THE INFLUENCE OF CREW VARIABILITY WHEN USING HIGH RESOLUTION TOPOGRAPHIC SURVEYS TO MONITOR INSTREAM HABITAT: A case study from the Columbia River basin

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1. INTRODUCTION

The goal of the Columbia Habitat Monitoring Program (CHaMP) is implement a standardized fish habitat monitoring program in watersheds with Endangered Species Act (ESA)-listed steelhead and Chinook populations of the Interior Columbia River Basin. The CHaMP protocol is composed of methods that capture topographic, substrate, riparian vegetation, large woody debris and fish cover features of spatially balanced locations within each watershed. Topographic data is captured using total stations and methods incorporating surveying both channel unit boundaries and topographic features affording DEM and bathymetric mapping of sample sites (Bouwes et al., 2011). DEMs will be used to monitor habitat and geomorphic changes at high spatial resolution through time.

In the summer of 2011 the CHaMP program concluded its pilot field season where 12 crews from 8 agencies and organizations sampled 325 sites within 10 watersheds. Like any monitoring campaign that might rely on different crews, either between years or among sites, CHaMP suffers from knowing whether calculated differences are real or due to noise from discrepancies in how the different crews sampled. To discern the extent of crew variability a study was conducted to intercompare topographic surfaces derived by different crews.

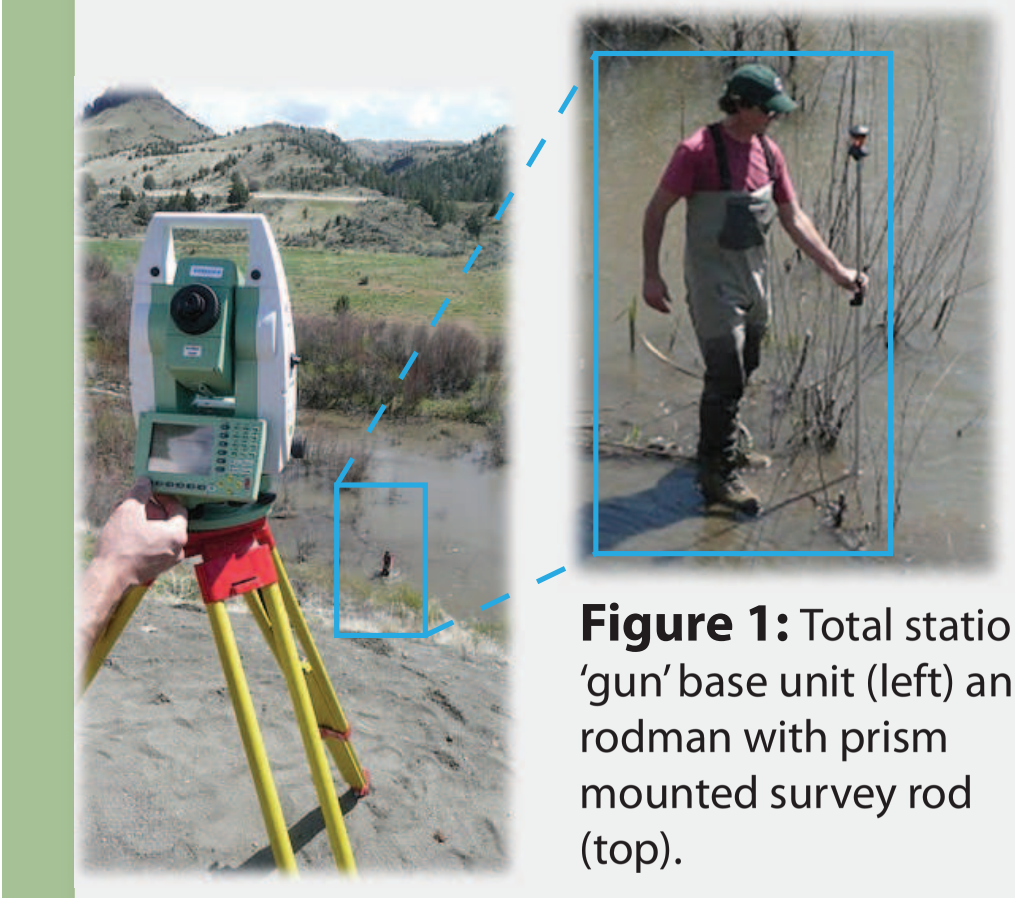


Figure 1: Total station 'gun' base unit (left) and rodman with prism mounted survey rod (top).

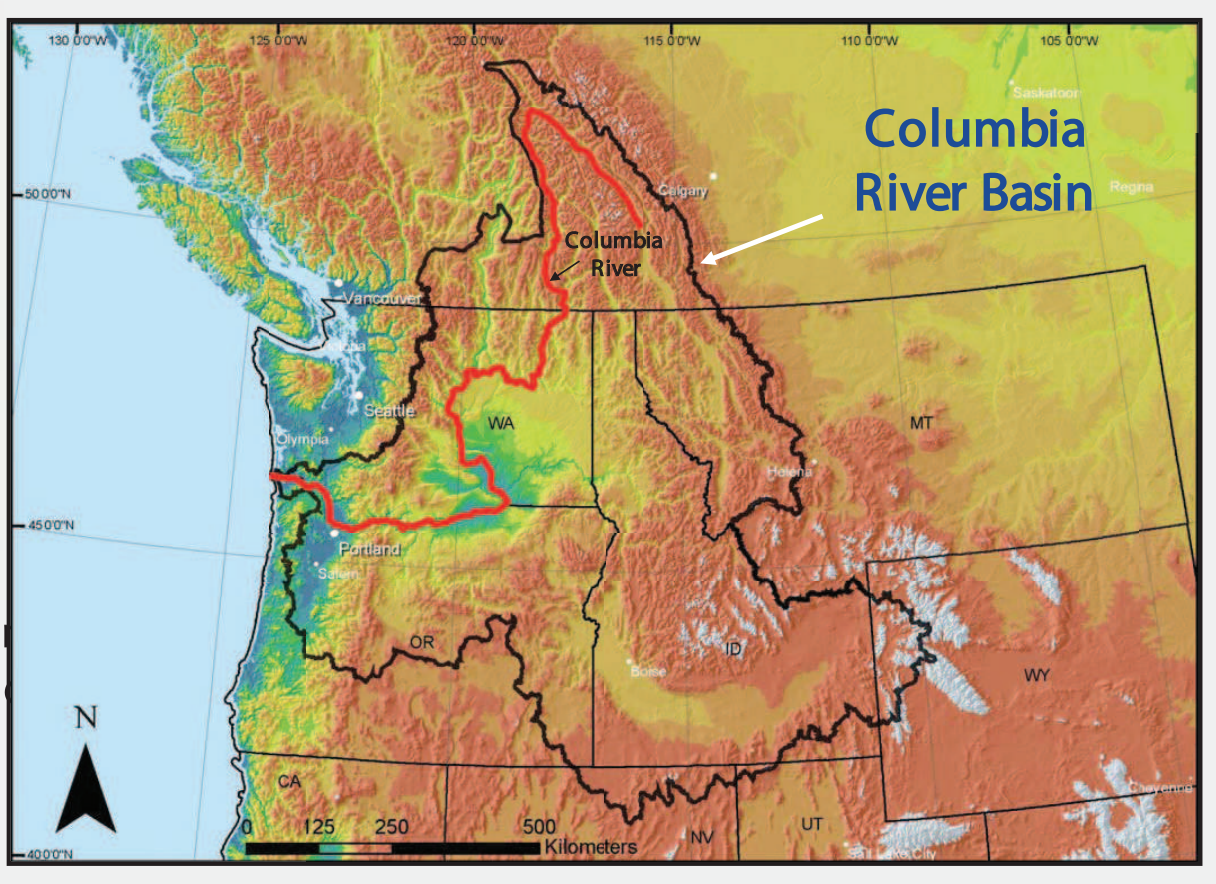


Figure 2: Columbia River basin

Questions:

- To what extent can large observed differences between crews be attributed to systematic surveying and processing errors?
- At specific sites, how does crew variability influence the quality of the data collected?
- To what extent does crew variability to limit our ability to:
  a. Reliably calculate DEM derived metrics such as water depth?
  b. Detect and interpret geomorphic changes from time series data?

2. STUDY SITE DESCRIPTION

Seven crews sampled the same six stream reaches in the Upper Grande Ronde River basin of Northeast Oregon (Figure 2). The Grande Ronde River flows in a northeasterly direction to its confluence with the Snake River. The basin encompasses 4238 km, has a mean elevation of 1267 m and a mean annual precipitation of 719 mm. The six sample reaches selected include 3 smaller lower order sites and 3 larger mainstem sites (Table 1).

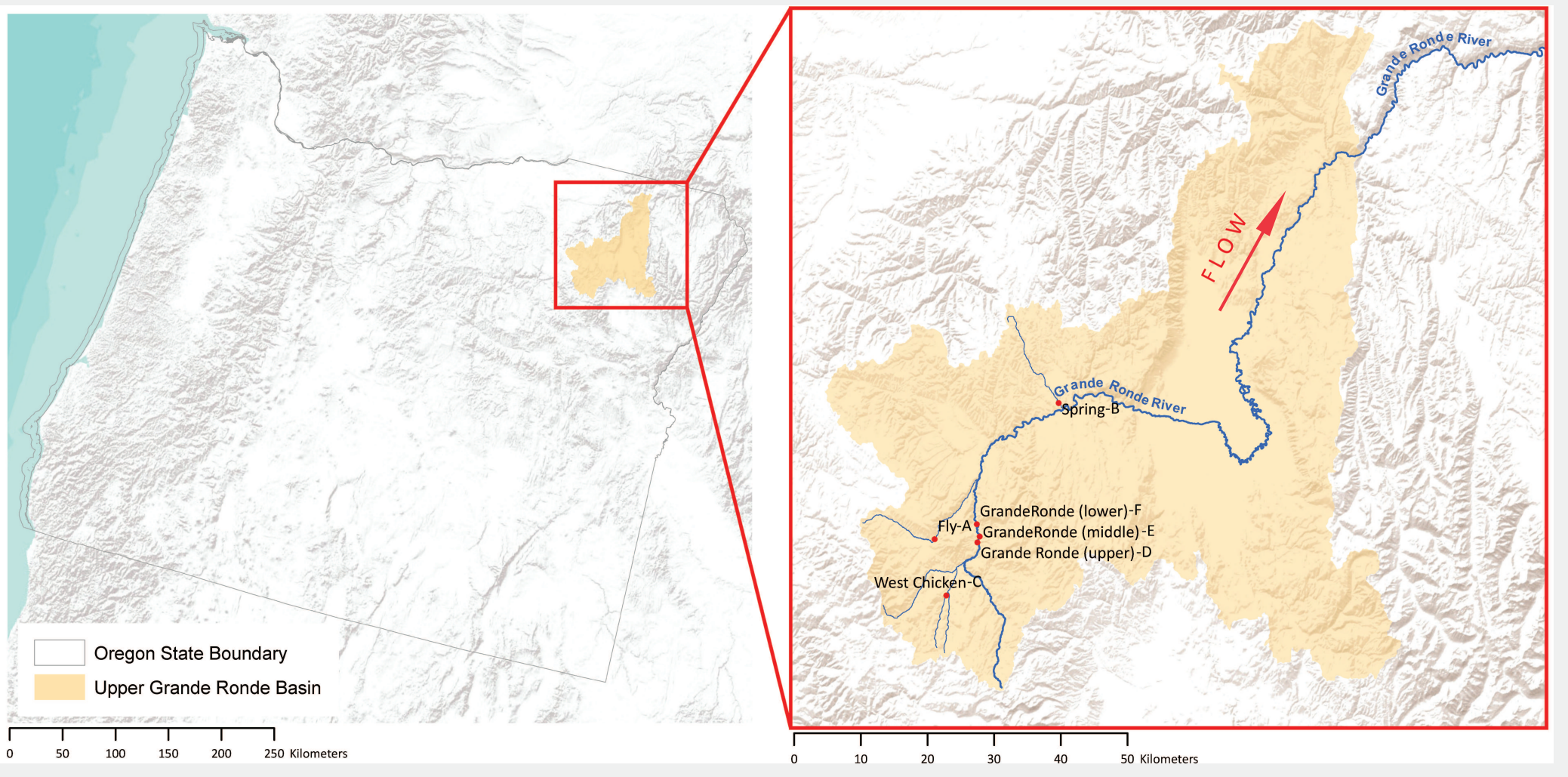
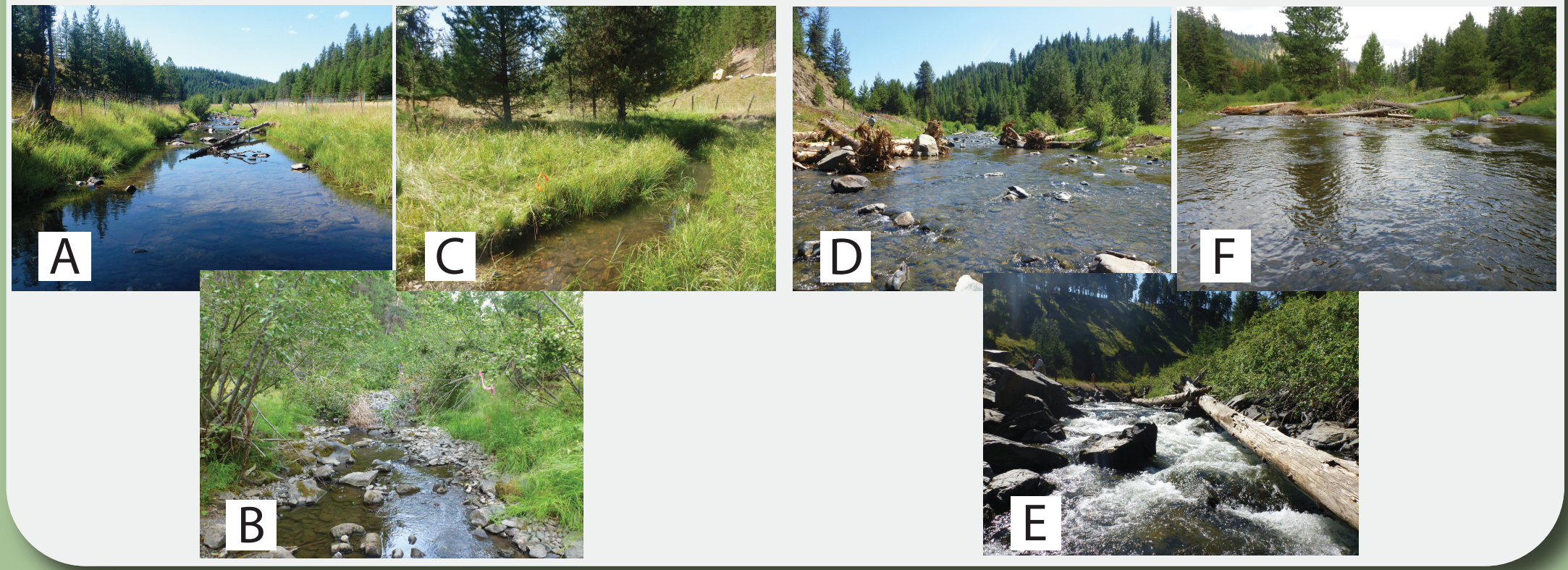


Figure 3: Upper Grande Ronde River watershed and study site locations.

	Site Characteristic				
Stream Name	Elevation (m)	Gradient (%)	Primary bedform class	Average 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: Sample site characteristics



3. STUDY METHODS

Survey Methods

- Crews followed the CHaMP protocol (Bouwes et al., 2011) using total station surveys (Figures 1 & 4)
- Crews were responsible for QA/QC, building and editing TINs and DEMs
- Also delineated habitat units, sampled invertebrate drift, measured substrate, canopy cover, riparian vegetation and pool tail fines.

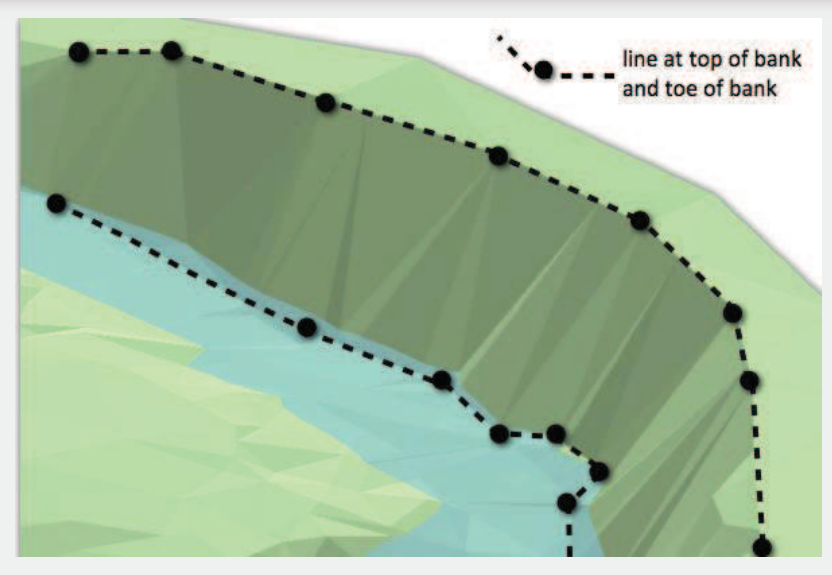


Figure 4: Example from CHaMP protocol of a TIN channel view showing proper use of toe of bank and top of bank breaklines.

Analysis Methods

- Raster max-min analysis to quantify maximum range of crew variability
- Spatially variable estimate of DEM error using Fuzzy Inference System (FIS; Table 4) developed by Wheaton et al. (2010)
- Calculated the coefficient of variation (StdDev/Mean) to allow comparison between data sets with different units and widely different means.
- Modeled potential geomorphic change scenario using Geomorphic Change Detection (GCD) software

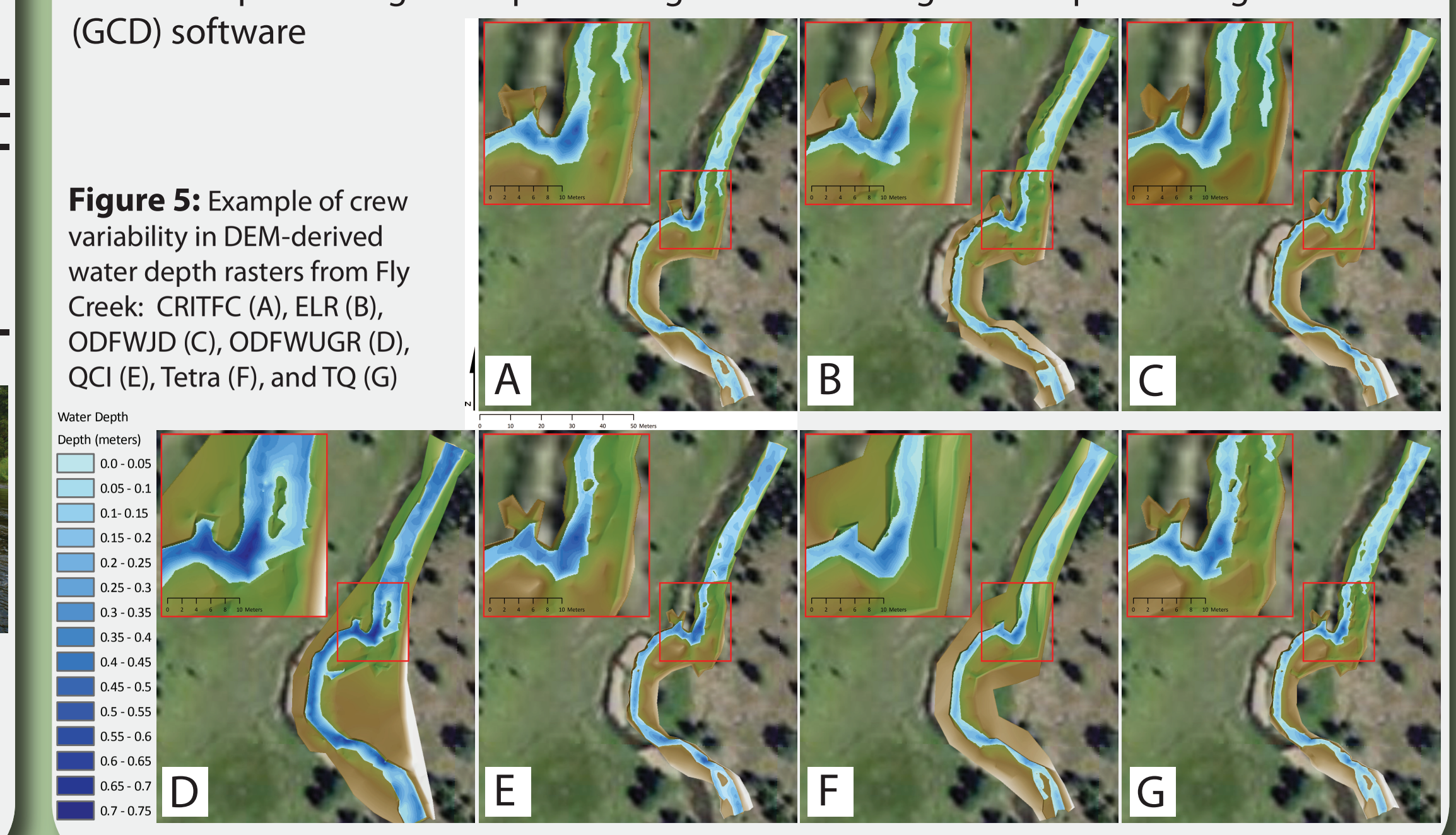


Figure 5: Example of crew variability in DEM-derived water depth rasters from Fly Creek: CRITFC (A), ELR (B), ODFWJD (C), ODFWUGR (D), QCI (E), Tetra (F), and TQ (G)

4. SURVEY & PROCESSING ERRORS

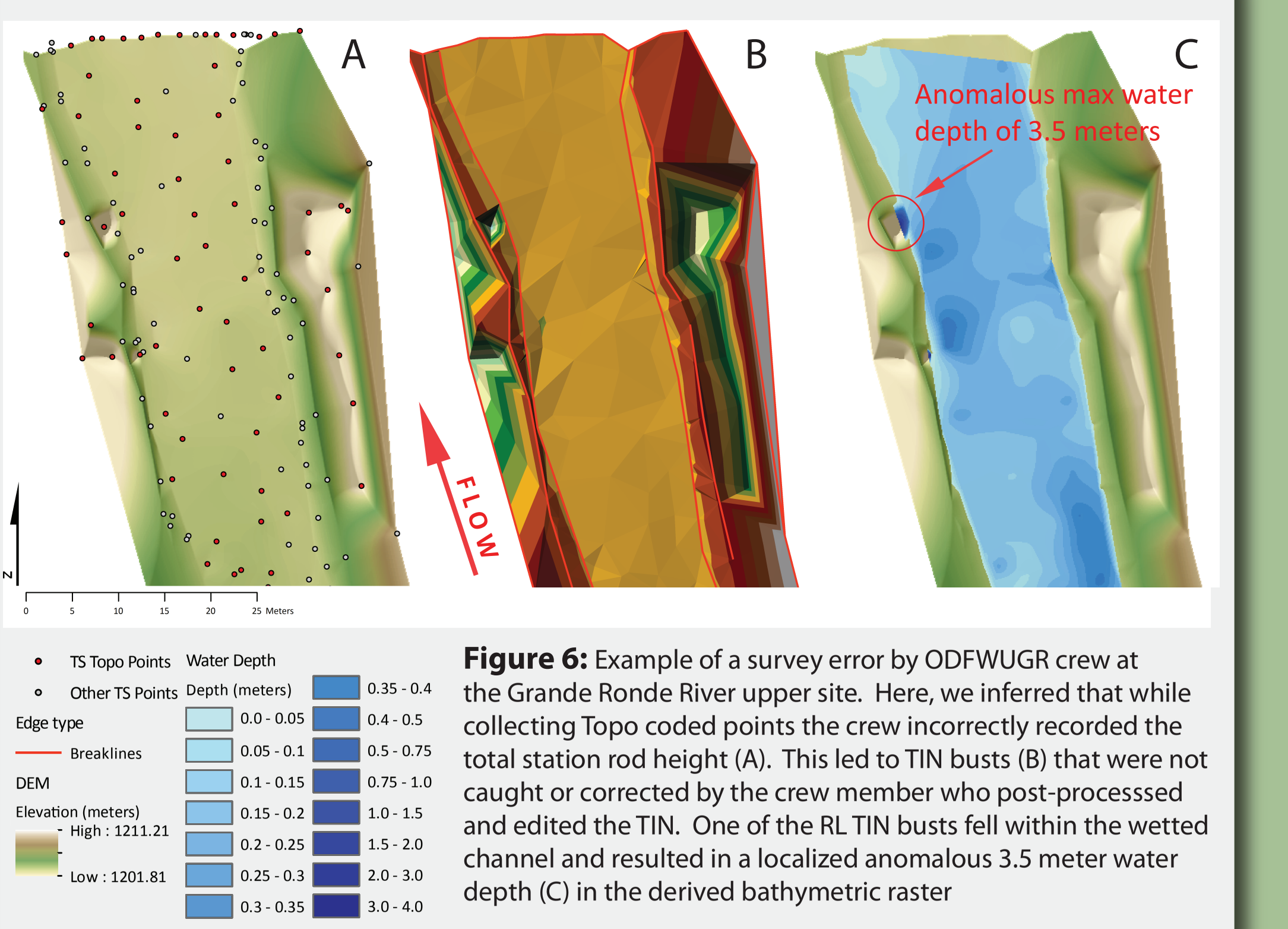


Figure 6: Example of a survey error by ODFWUGR crew at the Grande Ronde River upper site. Here, we inferred that while collecting Topo coded points the crew incorrectly recorded the total station rod height (A). This led to TIN busts (B) that were not caught or corrected by the crew member who post-processsed 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

TAKE HOME:

- **Most common errors were TIN busts not caught by crews when editing TINs. These were typically associated with incorrect rod heights.**
- **Most observed errors are easy to fix post-hoc (e.g. TIN bust). Some are difficult or nearly impossible to remedy post hoc and could compromise an entire survey (e.g. excessive error in a BS check).**
- **All observed errors are easy to avoid with clear guidance and training.**

			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 2: Summary of survey and post-processing issues.

5. RESULTS: RANGE OF VARIABILITY & SURFACE QUALITY

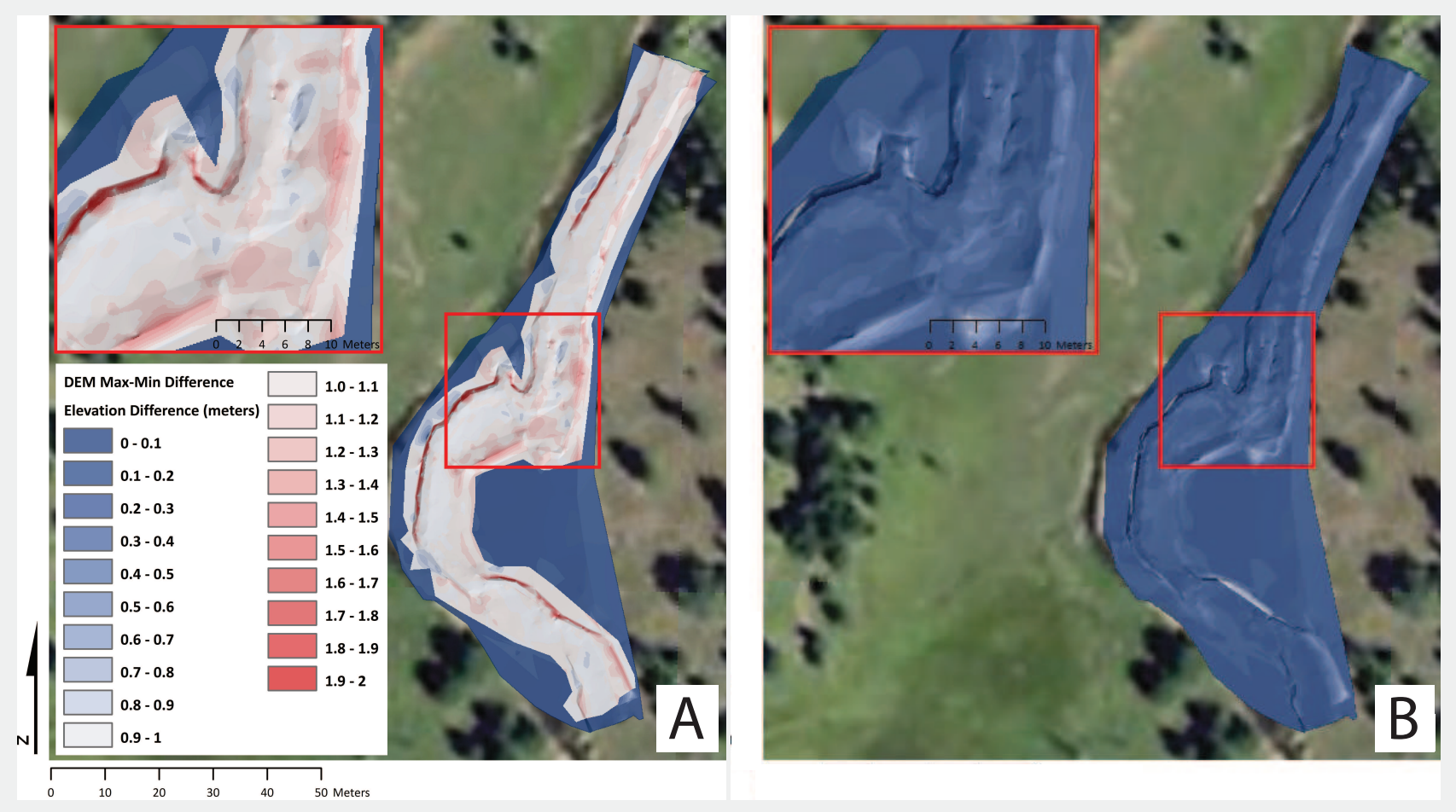


Figure 7: Fly Creek DEM maximum-minimum difference raster with (A) and without ELR crew (B) who made survey error of adding 1 meter to total station instrument height.

		Site							
	Statistic	Fly Creek	Fly Creek*	Spring Creek	West Chicken Creek	Grande Ronde River (upper)	Grande Ronde River (middle)	Grande Ronde River (lower)	Mean
DEM maximum - minimum difference (m)	Min	0	0	0	0	0	0	0	0
	Max	1.92	0.99	10.05	0.84	4.68	4.61	3.46	3.79
	Mean	0.67	0.10	0.10	0.05	0.21	0.39	0.23	0.25
	StdDev	0.50	0.50	0.29	0.09	0.43	0.47	0.20	0.35
Mean DEM elevation uncertainty (m)	Min	0.11	0.11	0.1	0.05	0.24	0.35	0.19	0.16
	Max	0.24	0.24	0.5	0.14	0.34	0.5	0.24	0.31
	Mean	0.19	0.19	0.21	0.08	0.29	0.43	0.22	0.23
	StdDev	0.04	0.04	0.13	0.04	0.04	0.05	0.02	0.05
	CV(%)	21.05	21.05	61.90	50.00	13.79	11.63	9.09	26.93

* without ELR due to survey blunder where added 1 meter to total station base unit height

Table 3: Results of DEM maximum-minimum difference and FIS elevation uncertainty raster output.

Figure 8: Fly Creek FIS estimated elevation error rasters for CRITFC (A) and ELR (B).

Rule:	Inputs		Output
	Slope %	Pt. ρ pts/m^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 4: FIS slope and point density ruleset

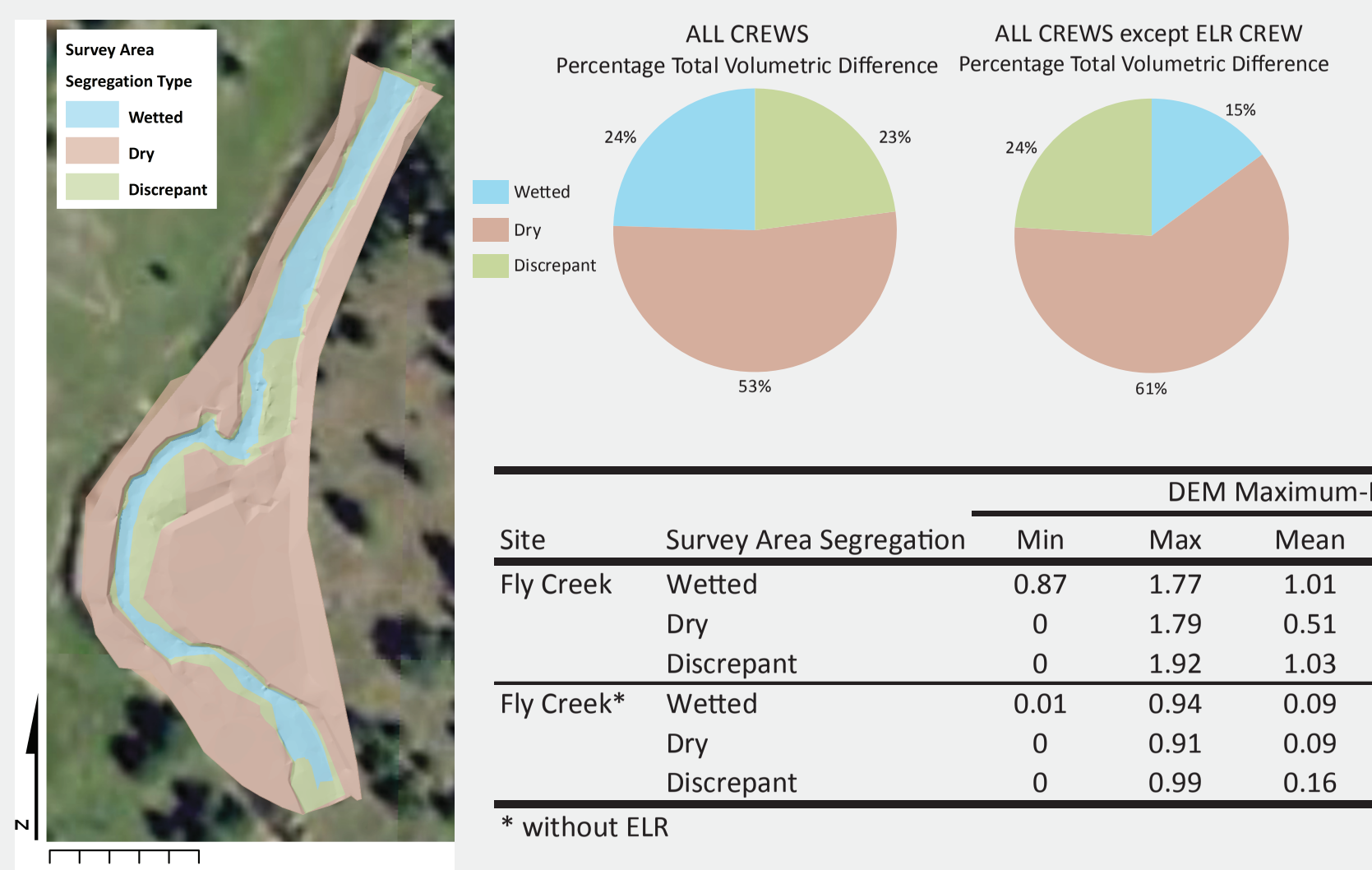


Figure 9: Fly Creek DEM max- min difference raster spatially segregated by survey area (wetted, dry, discrepant) with and without ELR crew.

		DEM Maximum-Minimum Difference				
Site	Survey Area Segregation	Min	Max	Mean	StdDev	Volume (m^3)/Area (m^2)
Fly Creek	Wetted	0.87	1.77	1.01	0.06	1.01
	Dry	0	1.79	0.51	0.52	0.51
	Discrepant	0	1.92	1.03	0.25	1.03
Fly Creek*	Wetted	0.01	0.94	0.09	0.06	0.09
	Dry	0	0.91	0.09	0.11	0.13
	Discrepant	0	0.99	0.16	0.14	0.17

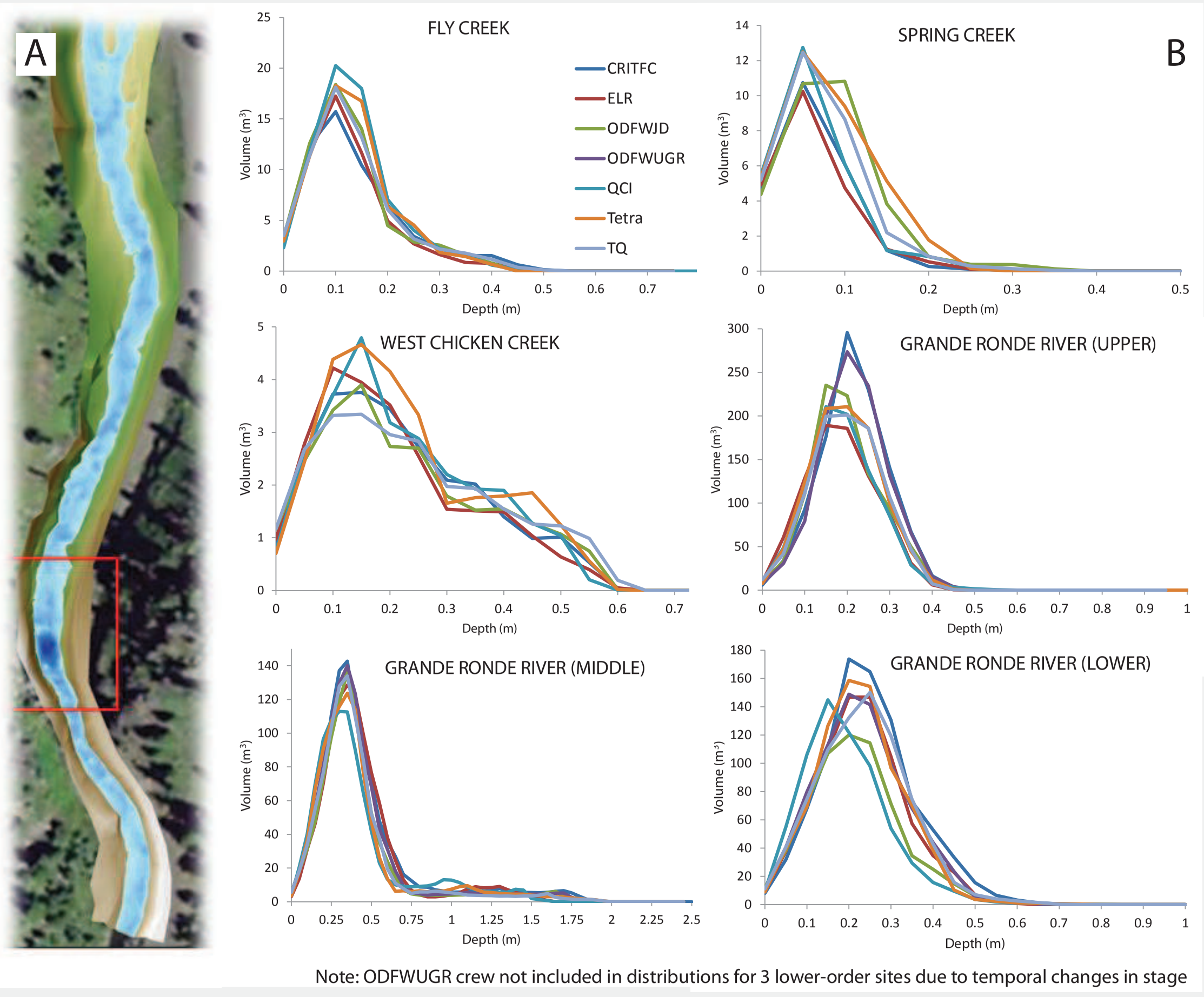
* without ELR

Table 5: Fly Creek DEM max-min difference spatially segregated by survey area (wetted, dry discrepant) with and without ELR crew.

TAKE HOME:

- **The range of variability among crews is within typical estimates of DEM error for total stations**
- **Variability is least in the wetted channel (i.e. the primary fish habitat) & worse on the margins and out of channel areas**
- **FIS should be calibrated for lower point density surveys & adjusted to account for breaklines**

6. RESULTS: EFFECT OF CREW SURVEY VARIABILITY ON DEM DERIVED WATER DEPTH RASTERS



Note: ODFWUGR crew not included in distributions for 3 lower-order sites due to temporal changes in stage

Figure 10: Example of a DEM-derived water depth raster from Grande Ronde River middle site (A). Water depth frequency distribution for all crews by site (B).

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	0.54
	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	0.08
	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	0.36
	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	0.05
	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	0.64
	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

Table 6: Summary DEM derived water depth rasters for each crew at each site, summarized across all crews at each sites and for the three lower order sites and mainstem sites.

- **At the lower order sites, average water depths vary by up to 3 cm while maximum water depth varies by 14 cm (Table 6). At the mainstem sites, average water depths vary by a up to 4 cm while maximum water depth varied by up to 3.14 m. CV values are relatively similar between crews at all sites indicating crews measured comparable variation of depths. This is also reflected in the depth frequency distributions (Figure 10B).**
- **Depth frequency distribution plots (Figure 10B) indicate DEM-derived water depth is not overly sensitive to highly localized differences among crews.**

7. RESULTS: 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. As this is only the first year of data collection in CHaMP, repeat topographic surveys were not available that captured 'real' geomorphic change. As such, we created an artificial DEM that represented a plausible future state of the channel. An 'obvious' change scenario was modeled whereby a beaver builds a dam between Time 1 and 2 with a subsequent flood resulting in channel avulsion. We hypothesized that all crews should be able to detect this change, regardless of crew variability because the magnitude of the signal exceeded likely DEM uncertainties. Each individual crew's DEM was used as Time 1. The ODFWUGR DEM was selected as truth and used to model potential change (i.e. Time 2 surface).

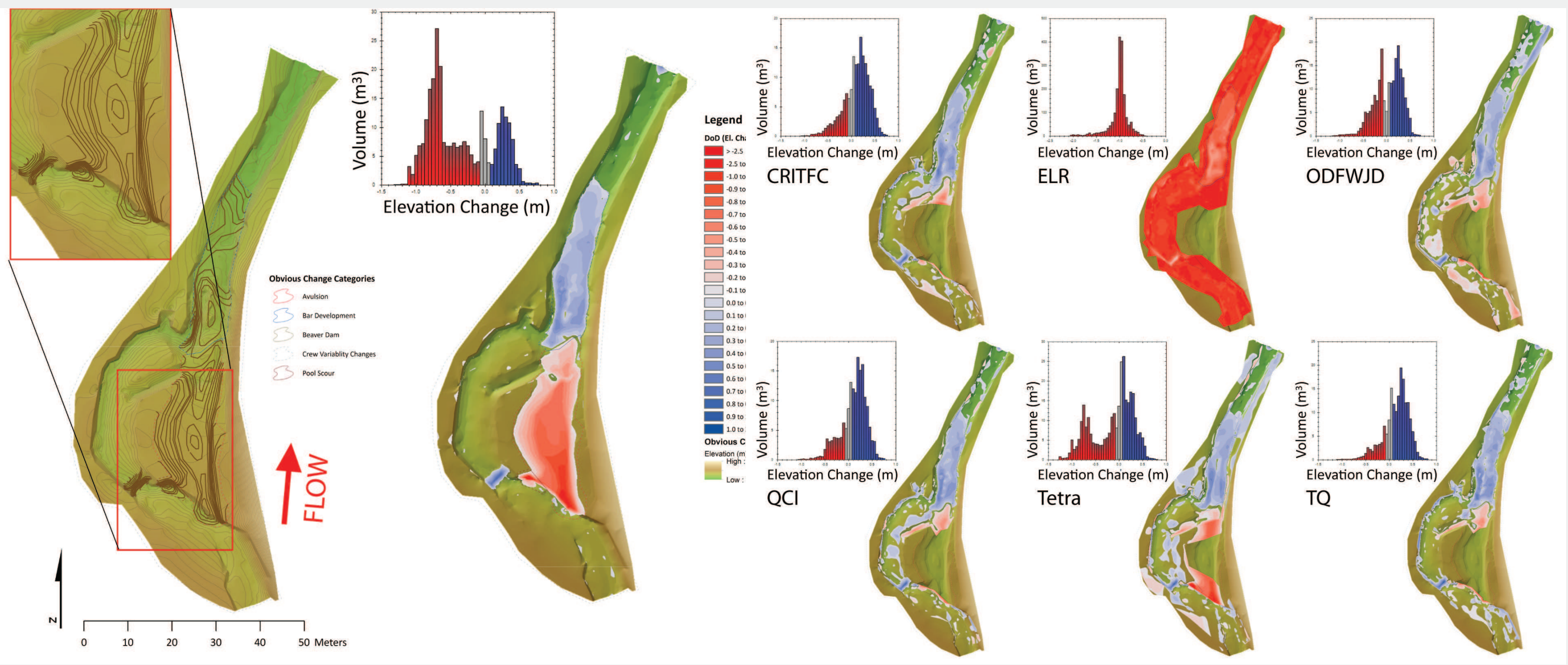


Figure 11: Results of modeled 'obvious' geomorphic change of Time 2 - Time 1. Here the ODFWUGR crew represents 'true' change. Areas in blue represent deposition while areas in red represent erosion. Histograms represent gross volumetric differences.

	Unthresholded (m^3)			Thresholded (m^3)			
Crew	Erosion	Deposition	Net	Erosion	Deposition	Net	Budget Result
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	In determinant
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
A verge w/o ELR	92	128	36	84 ± 20.8	106 ± 25.3	21.8 ± 33.5	Net Aggradational

Table 7: Results of modeled 'obvious' geomorphic change by crew. Time 2 and 1 surfaces were both unthresholded (straight DEM of difference) and thresholded with uniform error of 0.04 cm.

TAKE HOME:

- **All crews missed the 'true' net degradational signal as a result of not having a large enough survey area that extended onto the floodplain**
- **Most crews accurately captured the in-channel aggradation downstream of the avulsion**
- **Observed largest in-channel errors were along banks**
- **ELR crew discrepancy was due to error in adding 1 meter to the recorded total station instrument height**
- **Crews need better guidance on survey extents needed to detect large scale change such as channel avulsion**

8. CONCLUSIONS

- **Crews collected topographic data of sufficient quality and consistency** that their DEMs and water depths show the same basic spatial patterns. *Additional guidance on point densities and breakline data collection could help promote higher qualities and consistency.*
- **The largest observed differences among 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.*
- **Survey extent matters, particularly with long term datasets and ability to detect geomorphic change.** The topographic data among crews was 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.*
- Total stations are tried and true and most versatile (in CHaMP context), but not necessarily the most efficient at individual sample reaches

9. REFERENCES

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10. ACKNOWLEDGEMENTS

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Utah State University Spring Runoff Conference, 2012, Logan, UT

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