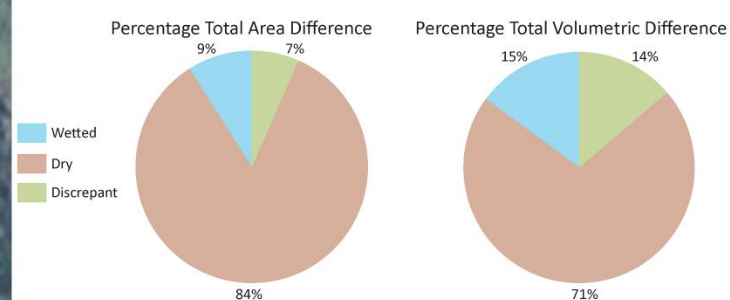


Figure 2A. CHaMP crew variability data for Spring Creek. Water extents (A) delineated for all 7 crews. Water depth maps derived from total station topography and edge of water boundary collected by ELR (B) and the water depth maximum-minimum difference, cell by cell, for all 7 crews (C). Gross volumetric water depth max-min difference histogram highlights the majority of volumetric differency is attributed to water depth discrepancy equal to or less than 10 cm. Results of spatially variable elevation uncertainty analysis for the ELR crew DEM (D) which was derived using a Fuzzy Inference System (FIS).



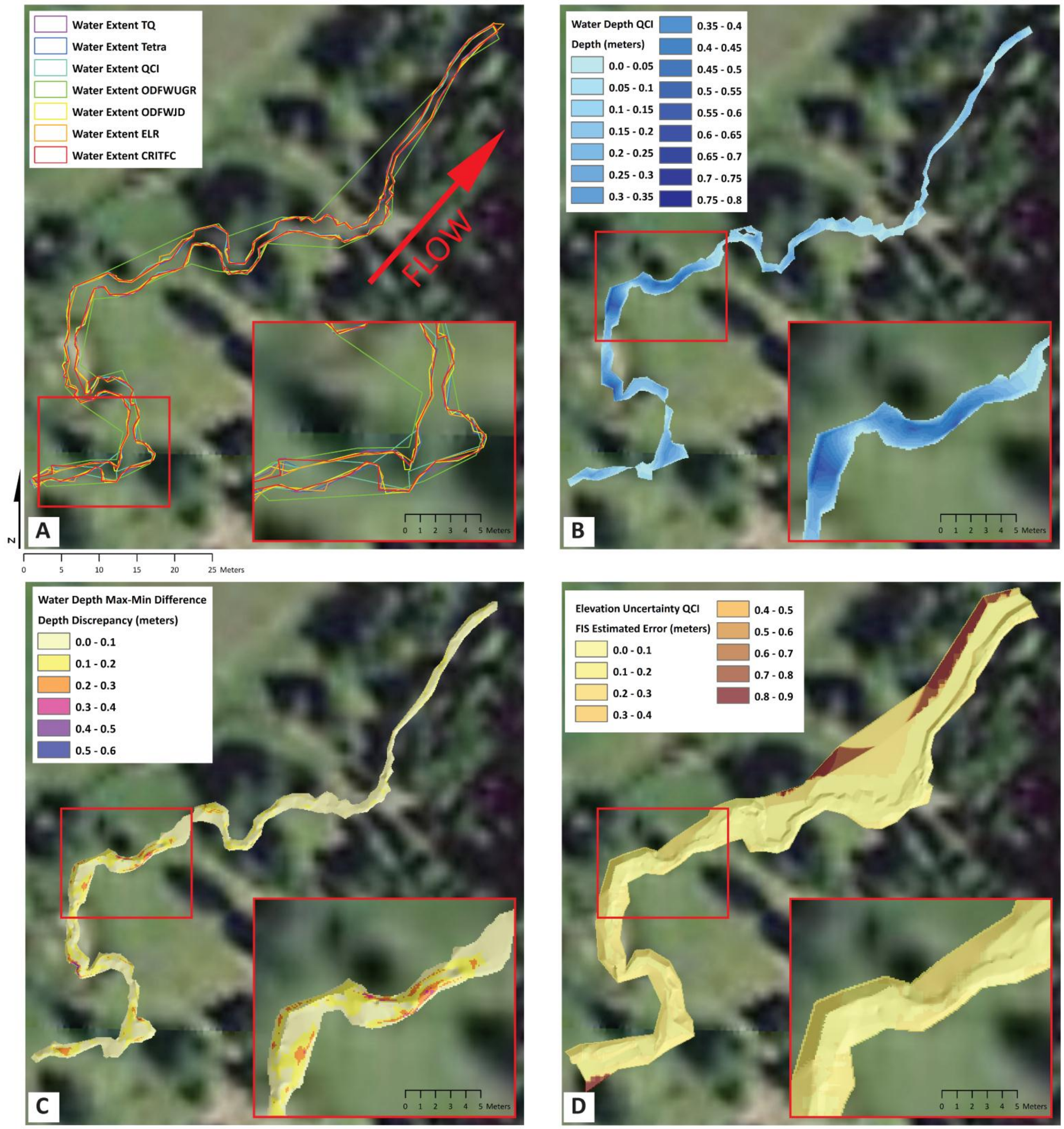




Survey Area Segretaion	DEM Maximum-Minimum Difference Area (m^2)	Volume (m^3)	Volume (m^3)/Area (m^2)
Wetted	369	58	0.16
Dry	3454	279	0.08
Discrepant	269	54	0.20

Figure 2B. CHaMP crew variability data for Spring Creek. Digital elevation model (DEM) generated from total station point data collected by ELR (A). The results of differencing the DEM maximum and minimum values, cell by cell, across all crews (B). Survey area segrgation (C; wetted, dry, discrepant) where wetted includes area that all crews surveyed as within the wetted channel, dry as the area that all crews surveyed outside of the wetted channel, and discrepant as the area that some crews surveyed as wet and some as dry. The pie chart shows these volumetric DEM max-min differences segregated by survey area (wetted, dry, discrepant). The table shows DEM maximum-minimum gross area, volume and normalized differences.

WEST CHICKEN CREEK SUMMARY



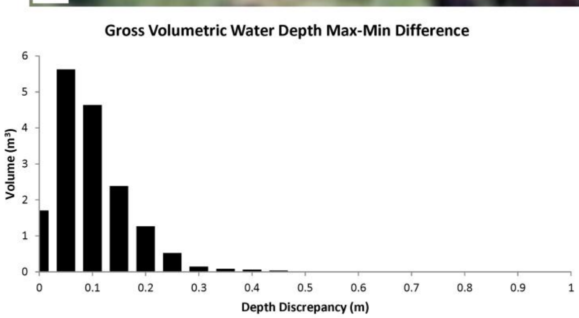
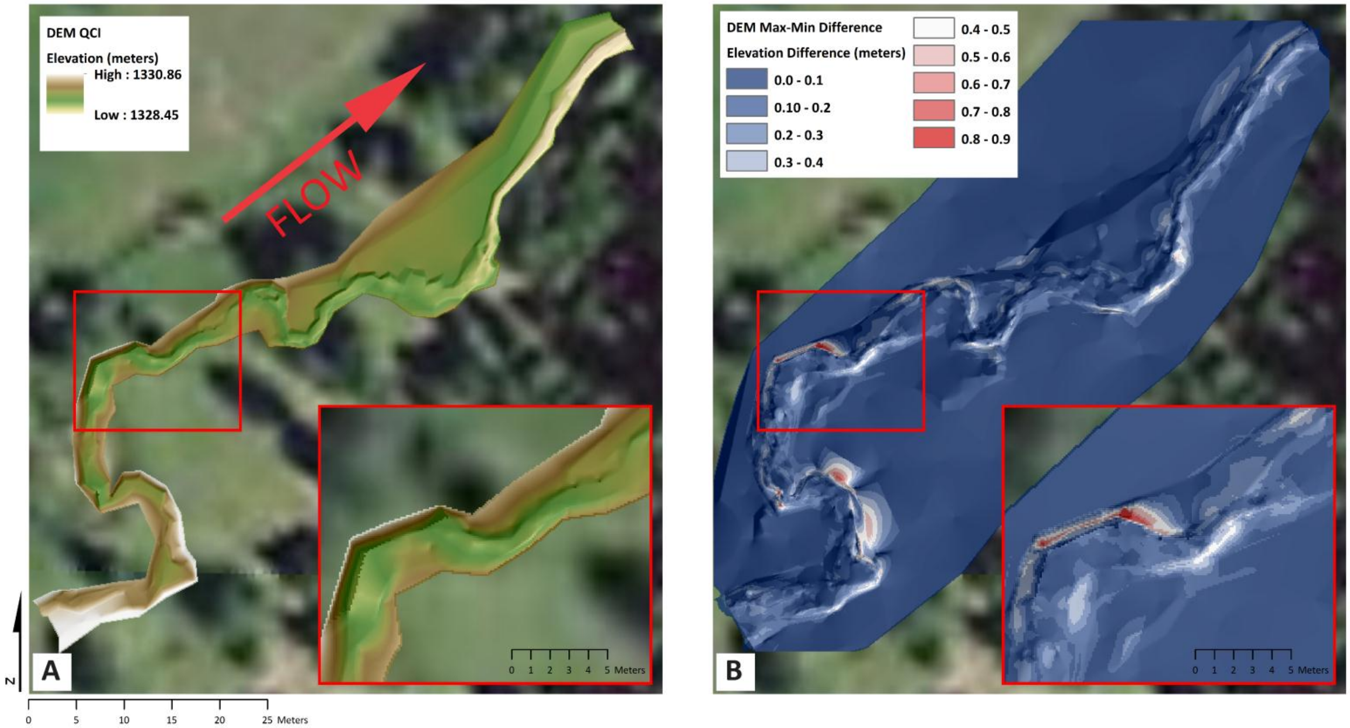
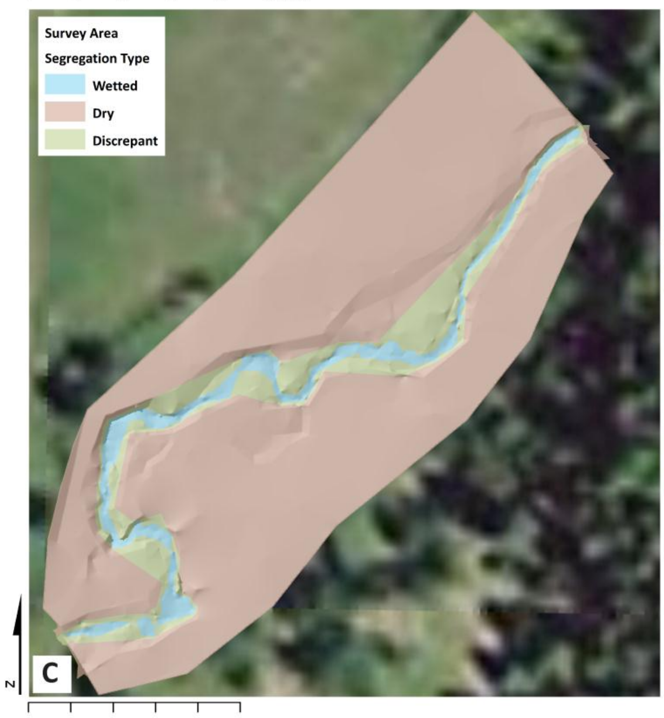
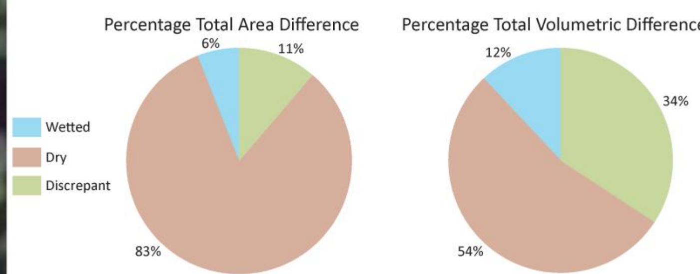


Figure 3A. CHaMP crew variability data for West Chicken Creek. Water extents (A) delineated for all 7 crews. Water depth maps derived from total station topography and edge of water boundary collected by QCI (B) and the water depth maximum-minimum difference, cell by cell, for all 7 crews (C). Gross volumetric water depth max-min difference histogram highlights the majority of volumetric differency is attributed to water depth discrepancy equal to or less than 20 cm. Results of spatially variable elevation uncertainty analysis for the QCI crew DEM (D) which was derived using a Fuzzy Inference System (FIS).



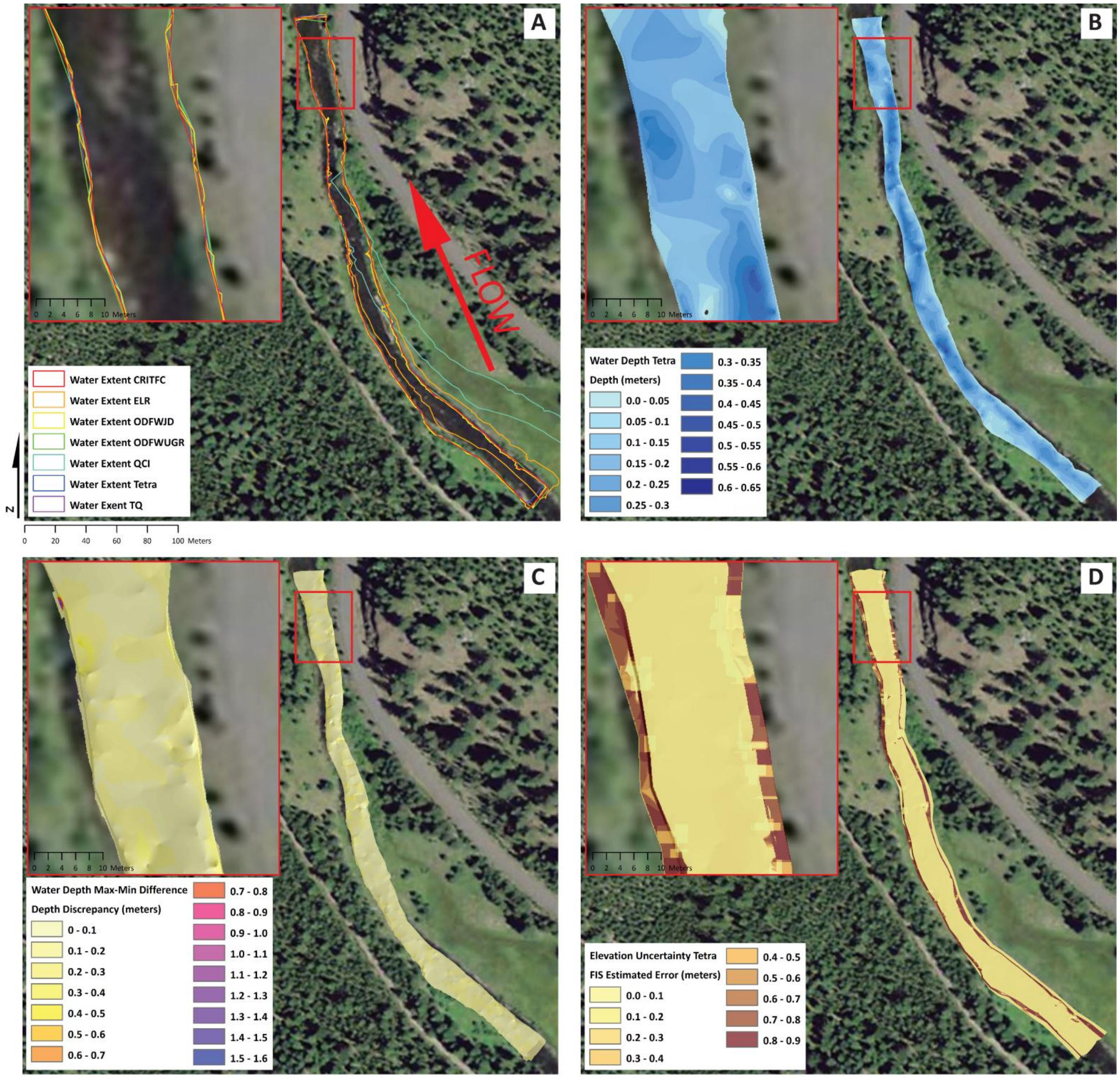




	DEM Maximum-Minimum Difference		
Survey Area Segretaion	Area (m^2)	Volume (m^3)	Volume (m^3)/Area (m^2)
Wetted	138	14	0.10
Dry	1895	64	0.03
Discrepant	258	41	0.16

Figure 3B. CHaMP crew variability data for West Chicken Creek. Digital elevation model (DEM) generated from total station point data collected by QCI (A). The results of differencing the DEM maximum and minimum values, cell by cell, across all crews (B). Survey area segrgation (C; wetted, dry, discrepant) where wetted includes area that all crews surveyed as within the wetted channel, dry as the area that all crews surveyed outside of the wetted channel, and discrepant as the area that some crews surveyed as wet and some as dry. The pie chart shows these volumetric DEM max-min differences segregated by survey area (wetted, dry, discrepant). The table shows DEM maximum-minimum gross area, volume and normalized differences.

UPPER GRANDE RONDE SUMMARY



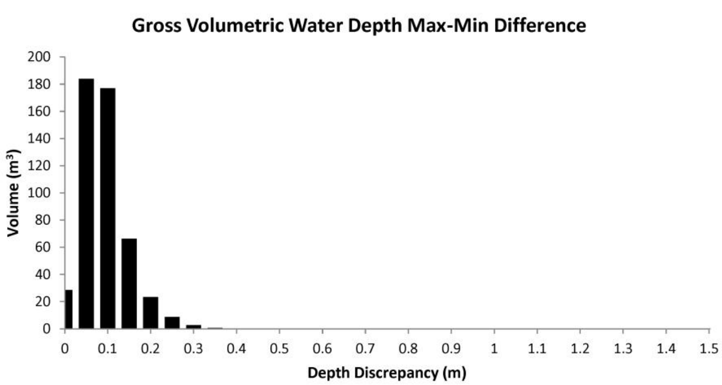
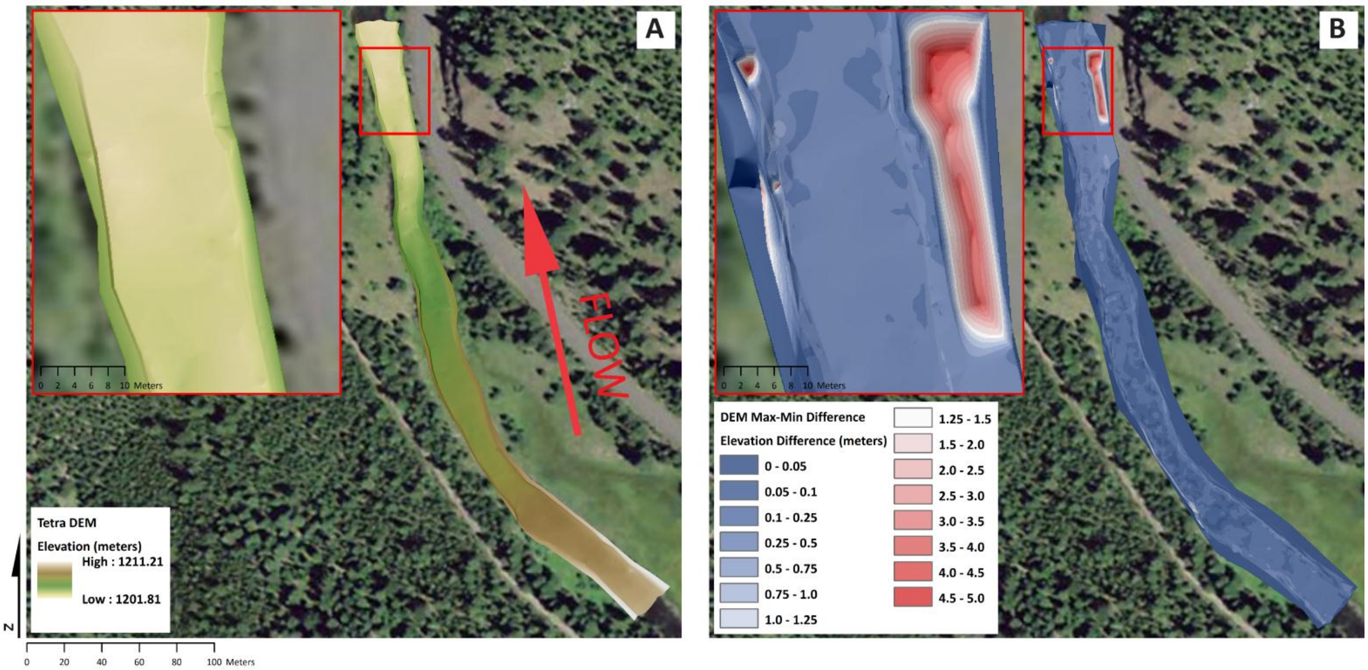
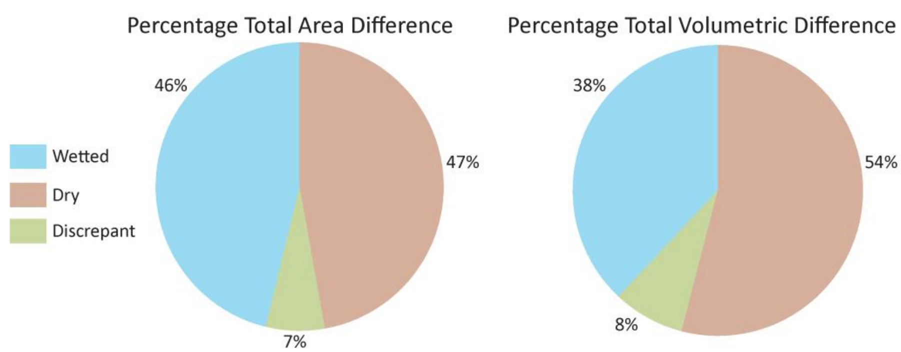


Figure 4A. CHaMP crew variability data for Grande Ronde River upper site. Water extents (A) delineated for all 7 crews. Water depth maps derived from total station topography and edge of water boundary collected by Tetra (B) and the water depth maximum-minimum difference, cell by cell, for 5 crews (C). QCI and ELR were removed from the DEM cell stats intercomparison due to rotation in upstream portion of their respective DEMs. Gross volumetric water depth max-min difference histogram highlights the majority of volumetric difference is attributed to water depth discrepancy equal to or less than 10 cm. Results of spatially variable elevation uncertainty analysis for the Tetra crew DEM (D) which was derived using a Fuzzy Inference System (FIS).

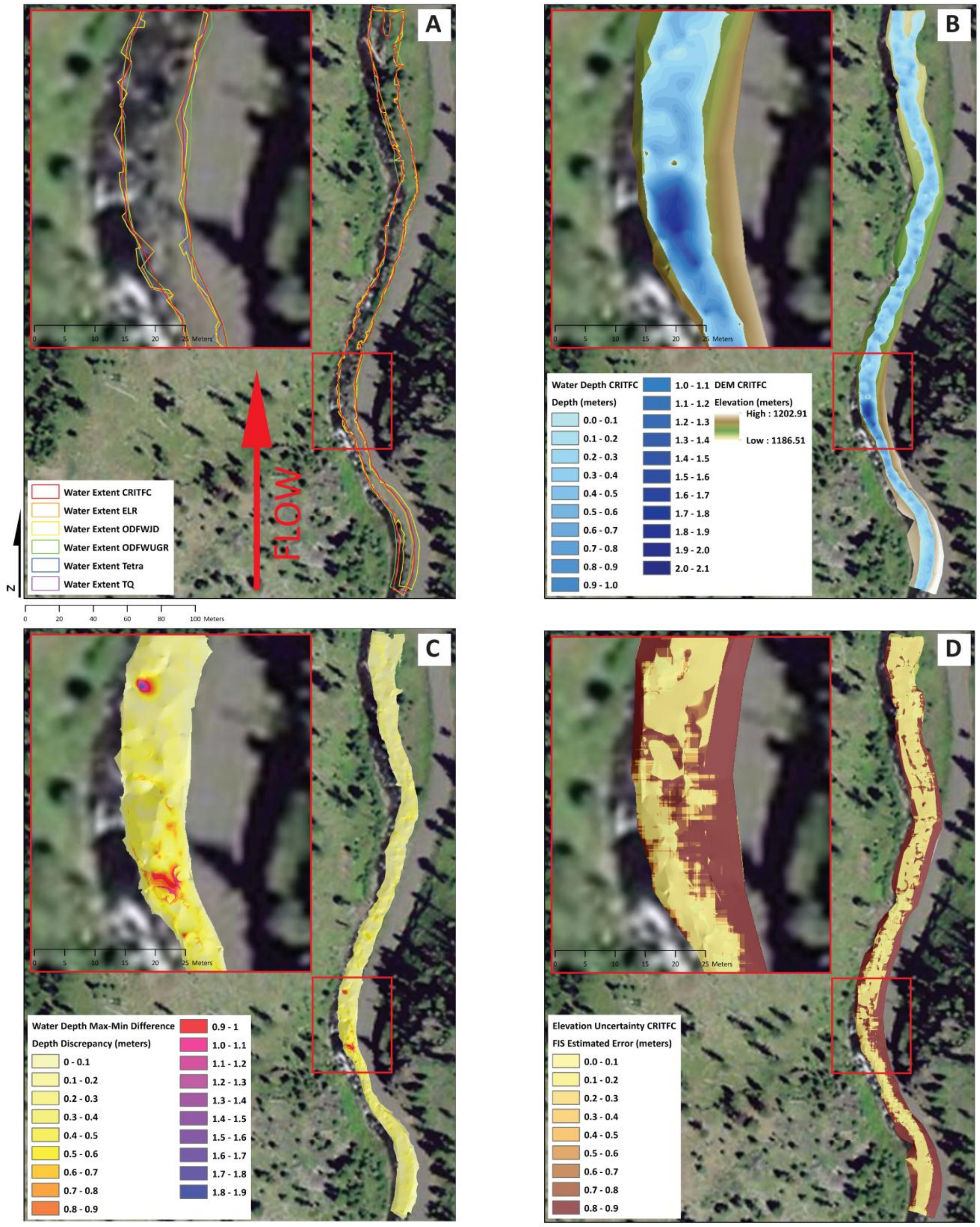




Survey Area Segretaion	DEM Maximum-Minimum Difference Area (m^2)	Volume (m^3)	Volume (m^3)/Area (m^2)
Wetted	2820	896	0.32
Dry	6302	2261	0.36
Discrepant	1313	892	0.68

Figure 4B. CHaMP crew variability data for Grande Ronde River upper site. Digital elevation model (DEM) generated from total station point data collected by Tetra (A). The results of differencing the DEM maximum and minimum values, cell by cell, 5 crews (B). QCI and ELR were removed from DEM cell stats intercomprison due to rotation of both crews DEMs in the US portion fo the survey. The rotation in the QCI DEM is attributed to an exceedingly high backsight check error that was accepted by the crew memeber operating the total station base unit partway through the survey. The reason for the ELR crew DEM misalignment could not be easily identified. Survey area segrgation (C; wetted, dry, discrepant) where wetted includes area that all crews surveyed as within the wetted channel, dry as the area that all crews surveyed outside of the wetted channel, and discrepant as the area that some crews surveyed as wet and some as dry. The pie chart shows these volumetric DEM max-min differences segregated by survey area (wetted, dry, discrepant). The table shows DEM maximum-minimum gross area, volume and normalized differences.

MIDDLE GRANDE RONDE SUMMARY



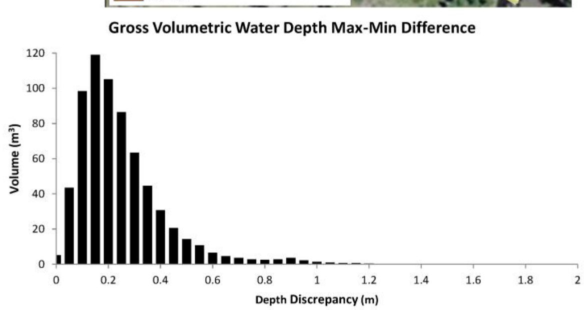
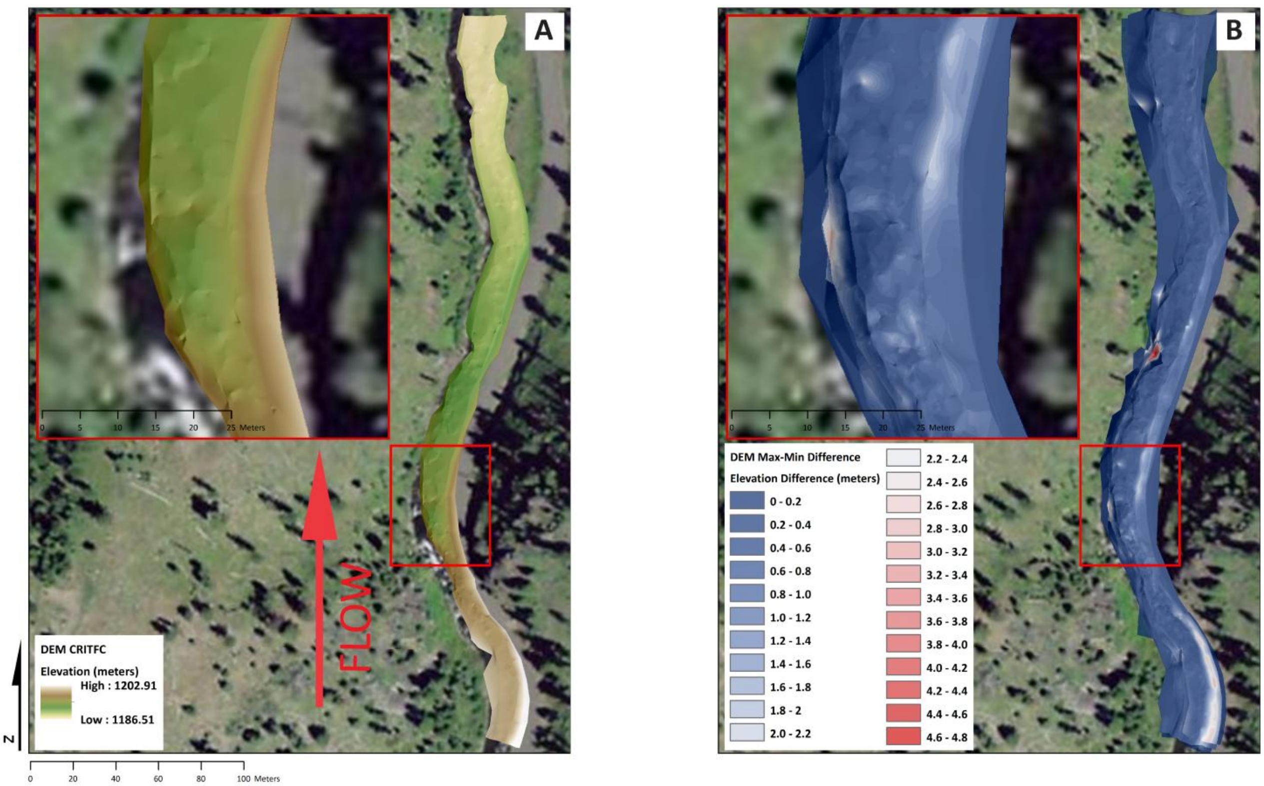
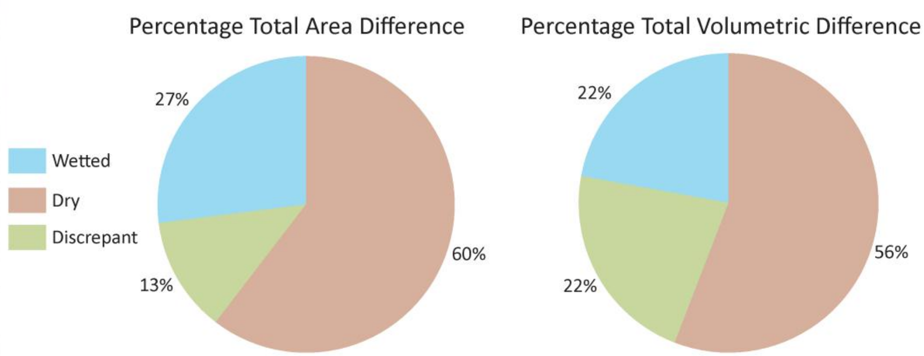


Figure 5A. CHaMP crew variability data for Grande Ronde River middle site. Water extents (A) delineated by 6 different crews with QCI removed due to transformation error. Water depth maps derived from total station topography and edge of water boundary collected by CRITFC (B) and the water depth maximum-minimum difference, cell by cell, for the 6 crews with QCI omitted (C). Gross volumetric water depth max-min difference histogram highlights the majority of volumetric differency is attributed to water depth discrepancy equal to or less than 20 cm. Results of spatially variable elevation uncertainty analysis for the CRITFC crew DEM (D) which was derived using a Fuzzy Inference System (FIS).

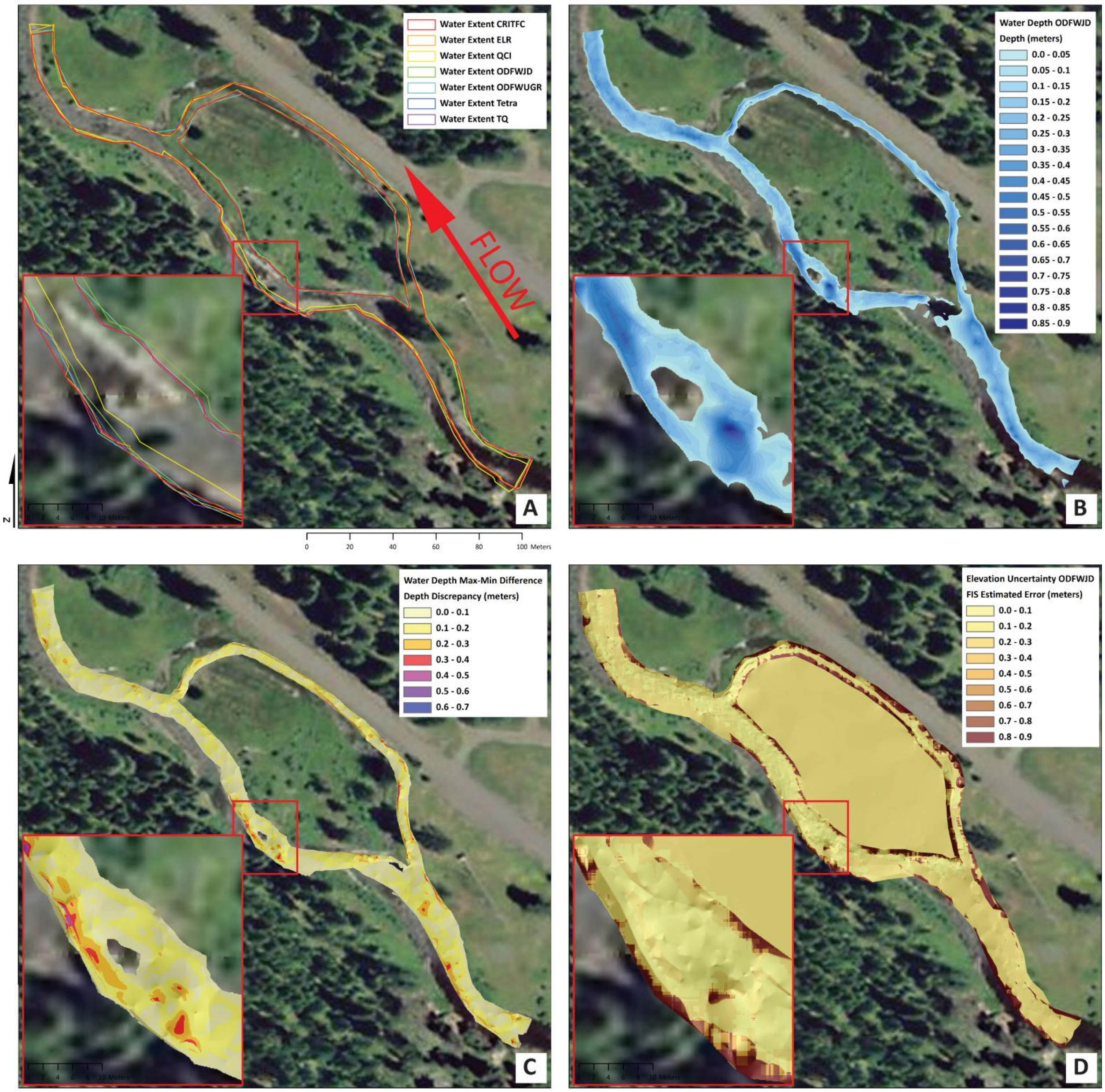




	DEM Maximum-Minimum Difference		
Survey Area Segretaion	Area (m^2)	Volume (m^3)	Volume (m^3)/Area (m^2)
Wetted	2820	896	0.32
Dry	6302	2261	0.36
Discrepant	1313	892	0.68

Figure 5B. CHaMP crew variability data for Grande Ronde River middle site. Digital elevation model (DEM) generated from total station point data collected by CRITFC (A). The results of differencing the DEM maximum and minimum values, cell by cell, across all crews (B). Survey area segrgation (wetted, dry, discrepant) where wetted includes area that all crews surveyed as within the wetted channel, dry as the area that all crews surveyed outside of the wetted channel, and discrepant as the area that some crews surveyed as wet and some as dry. The pie chart shows these volumetric DEM max-min differences segregated by survey area (wetted, dry, discrepant). The table shows DEM maximum-minimum gross area, volume and normalized differences.

LOWER GRANDE RONDE SUMMARY



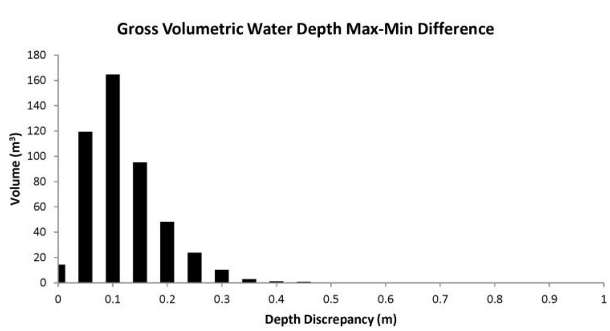
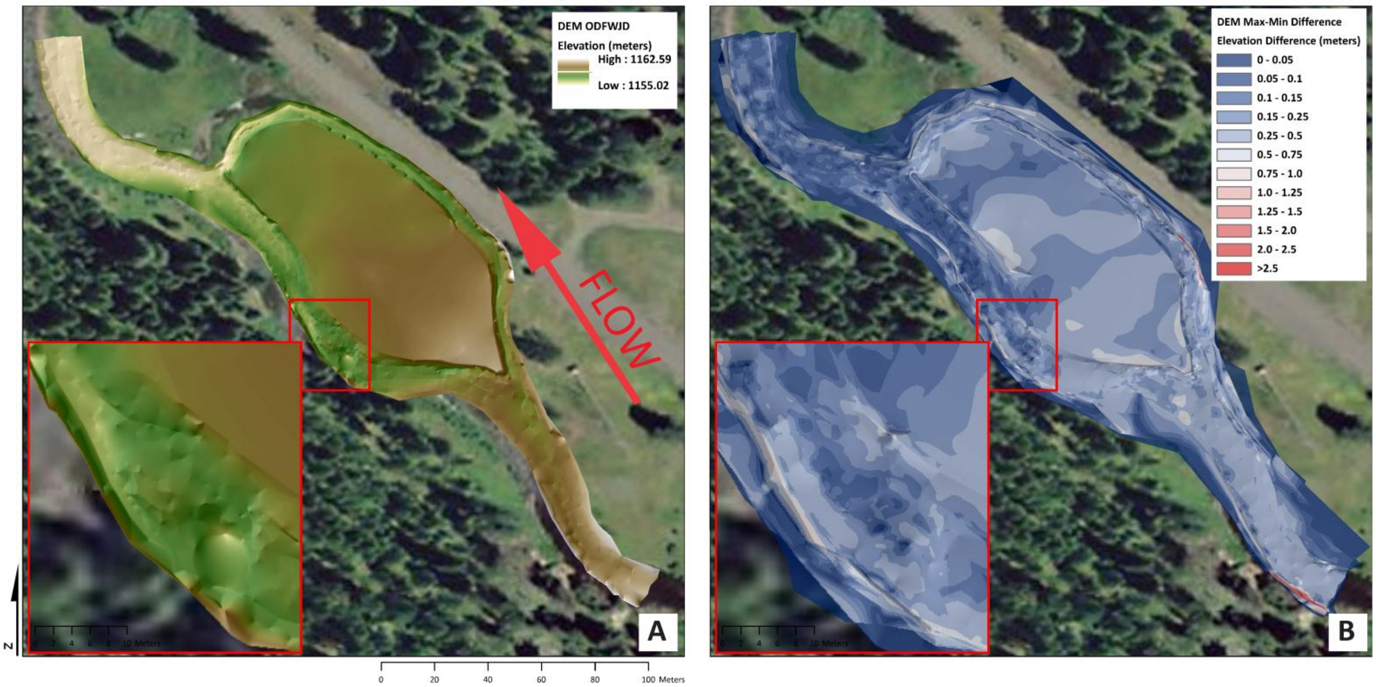
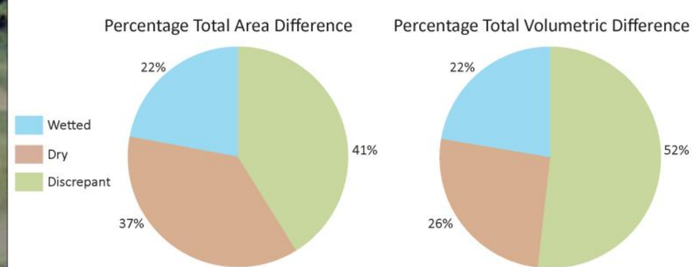


Figure 6A. CHaMP crew variability data for Grande Ronde River lower site. Water extents (A) delineated for all 7 crews. Water depth maps derived from total station topography and edge of water boundary collected by ODFWJD (B) and the water depth maximum-minimum difference, cell by cell, for 6 crews (C). The QCI crew was omitted from the DEM intercomparison due to a survey blunder which resulted in a shift in the upstream portion fo the survey area. Gross volumetric water depth max-min difference histogram highlights the majority of volumetric differenc is attributed to water depth discrepancy equal to or less than 20 cm. Results of spatially variable elevation uncertainty analysis for the ODFWJD crew DEM (D) which was derived using a Fuzzy Inference System (FIS).





	DEM Maximum-Minimum Difference		
Survey Area Segretaion	Area (m^2)	Volume (m^3)	Volume (m^3)/Area (m^2)
Wetted	3600	847	0.24
Dry	6010	982	0.16
Discrepant	6715	1964	0.29

Figure 6B. CHaMP crew variability data for Grande Ronde River lower site. Digital elevation model (DEM) generated from total station point data collected by ODFWJD (A). The results of differencing the DEM maximum and minimum values, cell by cell, across 6 crews (B). Here the QCI crew was removed from DEM intercomparisons due to a survey blunder that resulted in a shift in the upstream portion of the survey. Survey area segrgation (C; wetted, dry, discrepant) where wetted includes area that all crews surveyed as within the wetted channel, dry as the area that all crews surveyed outside of the wetted channel, and discrepant as the area that some crews surveyed as wet and some as dry. The pie chart shows these volumetric DEM max-min differences segregated by survey area (wetted, dry, discrepant). The table shows DEM maximum-minimum gross area, volume and normalized differences.

APPENDIX B – SURVEY AND POST-PROCESSING ISSUE COMMENTS

BACKGROUND

This appendix is a compilation of comments on survey and post-processing issues that were identified in the course of analyzing data for the CHaMP crew variability report. Survey and post-processing issues were categorized as blunders, red flags or weaknesses. Blunders were defined as flat out mistakes (e.g. incorrect rod height), red flags as actions that did not make sense (e.g. benchmark in wetted channel) and weaknesses as factors that could be improved (e.g. TIN editing). The appendix is organized by survey and post-processing issues. For each issue we: identified the site, the responsible crew, defined the type of problem (e.g. survey blunder), provided a detailed description of what we inferred may have been the cause of the blunder, commented on the resolution in the analysis, made recommendations on how to limit the occurrence of the problem and assessed the frequency of the issue.

SUMMARY OF FINDINGS

Blunders, red flags and weaknesses were identified using DEM and water depth maximum-minimum difference rasters and supporting ancillary data (e.g. TINs, total station job raw files). Due to time constraints we did not trace the source of each individual observed difference between crews, but instead chose to comment on the most obvious sources of error that we believe should have been detected by either the crew or the QA/QC lead. Incidences of twenty-two major systematic survey blunders or errors were found (Table 1). As many of the same blunders were made by more than one crew, we elected to describe in detail a total of twelve major issues encountered. Of those, nine were associated with problems in the field during surveying, and three resulted during post-processing. Encouragingly, most observed errors are easy to fix post-hoc (e.g. TIN bust). However some survey errors, such as excessive error in backsight checks, are difficult or nearly impossible to remedy post-hoc and could compromise an entire survey. Yet with clearer guidance and training, all observed blunders detailed in this appendix should be easy to avoid in subsequent sampling years.

			Crew							
			CRITFC	ELR	ODFWJD	ODFWUGR	QCI	Tetra	TQ	Total
Survey Problems	Red Flags	Benchmarks in wetted channel	-	-	-	1	-	-	-	1
		Control points in wetted channel	1	1	1	1	1	1	1	7
		Excessive error in BS check	-	-	-	-	2	-	-	2
	Blunders	Incorrect rod height	-	-	2	1	-	-	-	3
		Incorrect Total Station base height	-	1	-	-	-	-	-	1
Post-processing Problems	Blunders	Mistakes when connecting EW points	-	-	-	1	1	-	-	2
		Missed large TIN busts in edits	-	-	2	1	-	-	-	3
	Weaknesses	Did not clip out islands > BF	-	1	-	-	1	1	-	3

Easy to Remedy
Difficult/Impossible to Remedy

Table 1. Summary of observed survey and post-processing issues

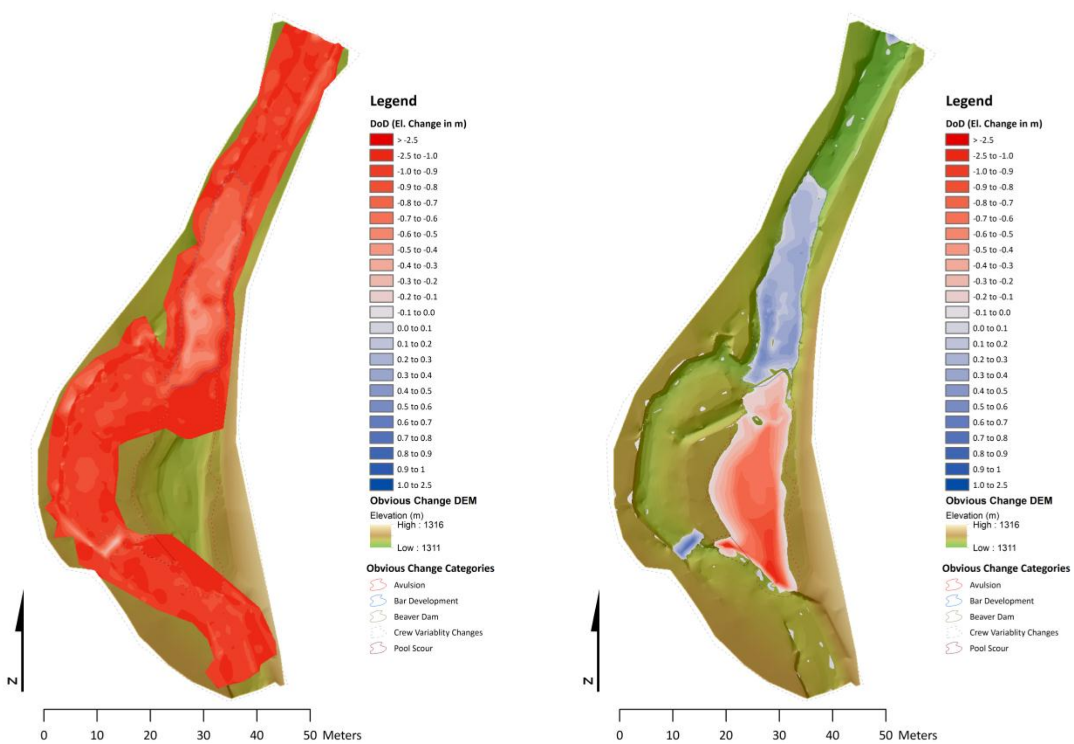
SPECIFIC SURVEY PROBLEMS IDENTIFIED

FLY CREEK DSGN-000094

CREW: ELR

PROBLEM: Survey Blunder

DESCRIPTION: ELR DEM elevations range from 1312.2 to 1315.8 meters while DEMs generated by all other crews range in elevation from 1311.2 to 1314.7 meters. This reach wide, roughly 1 meter elevation discrepancy and the fact the crew completed the entire survey from a single control point indicates the ELR crew may have recorded an incorrect total station instrument height.



The giveaway of the datum offset problem is clear in the DEM of Difference (DoD) above, which shows an entirely degradational signal for the ELR survey (left), when all other surveys showed both a depositional and erosional signal (right). Refer to the main text and Figure 17 for details of this example.

DATASET: SFR Geodatabase

RESOLUTION IN ANALYSIS: None

RECOMMENDATION: Have crews write down instrument height and station coordinate values in a field notebook and as part of Foresight QA/QC back in the office, double check that instrument heights and control point coordinates agree. This will hopefully reinforce double-checking instrument heights.

ASSESSMENT: Rare issue

SPRING CREEK DSGN4-000092

CREW: ODFWUGR

PROBLEM: Survey Red Flag

DESCRIPTION: Benchmark placed in middle of wetted channel. From what we can infer from topography and aerial imagery, this benchmark was not placed on a vegetated island or a stable boulder, but in the middle of the wetted channel. The wetted channel, vegetated islands and stable boulders are not ideal benchmark locations.

DATASET: SFR Geodatabase

RESOLUTION IN ANALYSIS: None

RECOMMENDATION: Benchmarks should always be placed outside the active flood zone in stable areas. This specific benchmark should be replaced. Clearer guidance in the both the protocol and crew training should be provided on placement of benchmarks.

ASSESSMENT: Rare issue and easy to fix during a revisit to the site. Did not appear to influence quality of data in this survey, but could limit ability to reoccupy the site at a later date.

SPRING CREEK DSGN4-000092

CREW: ALL

PROBLEM: Survey Red Flag

DESCRIPTION: Multiple control points in wetted channel. This reach was obviously difficult to traverse and survey due to the riparian vegetation.

DATASET: SFR Geodatabase

RESOLUTION IN ANALYSIS: None

RECOMMENDATION: May or may not be of concern. This sample reach was relatively brushy with vegetation extending across the wetted channel. The presence of dense vegetation increases the difficulty of identifying total station control set-up locations with adequate line of sight while also minimizing the number of overall set-ups needed to complete a survey. Yet placing control points in the wetted channel, rather than on the bank, introduces higher risk of the total station becoming unlevel (e.g. the tripod becoming un-level due to movement of substrate on the bed). More emphasis should be placed in protocol and in crew training on the potential downsides and risks of setting up in the channel, and how to mitigate for these (e.g. frequent backsight checks and exercising extra caution).

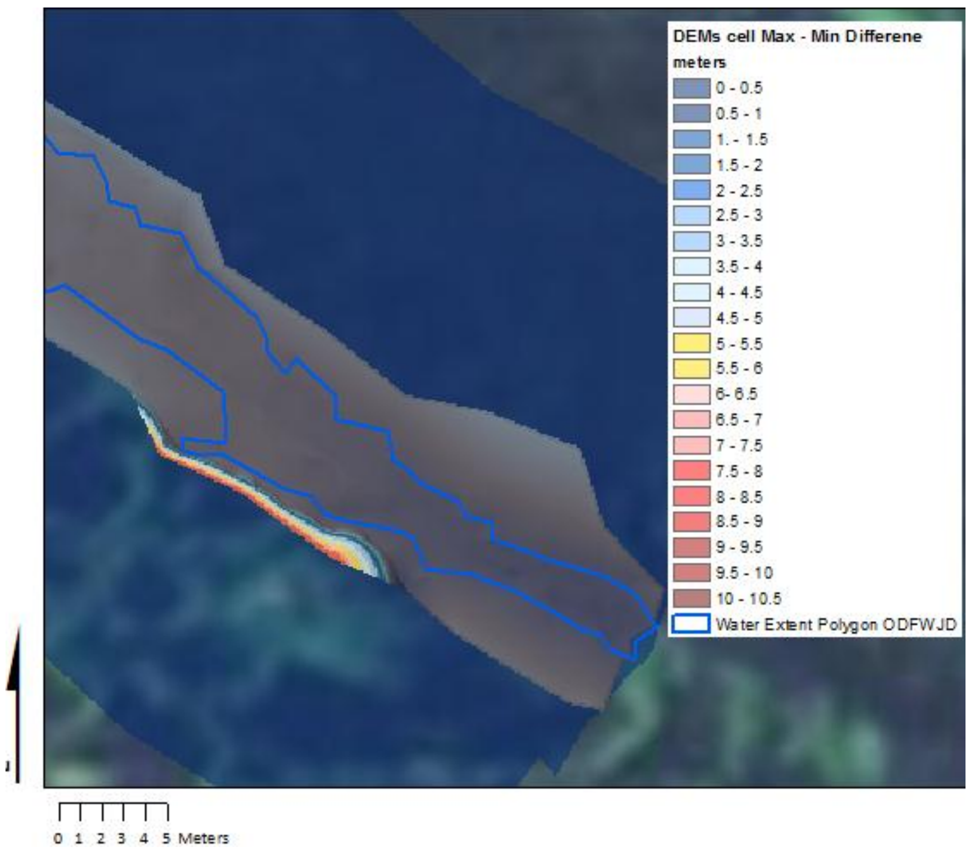
ASSESSMENT: Recurring problem for site

SPRING CREEK   DSGN4-000092

CREW: ODFWJD

PROBLEM: Survey Blunder

DESCRIPTION: Incorrect rod height on river right bank (approx. 2 meter from edge of water) resulting in a maximum observed difference of approximately 10.5 meters between the ODFWJD's DEM and DEMs generated by other crews (see below).



DATASET: SFR Geodatabase

RESOLUTION IN ANALYSIS: None

RECOMMENDATION: Crews should be instructed to invest ample time editing TINs. When a crew spends an entire day at a site they should be able to detect survey point blunders in the TIN (here a steep 9 meter elevation rise directly adjacent to the water's edge). To make such busts easier to detect crews should increase the number of classes in the TIN elevation symbology to a minimum of 15 classes.

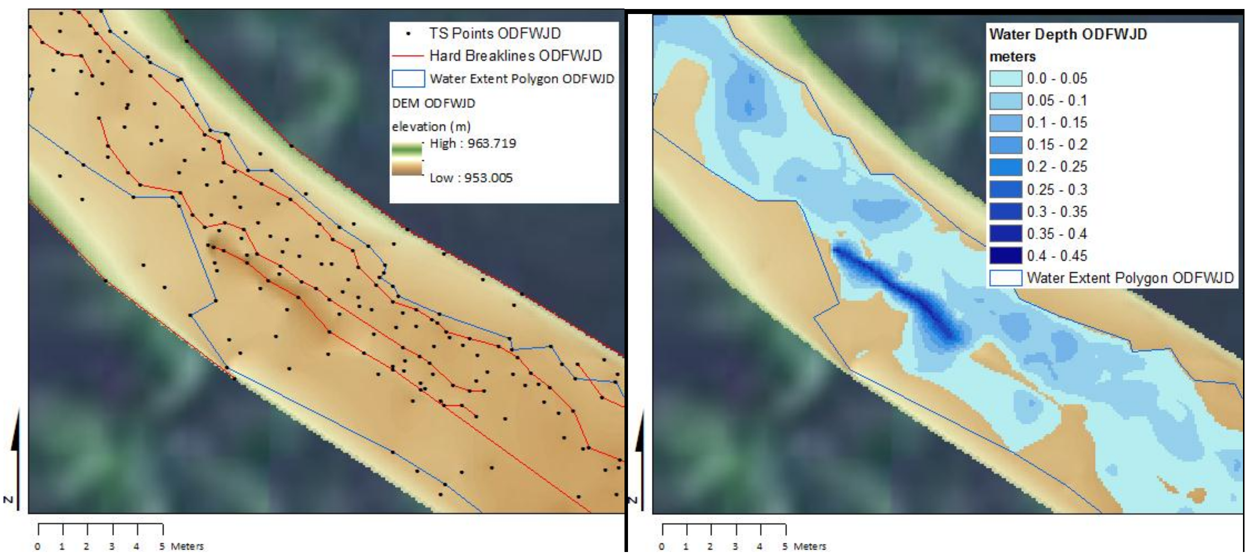
ASSESSMENT: Recurring problem for site

SPRING CREEK DSGN4-000092

CREW: ODFWJD

PROBLEM: Survey Blunder

DESCRIPTION: It appears that an elevation bust in middle of channel caused either by an incorrect rod height or a poorly placed breakline (see figure below). It is difficult to be certain with the available information. The breakline defined in the elevation bust is coded 'bl' so it is difficult to know what topographic feature the breakline was meant to capture. While this bust did not lead to a large overall elevation difference when compared with DEMs generated by other crews (local maximum difference of approx. 0.29 m), the water depth map highlights how elevation busts can propagate to topographically derived metrics. Here, these busts result in a small concave depression (i.e. a pool) not present in water depth maps created by any other crew. It should be noted the discrepancy could have resulted from the ODFWJD crew choosing to capture a topographic feature they found interesting that was not detailed by other crews.



DATASET: SFR Geodatabase

RESOLUTION IN ANALYSIS: None

RECOMMENDATION: Remind crews when breaklines are and are not pertinent. If crews are collecting breaklines coded 'bl' may want to include a 'comment' field that allows them to note what topographic feature they are capturing that it is not summarized by other available codes (e.g. edge of bar).

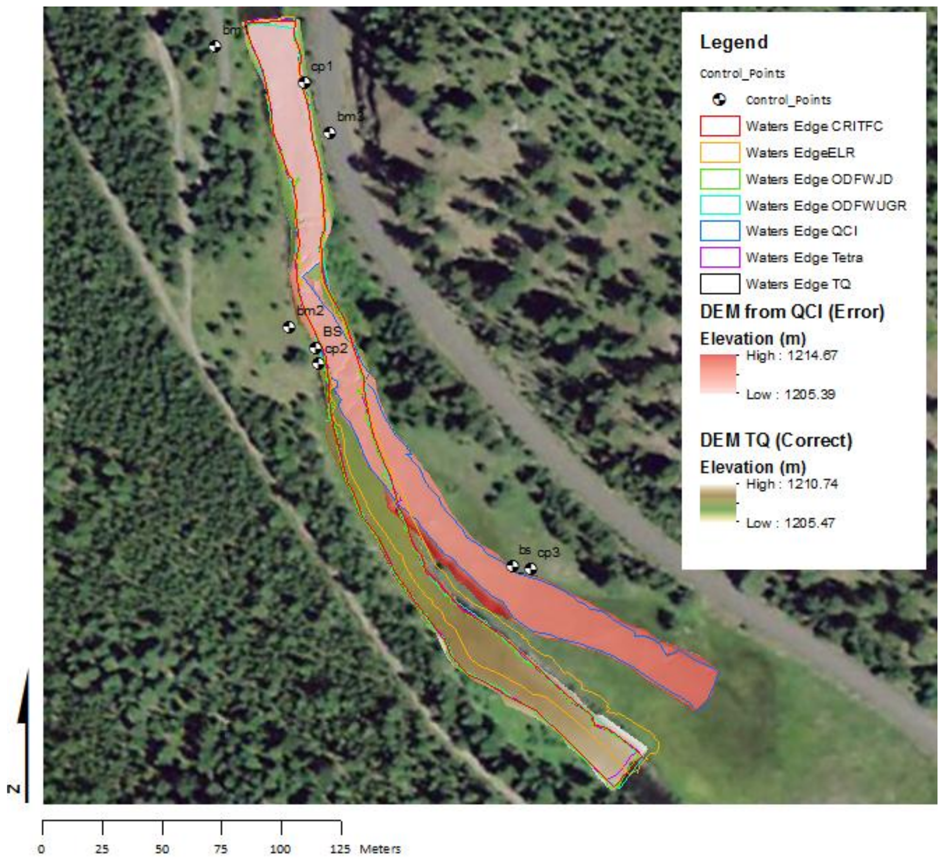
ASSESSMENT: Recurring problem for all crews and sites. Localized elevation busts are a relatively common issue for all crews and sites. Yet not all elevation busts are as extensive as the one noted above and are not propagated through to water depth maps. Most elevation busts are the result of one 'bad' point and can be easily removed in TIN editing.

GRANDE RONDE RIVER UPPER DSGN4-000277

CREW: QCI

PROBLEM: Potential Survey Blunder

DESCRIPTION: It appears there was a blunder made by the crew where they accepted relatively high backsight check errors at 2 separate control points. As a result the bottom third of the site (which was surveyed first) is consistent with the other crews; whereas, the upper two-thirds of the site are inconsistent with the other crews (see discrepancy in figure below). Looking at the raw file (see table below) we hypothesize that at CP2 the initial backsight check error was in excess of that permitted in the CHaMP protocol (HD err=0.030m; VD err=0.015m). The crew member re-shot the backsight several times until they received what they thought was an acceptable level of error (HD err=0.022m; VD err=0.018m). But here the angular error was quite high and was likely not noticed by the crew. We infer this high angular error may have resulted in the substantial shift in the data of up to 30 meters. It appears that the crew also accepted a backsight check error in excess of that considered acceptable in the CHaMP protocol (HD err=0.033m; VD err=0.022m).



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--BS check 258 - 4:ZE86.534919,SD6.265901,HD err= 0.047167, VD err= 0.018084
--BS Circle check : angular err= 0.00017
--BS check 258 - 4:ZE86.542175,SD6.267001,HD err= 0.048319, VD err= 0.017156
--BS Circle check : angular err= 0.003488
--BS check 258 - 4:ZE86.512825,SD6.263001,HD err= 0.044038, VD err= 0.0222
--BS Circle check : angular err= 0.113271
--BS check 258 - 4:ZE86.54415,SD6.256801,HD err= 0.038166, VD err= 0.016007
--BS Circle check : angular err= 1.145166
--BS check 258 - 4:ZE86.53005,SD6.240401,HD err= 0.021624, VD err= 0.018175
--BS Circle check : angular err= 12.182452
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--BS Circle check : angular err= 0.000319
--BS check 569 - 570:ZE88.03545,SD7.596701,HD err= 0.034321, VD err= 0.027862
--BS Circle check : angular err= 1.421098
--BS check 569 - 570:ZE88.064088,SD7.595501,HD err= 0.033326, VD err= 0.021698
--BS Circle check : angular err= 0.590352
--Foresight Target:My Prism, HR:1.7 (1.7 + 0.0 Offset), Prism Const.:-30.0mm
--HR:1.7 (1.7 + 0.0 Offset)
```

DATASET: SFR Geodatabase

RESOLUTION IN ANALYSIS: None

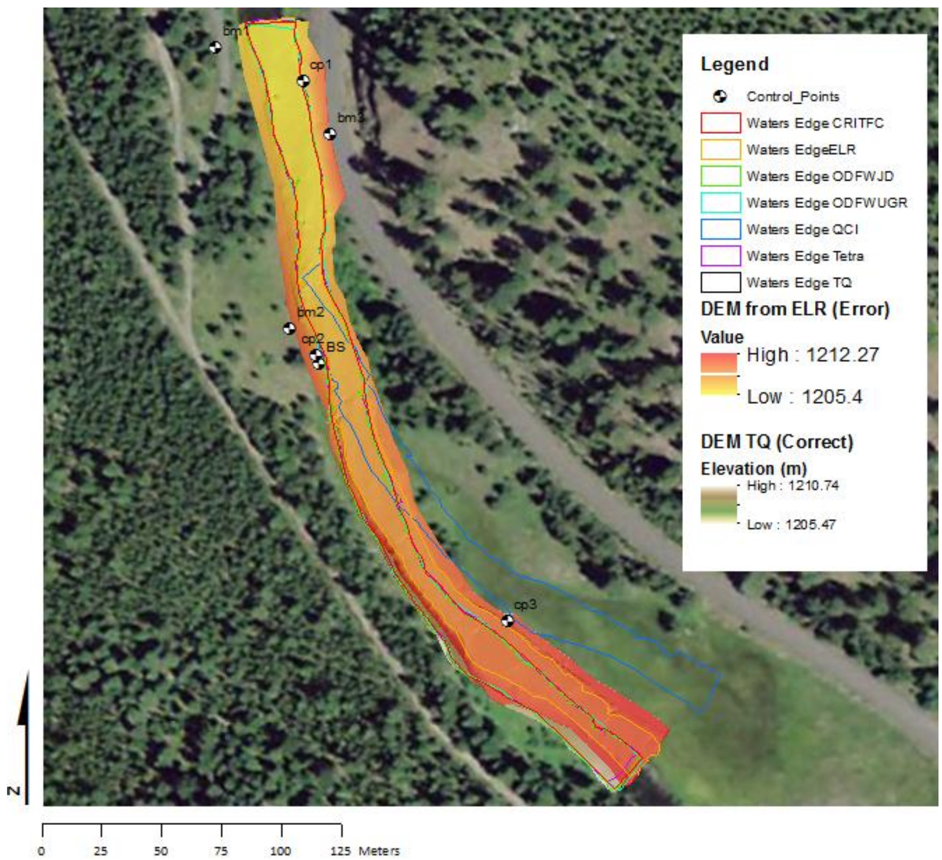
RECOMMENDATION: Such errors are extremely difficult, if no nearly impossible, to correct. All points surveyed from CP2 will have the positional and angular error propagated into them. Additionally, we do not know if the error is a result of instrument problems (e.g. sudden change in temperature), if it is a consequence of an occupation error of the instrument (e.g. total station not level or exactly over the control point) or an occupation error of the backsight (e.g. backsight prism not level or exactly over the point). In its current form, the CHaMP protocol does not spell out exactly how crews should troubleshoot or rectify repeated high backsight check error readings.

ASSESSMENT: Recurring problem for crew

CREW: ELR

PROBLEM: Potential Survey Blunder or Potential Post Processing Blunder

DESCRIPTION: It appears there was a blunder made either during the survey or during post-processing. The result is approximately the upper fifth of the site is inconsistent with the other crews (see discrepancy in figure below). The raw total station survey file was examined and we could not locate any erroneously high backsight checks such as that detailed above that led to the QCI data shift at this same site. Here, for the ELR crew, we were not able to identify the source of the data 'shift'. However, this is of concern as if a shift in the data were not identified by the crew or the QA/QC lead it could compromise future Geomorphic Change Detection time series comparisons.



DATASET: SFR Geodatabase

RESOLUTION IN ANALYSIS: None

RECOMMENDATION: None

ASSESSMENT: Rare issue

GRANDE RONDE RIVER UPPER DSGN4-000277

CREW: ODFWUGR

PROBLEM: Survey Red Flag

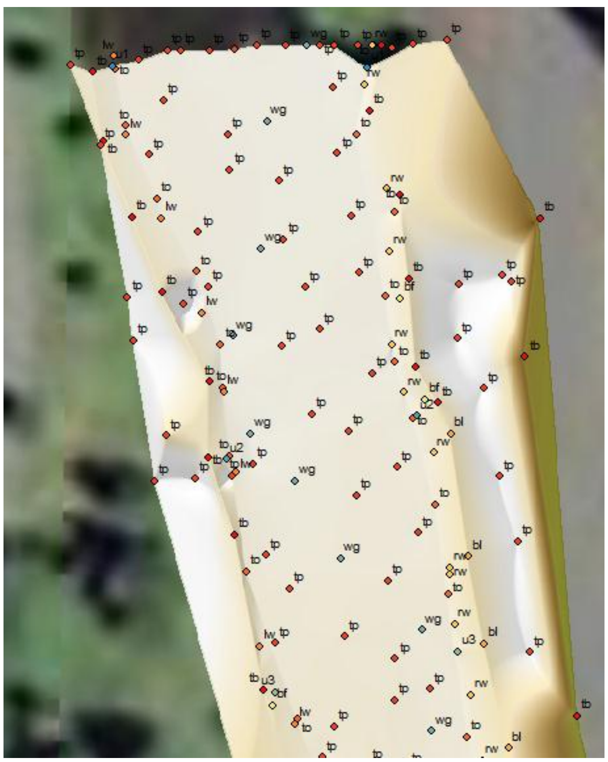
DESCRIPTION: Here we inferred that an incorrect rod height on out of channel topo points (tp) lead to TIN busts and incorrect DEM elevations. The river left in-channel bust resulted in an observed maximum depth of 3.62 meters. All other crews observed a maximum depth equal to or less than 0.6 meters (mean max depth = 0.5185, stdev = 0.04 m).

DATASET: SFR Geodatabase

RESOLUTION IN ANALYSIS: None

RECOMMENDATION: Crews need to use more caution when changing rod height. These busts should have been caught by crews when visually inspecting an editing data.

ASSESSMENT: Choose an item.

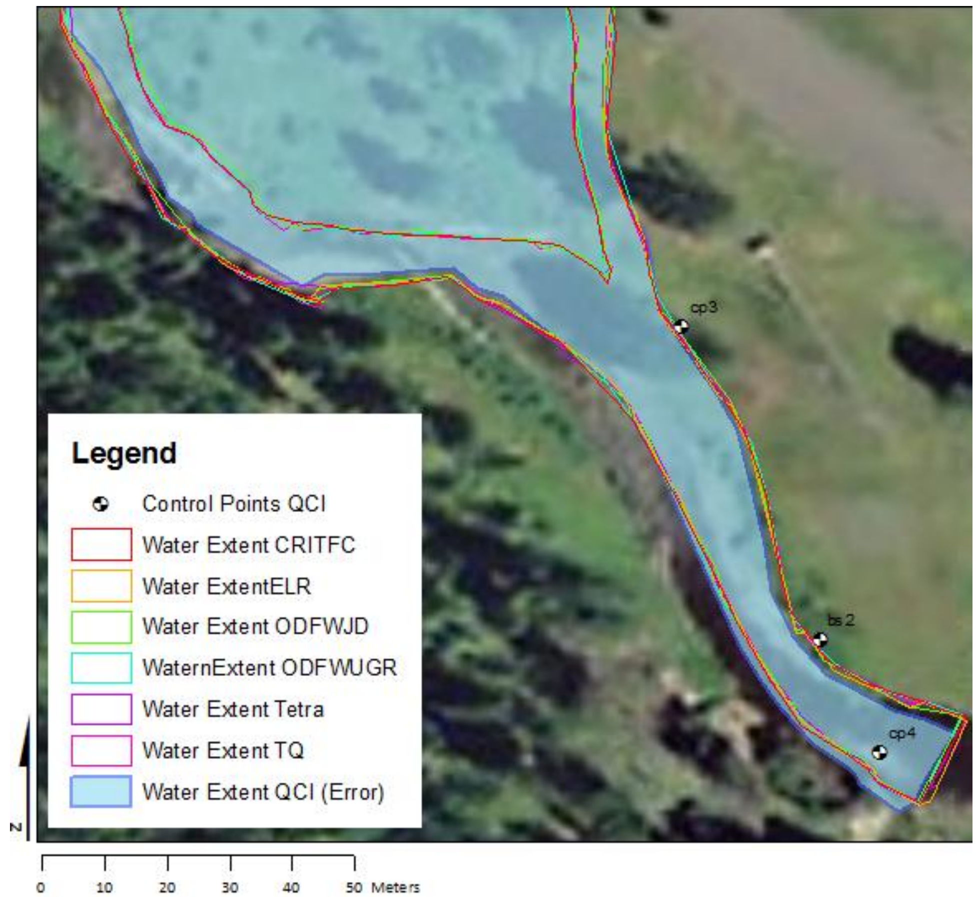


GRANDE RONDE RIVER LOWER CBW05583-235322

CREW: QCI

PROBLEM: Survey Red Flag

DESCRIPTION: When occupying CP3 and CP4 and performing the BS check the crew member operating the total station received error readings in excess of what is acceptable in the CHaMP protocol (i.e. max HD err=0.030 VD err=0.015). In both instances the crew member saw the error but either misread or disregarded it and began surveying in topography from the total station occupied control point. Another possibility is the crew member did not understand the reading of the backsight check, but this is unlikely as it is apparent they tried re-shoot the backlight multiple times before accepting the error reading (see tables below). While the backsight error reading from CP3 was not overly high, the backsight check horizontal error reading from CP4 was alarmingly high (HD err=0.297). As a result of accepting the backsight check errors approximately one-third of the surveyed topography is shifted relative to the other crews (see fig). The survey 'shift' translated into discrepancies in the water extent polygon and observed maximum elevation differences between crews.



```
OC,OP410,N 3094.182574,E 2136.487858,EL1001.397891,--cp3
--HR:3.7 (3.7 + 0.0 Offset)
LS,HI0.997,HR3.7
BK,OP410,BP411,BS86.552677,BC0.0000
--Fixed HR at Backsight:1.508 (1.508 + 0.0 Offset), Prism Const.:0.0mm
--BS check 410 - 411:ZE89.28025,SD54.812007,HD err= 0.06669, VD err= -0.015061
--BS Circle check : angular err= 0.000336
--BS check 410 - 411:ZE89.280856,SD54.791807,HD err= 0.046506, VD err= -0.016859
--BS Circle check : angular err= 1.472204
BK,OP410,BP411,BS86.552677,BC0.0000
--Fixed HR at Backsight:1.508 (1.508 + 0.0 Offset), Prism Const.:0.0mm
--BS check 410 - 411:ZE89.275419,SD54.784407,HD err= 0.039071, VD err= -0.01311
--BS Circle check : angular err= 0.000081
--BS check 410 - 411:ZE89.281756,SD54.772507,HD err= 0.027229, VD err= -0.019428
--BS Circle check : angular err= 0.000047
--BS check 410 - 411:ZE89.282863,SD54.767007,HD err= 0.021756, VD err= -0.022416
--BS Circle check : angular err= 1.530246
--Foresight Target:My Prism, HR:1.7 (1.7 + 0.0 Offset), Prism Const.:-30.0mm
--HR:1.7 (1.7 + 0.0 Offset)
LS,HI0.997,HR1.7
SS,OP410,FP412,AR178.35043,ZE89.311131,SD38.650705,--tb
SS,OP410,FP413,AR179.180347,ZE90.155519,SD38.756005,--lw
```

```
OC,OP649,N 3099.854808,E 2211.4409,EL1001.539428,--cp4
--HR:1.7 (1.7 + 0.0 Offset)
LS,HI1.468,HR1.7
BK,OP649,BP411,BS262.192367,BC0.0000
--Fixed HR at Backsight:1.508 (1.508 + 0.0 Offset), Prism Const.:0.0mm
--BS check 649 - 411:ZE90.142475,SD20.788302,HD err= 0.315675, VD err=
0.000781--BS Circle check : angular err= 0.000013
BK,OP649,BP411,BS262.192367,BC0.0000
--Fixed HR at Backsight:1.508 (1.508 + 0.0 Offset), Prism Const.:0.0mm
--BS check 649 - 411:ZE90.144881,SD20.776102,HD err= 0.303464, VD err= -
0.001591--BS Circle check : angular err= 0.000037
BK,OP649,BP411,BS262.192367,BC0.0000
--Fixed HR at Backsight:1.508 (1.508 + 0.0 Offset), Prism Const.:0.0mm
--BS check 649 - 411:ZE90.133913,SD20.770102,HD err= 0.297493, VD err=
0.005452--BS Circle check : angular err= 0.000012
SS,OP649,FP744,AR275.420583,ZE89.365344,SD5.465101,--to
SS,OP649,FP745,AR275.503956,ZE89.053013,SD5.714401,--lw
```

DATASET: CHaMP site exported dataset

RESOLUTION IN ANALYSIS: None

RECOMMENDATION: Such issues are of concern as they are very difficult, if not near impossible, to remedy. If crews are receiving high backsight error readings, re-shooting the backsight, still receiving high errors and then accepting them and continuing to survey this indicates crews may not know how to actually troubleshoot or remedy positional errors. Section 7 Step 3(vi) of the protocol instructs crews to, *"make sure the error is not greater than .030 for horizontal error and .015 for vertical error. Repeat procedure if backsight error is* *unacceptable"*. But this does not provide crews with any instruction about what to do if repeating shots of the backsight result in unacceptable errors. It is imperative that crews know how to correct this in the field as such shifts in the surveys will undoubtedly confound the ability to conduct time series geomorphic change detection analysis.

SPECIFIC POST-PROCESSING PROBLEMS IDENTIFIED

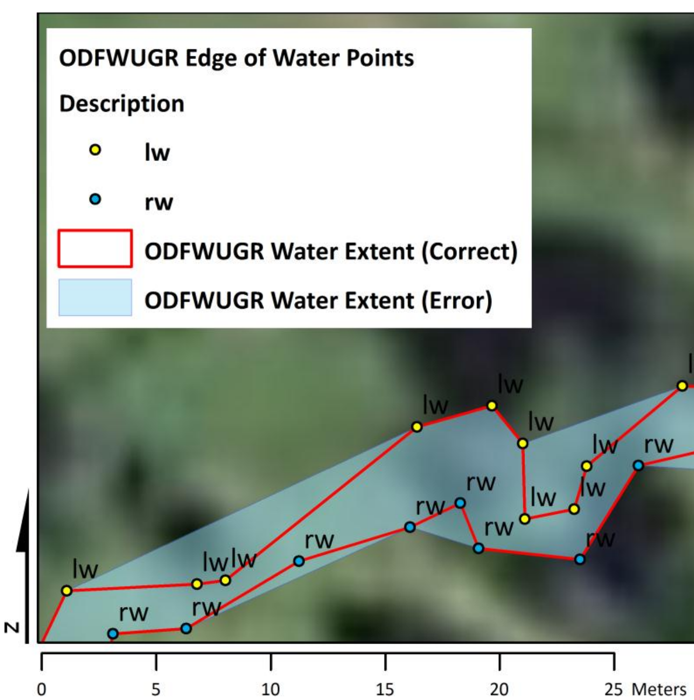
Only three post processing problems were identified, and all were associated with the manual creation of water's edge polygons from water's edge points. These blunders were not fixed for the purposes of the analyses done in this report, and both of these analyses are i) easy to identify in the absence of comparison data, ii) easy to fix post-hoc, iii) straight-forward to catch during QA/QC, and iv) could be avoided with clearer directions in the protocol and/or development or implementation of some semi-automated tools/checks for deriving water's edge extents.

WEST CHICKEN CREEK DSGN4-000006

CREW: ODFWUGR

PROBLEM: Post Processing Blunder

DESCRIPTION: The water extent polygon was incorrectly delineated during post processing. Crews manually draw polygons to delineate the water's edge during post processing, by connecting the points. It is quite apparent that the water extent polygon does not follow or connect all of the edge or water points collected in the field (see figure below). This, the substantial width of the extent polygon, and its over-generalized shape should have been a red-flag not only by the crew but also by the crew lead inspecting the submitted water's edge and water depth maps during manual QA/QC.



DATASET: SFR Geodatabase

RESOLUTION IN ANALYSIS: Sent back to crew; no resolution was necessary for purposes of this study.

RECOMMENDATION: More care needs to be taken by crew member's delineating water extent polygons as well as by QA/QC. These are obvious and easily remediated blunders.

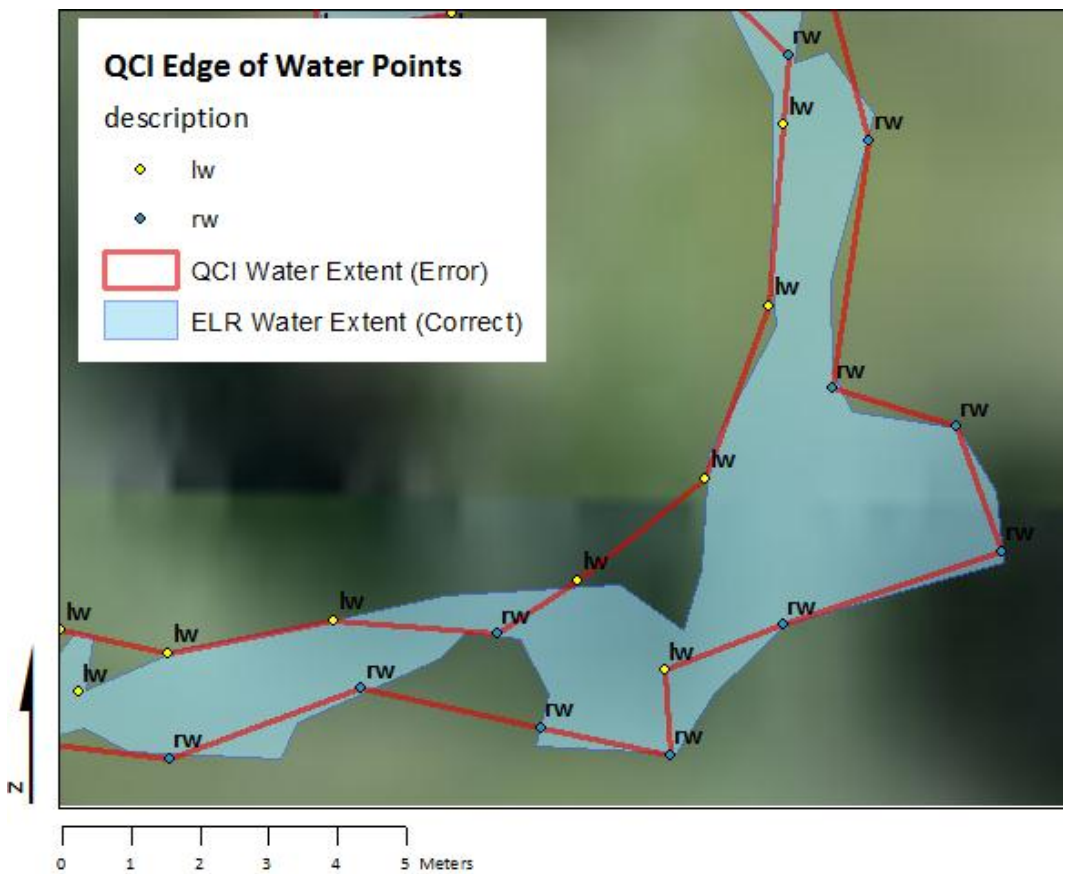
ASSESSMENT: Recurring problem for site, presumably because the flows were so low at the time of the survey. This leads to water extent edge polygons with odd shapes.

WEST CHICKEN CREEK DSGN4-000006

CREW: QCI

PROBLEM: Post Processing Blunder

DESCRIPTION: The water extent polygon was incorrectly delineated by the field crew member processing the data. The water extent polygon does not correctly follow or connect the edge of water points (see figure below). Here, the crew has connected a right edge of water point along the left edge of the water extent. This error should have been caught by the crew and may indicate they are not labeling points while creating water extent polygons.



DATASET: SFR Geodatabase

RESOLUTION IN ANALYSIS: Sent back to crew; no resolution was necessary for purposes of this study.

RECOMMENDATION: More care needs to be taken by crew member's delineating water extent polygons. This type of blunder, which involves a crew erroneously connecting a handful of points, is quite difficult for QA/QC personnel who did not survey the reach to catch later on in the office. These blunders can be easily remediated if a crew catches the error. Crews should be reminded to turn on point code labels in ArcGIS when creating water extent polygons.

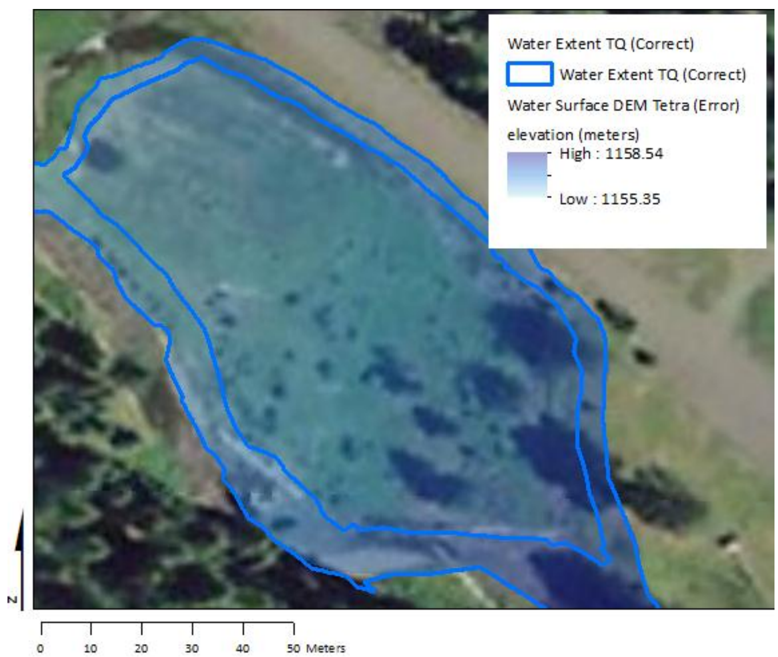
ASSESSMENT: Recurring problem for site, presumably because the flows were so low at the time of the survey. This leads to water extent edge polygons with odd shapes.

GRANDE RONDE RIVER LOWER CBW05583-235322

CREW: TETRA, ELR, QCI

PROBLEM: Post Processing Weakness

DESCRIPTION: When post-processing it appears the crew members editing the data did not correctly delineate the edge of water boundary around an island resulting in water surface DEMs that appear to 'inundate' the surface of the island (see figure below). All three crews with this error collected edge of water points and breaklines around the island in the field, but did not 'clip' the island feature from the water extent polygon.



DATASET: SFR Geodatabase

RESOLUTION IN ANALYSIS: None

RECOMMENDATION: May or not be of concern. Since topography was collected on the island, the derived water depth maps are correctly contained within the wetted channel. Overall, may want to encourage crews to 'clip' out islands to have greater consistency between crews.

ASSESSMENT: Recurring problem for site