Subject Matter Expert Report: HABITAT AVAILABILITY IN RELATION TO FLOW

Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population




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EXECUTIVE SUMMARY

Abundances of both juvenile and adult life stages of Westslope Cutthroat Trout (WCT) in the upper Fording River (UFR) were substantively lower in 2019 than 2017, indicating a large decline during the two-year period between September 2017 and September 2019 (the Westslope Cutthroat Trout Population Decline Window, hereafter referred to as the Decline Window). Teck Coal Limited (Teck Coal) initiated the "Evaluation of Cause" to determine whether and to what extent various stressors and conditions played a role in the decline of WCT. One of several potential stressors that has been identified for evaluation is reduced availability of hydraulically suitable habitat for WCT in the UFR due to instream flow conditions. This report uses habitat time series modelling to investigate whether reduced habitat availability due to instream flow conditions contributed to the WCT decline. Reduced habitat availability could potentially cause, or contribute to, reduced WCT abundance if WCT are concentrated into remaining habitats and then suffer mortality either due to competition for limited resources or due to localized environmental changes or impacts where individuals are concentrated.

We investigated the potential role of flow-related habitat availability on reduced WCT abundance by first determining whether hydraulically suitable habitat was reduced during critical life history periods of WCT during the Decline Window relative to preceding years (2014-2016). This was accomplished by developing habitat-flow relationships (through field sampling at transects, data from hydrometric gauges, and hydraulic modelling) and comparing time series for weighted usable area (WUA) for critical WCT time periods (overwintering, spawning, summer rearing) between the Decline Window and prior years. (Overwintering migration is addressed separately in the Fish Passage report, Harwood *et al.* 2021). WUA was the metric used to quantify habitat availability for WCT and was based on hydraulic characteristics (velocity and depth) and habitat suitability criteria (HSC), which differ by fish species and life stage periodicity. We then evaluated whether habitat availability was lower during the Decline Window than prior. This comparison was used to determine if reduced habitat availability was sufficient to cause or contribute to the observed decline in WCT abundance. We identified requisite conditions (conditions that would need to be true if habitat availability was responsible for the observed decline in WCT abundance) by evaluating Intensity, Timing, Duration, Location, and Spatial Extent of habitat availability by WCT critical time period (i.e., reduction in availability of suitable habitat must have occurred during a critical WCT life history period within the Decline Window, within some or most of the UFR, and it must have been substantive and prolonged). It is important to note that the evaluation of changes to habitat availability in this report only considers suitability of hydraulic habitat for fish, and hence only reflect flow-related changes to habitat availability in locations where fish are overwintering, rearing, and spawning.

Comparison of habitat time series during the Decline Window relative to previous years identified little change in spawning, rearing and overwintering WCT habitat availability in the UFR. Average habitat availability in the Decline Window ranged from 93% to 122% of pre-Window habitat availability depending on the WCT life history time period assessed. The summer rearing period in Henretta Creek in 2017 was found to have reduced habitat availability; the UFR mainstem in

September of 2017 at the beginning of the Decline Window was to also found to have reduced habitat availability albeit to a lesser extent than in Henretta Creek. Specifically, habitat availability was reduced by 25% for the summer rearing period in Henretta Creek relative to average during the pre-Window period. This section of Henretta Creek corresponds to reach H1 in the Cope (2020) dataset, which has had relatively low density of WCT observed throughout the pre-Window time series in comparison to the significantly higher number of WCT adults and juveniles observed in the mainstem UFR. The summer rearing period in 2017 also corresponds to observations of high WCT density across river segments in the UFR, which were followed by sharp declines in the next surveys in 2019 (Cope 2020). These combined observations suggest that it is unlikely that flow-related shifts in rearing habitat availability was the sole or contributing cause of WCT decline.

Available flow data indicate that there has been little change in spawning or overwintering habitat availability during the Decline Window in the UFR compared to the pre-Window period. The requisite conditions for Timing, Duration, Location and Spatial Extent were thus not met for the summer rearing, spawning and overwintering periods. For overwintering, however, we caution that this analysis does not incorporate the effects of ice formation (addressed in Whelan *et al.* 2021) or access to overwintering habitat (fish migration addressed in Harwood *et al.* 2021), and there is uncertainty in the predictions for overwintering due to gaps in the flow data record.

Uncertainties were identified in relation to the development of habitat-flow relationships, although the level of uncertainty was generally evaluated to be low enough to not affect the conclusions of the Evaluation of Cause (EoC). The greatest uncertainty was identified in relation to the relationship between transect flow and flow at the FR_FRNTP hydrometric gauge owing to longitudinal variation in discharge along the UFR mainstem (e.g., variation in flow due to downwelling and upwelling from hyporheic exchange, inflows from tributaries and groundwater, and infrastructure presence).

Uncertainties identified in relation to the Evaluation of Cause were, in part, related to gaps in the flow record. Specifically, data gaps due to hydrometric gauge icing (December 20, 2017 to March 14, 2018, and November 9, 2018 to January 20, 2019) during the overwintering period of the Decline Window led to uncertainty about final conclusions. Nevertheless, examination of the timing of the data gaps as well as the antecedent and subsequent conditions suggested that anomalies are unlikely in those periods and conclusions from the habitat time series analyses are unlikely to have been affected by the data gaps.

In summary, the available evidence indicates that this stressor was not the sole cause of the decline. We are unable to rule out this stressor as a contribution to the decline; however, the evidence suggests the contribution is likely to be minor.

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SIGNATORY PAGE

Certification: *stamped version on file.*

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ACRONYMNS AND ABBREVIATIONS

EoC Evaluation of Cause

FRO Fording River Operations

IFS Instream Flow Study

HC Henretta Creek

HSC Habitat Suitability Criteria

OEMP Operational Environmental Monitoring Plan

SME Subject Matter Expert

UFR Upper Fording River

WCT Westslope Cutthroat Trout

WUW Weighted Usable Width

WUA Weighted Usable Area

READER'S NOTE

What is the Evaluation of Cause and what is its purpose?

The Evaluation of Cause is the process used to investigate, evaluate and report on the reasons the Westslope Cutthroat Trout population declined in the upper Fording River between fall 2017 and fall 2019.

Background

The Elk Valley is located in the southeast corner of British Columbia (BC), Canada. It contains the main stem of the Elk River (220 km long) and many tributaries, including the Fording River (70 km long). This report focuses on the upper Fording River, which starts 20 km upstream from its confluence with the Elk River at Josephine Falls. The Ktunaxa First Nation has occupied lands in the region for more than 10,000 years. Rivers and streams of the region provide culturally important sources of fish and plants.

The upper Fording River watershed is at a high elevation and is occupied by only one fish species, a genetically pure population of Westslope Cutthroat Trout *(Oncorhynchus clarkii lewisi)* — an iconic fish species that is highly valued in the area. This population is physically isolated because Josephine Falls is a natural barrier to fish movement. The species is protected under the federal Fisheries Act and the Species at Risk Act. In BC, the Conservation Data Center categorized Westslope Cutthroat Trout as "*imperiled or of special concern, vulnerable to extirpation or extinction.*" Finally, it has been identified as a priority sport fish species by the Province of BC.

The upper Fording River watershed is influenced by various human-caused disturbances including roads, a railway, a natural gas pipeline, forest harvesting and coal mining. Teck Coal Limited (Teck Coal) operates the three surface coal mines within the upper Fording River

Evaluation of Cause

Following identification of the decline in the Westslope Cutthroat Trout population, Teck Coal initiated an Evaluation of Cause process. The overall results of this process are reported in a separate document (Evaluation of Cause Team, 2021) and are supported by a series of Subject Matter Expert reports.

The report that follows this Reader's Note is one of those Subject Matter Expert Reports.

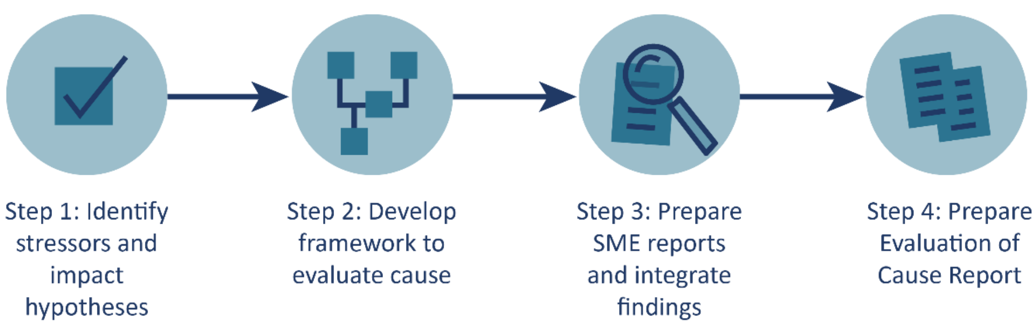
watershed, upstream of Josephine Falls: Fording River Operations, Greenhills Operations and Line Creek Operations.

Monitoring conducted for Teck Coal in the fall of 2019 found that the abundance of Westslope Cutthroat Trout adults and sub-adults in the upper Fording River had declined significantly since previous sampling in fall 2017. In addition, there was evidence that juvenile fish density had decreased. Teck Coal initiated an *Evaluation of Cause* process. The overall results of this process are reported separately (Evaluation of Cause Team, 2021) and are supported by a series of Subject Matter Expert reports such as this one. The full list of SME reports follows at the end of this Reader's Note.

Building on and in addition to the Evaluation of Cause, there are ongoing efforts to support fish population recovery and implement environmental improvements in the upper Fording River.

How the Evaluation of Cause was approached

When the fish decline was identified, Teck Coal established an *Evaluation of Cause Team* (the Team), composed of *Subject Matter Experts* and coordinated by an Evaluation of Cause *Team Lead.* Further details about the Team are provided in the Evaluation of Cause report. The Team developed a systematic and objective approach (see figure below) that included developing a Framework for Subject Matter Experts to apply in their specific work. All work was subjected to rigorous peer review.



Conceptual approach to the Evaluation of Cause for the decline in the upper Fording River Westslope Cutthroat Trout population.

With input from representatives of various regulatory agencies and the Ktunaxa Nation Council, the Team initially identified potential stressors and impact hypotheses that might explain the cause(s) of the population decline. Two overarching hypotheses (essentially, questions for the Team to evaluate) were used:

- Overarching Hypothesis #1: The significant decline in the upper Fording River Westslope Cutthroat Trout population was a result of a single acute stressor[1] or a single chronic stressor[2].
- Overarching Hypothesis #2: The significant decline in the upper Fording River Westslope Cutthroat Trout population was a result of a combination of acute and/or chronic stressors, which individually may not account for reduced fish numbers, but cumulatively caused the decline.

The Evaluation of Cause examined numerous stressors in the UFR to determine if and to what extent those stressors and various conditions played a role in the Westslope Cutthroat Trout's decline. Given that the purpose was to evaluate the cause of the decline in abundance from 2017 to 2019[3], it was important to identify stressors or conditions that changed or were different during that period. It was equally important to identify the potential stressors or conditions that did not change during the decline window but may, nevertheless, have been important constraints on the population with respect to their ability to respond to or recover from the stressors. Finally, interactions between stressors and conditions had to be considered in an integrated fashion. Where an *impact hypothesis* depended on or may have been exacerbated by interactions among stressors or conditions, the interaction mechanisms were also considered.

The Evaluation of Cause process produced two types of deliverables:

1. **Individual Subject Matter Expert (SME) reports** (such as the one that follows this Note): These reports mostly focus on impact hypotheses under Overarching Hypothesis #1 (see list, following). A Framework was used to align SME work for all the potential stressors, and, for consistency, most SME reports have the same overall format. The format covers: (1) rationale for impact hypotheses, (2) methods, (3) analysis and (4) findings, particularly

[1] Implies September 2017 to September 2019.

[2] Implies a chronic, slow change in the stressor (using 2012–2019 timeframe, data dependent).

[3] Abundance estimates for adults/sub-adults are based on surveys in September of each year, while estimates for juveniles are based on surveys in August.

whether the requisite conditions[4] were met for the stressor(s) to be the sole cause of the fish population decline, or a contributor to it. In addition to the report, each SME provided a summary table of findings, generated according to the Framework. These summaries were used to integrate information for the Evaluation of Cause report. Note that some SME reports did not investigate specific stressors; instead, they evaluated other information considered potentially useful for supporting SME reports and the overall Evaluation of Cause, or added context (such as in the SME report that describes climate (Wright et al., 2021).

2. **The Evaluation of Cause report** (prepared by a subset of the Team, with input from SMEs): This overall report summarizes the findings of the SME reports and further considers interactions between stressors (Overarching Hypothesis #2). It describes the reasons that most likely account for the decline in the Westslope Cutthroat Trout population in the upper Fording River.

Participation, Engagement & Transparency

To support transparency, the Team engaged frequently throughout the Evaluation of Cause process. Participants in the Evaluation of Cause process, through various committees, included:

Ktunaxa Nation Council

BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development

BC Ministry Environment & Climate Change Strategy

Ministry of Energy, Mines and Low Carbon Innovation

Environmental Assessment Office

[4] These are the conditions that would need to have occurred for the impact hypothesis to have resulted in the observed decline of Westslope Cutthroat Trout population in the upper Fording River.

Citation for the Evaluation of Cause Report

When citing the Evaluation of Cause Report use:

Evaluation of Cause Team, (2021). *Evaluation of Cause — Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited by Evaluation of Cause Team.

Citations for Subject Matter Expert Reports

Focus	Citation for Subject Matter Expert Reports
Climate, temperature, and streamflow	Wright, N., Greenacre, D., & Hatfield, T. (2021). *Subject Matter Expert Report: Climate, Water Temperature, Streamflow and Water Use Trends. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Ecofish Research Ltd.
Ice	Hatfield, T., & Whelan, C. (2021). *Subject Matter Expert Report: Ice. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. Report Prepared by Ecofish Research Ltd.
Habitat availability (instream flow)	Healey, K., Little, P., & Hatfield, T. (2021). *Subject Matter Expert Report: Habitat availability. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited by Ecofish Research Ltd.
Stranding – ramping	Faulkner, S., Carter, J., Sparling, M., Hatfield, T., & Nicholl, S. (2021). *Subject Matter Expert Report: Ramping and stranding. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited by Ecofish Research Ltd.

Focus	Citation for Subject Matter Expert Reports
Stranding – channel dewatering	Hatfield, T., Ammerlaan, J., Regehr, H., Carter, J., & Faulkner, S. (2021). *Subject Matter Expert Report: Channel dewatering. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited by Ecofish Research Ltd.
Stranding – mainstem dewatering	Hocking M., Ammerlaan, J., Healey, K., Akaoka, K., & Hatfield T. (2021). *Subject Matter Expert Report: Mainstem dewatering. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd. and Lotic Environmental Ltd. Zathey, N., & Robinson, M.D. (2021). *Summary of ephemeral conditions in the upper Fording River Watershed. In Hocking et al. (2021). Subject Matter Expert Report: Mainstem dewatering. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd. and Lotic Environmental Ltd.
Calcite	Hocking, M., Tamminga, A., Arnett, T., Robinson M., Larratt, H., & Hatfield, T. (2021). *Subject Matter Expert Report: Calcite. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd., Lotic Environmental Ltd., and Larratt Aquatic Consulting Ltd.
Total suspended solids	Durston, D., Greenacre, D., Ganshorn, K & Hatfield, T. (2021). *Subject Matter Expert Report: Total suspended solids. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Ecofish Research Ltd.
Fish passage (habitat connectivity)	Harwood, A., Suzanne, C., Whelan, C., & Hatfield, T. (2021). *Subject Matter Expert Report: Fish passage. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd. Akaoka, K., & Hatfield, T. (2021). Telemetry Movement Analysis. In Harwood et al. (2021). *Subject Matter Expert Report: Fish passage. Evaluation of Cause – Decline in upper*

Focus	Citation for Subject Matter Expert Reports
	Fording River Westslope Cutthroat Trout population. Report prepared for Teck Coal Ltd. by Ecofish Research Ltd.
Cyanobacteria Algae / macrophytes	Larratt, H., & Self, J. (2021). *Subject Matter Expert Report: Cyanobacteria, periphyton and aquatic macrophytes. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Larratt Aquatic Consulting Ltd.
Water quality (all parameters except water temperature and TSS [Ecofish])	Costa, EJ., & de Bruyn, A. (2021). *Subject Matter Expert Report: Water quality. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Golder Associates Ltd. Healey, K., & Hatfield, T. (2021). *Calculator to assess Potential for cryoconcentration in upper Fording River.* In Costa, EJ., & de Bruyn, A. (2021). *Subject Matter Expert Report: Water quality. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Golder Associates Ltd.
Industrial chemicals, spills and unauthorized releases	Van Geest, J., Hart, V., Costa, EJ., & de Bruyn, A. (2021). *Subject Matter Expert Report: Industrial chemicals, spills and unauthorized releases. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Golder Associates Ltd. Branton, M., & Power, B. (2021). *Stressor Evaluation – Sewage.* In Van Geest et al. (2021). *Industrial chemicals, spills and unauthorized releases. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Golder Associates Ltd.
Wildlife predators	Dean, D. (2021). *Subject Matter Expert Report: Wildlife predation. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by VAST Resource Solutions Inc.

Focus	Citation for Subject Matter Expert Reports
Poaching	Dean, D. (2021). *Subject Matter Expert Report: Poaching. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by VAST Resource Solutions Inc.
Food availability	Orr, P., & Ings, J. (2021). *Subject Matter Expert Report: Food availability. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Minnow Environmental Inc.
Fish handling	Cope, S. (2020). *Subject Matter Expert Report: Fish handling. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Westslope Fisheries Ltd.
	Korman, J., & Branton, M. (2021). *Effects of capture and handling on Westslope Cutthroat Trout in the upper Fording River: A brief review of Cope (2020) and additional calculations.* Report prepared for Teck Coal Limited. Prepared by Ecometric Research and Azimuth Consulting Group.
Infectious disease	Bollinger, T. (2021). *Subject Matter Expert Report: Infectious disease. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by TKB Ecosystem Health Services Ltd.
Pathophysiology	Bollinger, T. (2021). *Subject Matter Expert Report: Pathophysiology of stressors on fish. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by TKB Ecosystem Health Services Ltd.
Coal dust and sediment quality	DiMauro, M., Branton, M., & Franz, E. (2021). *Subject Matter Expert Report: Coal dust and sediment quality. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Azimuth Consulting Group Inc.

Focus	Citation for Subject Matter Expert Reports
Groundwater quality and quantity	Henry, C., & Humphries, S. (2021). *Subject Matter Expert Report: Hydrogeological stressors. Evaluation of Cause - Decline in upper Fording River Westslope Cutthroat Trout population.* Report Prepared for Teck Coal Limited. Prepared by SNC-Lavalin Inc.

1. INTRODUCTION

Abundances of adult and juvenile life stages of Westslope Cutthroat Trout (WCT) in the upper Fording River (UFR) have been estimated since 2012 through high-effort snorkel and electrofishing surveys, supported by radio-telemetry and redd surveys (Cope *et al.* 2016). Surveys using similar methods were conducted in the summer/fall of 2012-2014, 2017, and 2019. Abundances of both juvenile and adult life stages were substantively lower in 2019 than 2017, indicating that a large decline occurred during that two-year period between 2017 and 2019[5] (hereafter referred to as the Westslope Cutthroat Trout Population Decline Window, also Decline Window; Cope 2020). The magnitude of the decline as well as refinements in the timing of decline are reviewed in detail by Cope (2020) and Korman (2021).

Teck Coal Limited (Teck Coal) initiated the "Evaluation of Cause" to assess factors responsible for the population decline. The Evaluation of Cause evaluates numerous impact hypotheses to determine whether and to what extent various stressors and conditions played a role in the decline of WCT. Given that the primary objective is to evaluate the cause of the sudden decline from 2017 to 2019, it is important to identify stressors or conditions that were different during the Decline Window relative to previous years (2014 to 2016). However, it is equally important to identify all potential stressors or conditions that did not change during the Decline Window but nevertheless may be important constraints on the population. Finally, interactions must also be considered. Where an impact hypothesis depends on interactions among stressors or conditions, or where the impact may be exacerbated by particular interactions, the mechanisms of interaction are considered as part of the evaluation of specific impact hypotheses.

A project team is evaluating the cause of decline and is investigating two "overarching" hypotheses:

- Overarching Hypothesis #1: The significant decline in the UFR WCT population was a result of a single acute stressor[6] or a single chronic stressor[7].
- Overarching Hypothesis #2: The significant decline in the UFR WCT population was a result of a combination of acute and/or chronic stressors, which individually may not account for reduced WCT numbers, but cumulatively caused the decline.

Ecofish Research Ltd. (Ecofish) was asked to provide support as Subject Matter Experts (SME) for evaluation of stressors. One potential stressor on WCT in the UFR is habitat availability in relation to flow. This report uses habitat time series modelling to evaluate if and to what extent changes in habitat availability due to instream flow conditions contributed to the WCT decline. Discussion of additional

[5] Abundance estimates for adults / sub-adults are based on surveys in September of each year, while estimates for juveniles are based on surveys in August.

[6] Implies the single acute stressor acted between September 2017 to September 2019.

[7] Implies a chronic slow change in the stressor (using 2012-2019 timeframe, data dependent).

aspects of flow-related changes to habitat during the Decline Window is provided in other SME reports, specifically the Fish Passage report (Harwood *et al.* 2021), the Overwintering report (Whelan *et al.* 2021), the Ramping and Stranding report (Faulkner *et al.* 2021a), and the Channel Dewatering report (Faulkner *et al.* 2021b), and discussion of the physical environment during the Decline Window is provided in the Climate, Temperature, and Streamflow Trends report (Wright *et al.* 2020b).

1.1. Background

1.1.1. Overall Background

This document is one of a series of SME reports that supports the overall Evaluation of Cause (EoC) of the UFR WCT population decline and synthesizes information across multiple stressors and potential interactions (EoC Team 2021). For general information, see the preceding Reader's Note. Map 1 provides an overview of the project area.

1.1.2. Report Background

Changes to river water depth and velocity, resulting from increased or reduced streamflow, have the potential to alter the availability of suitable habitat for fish (Shirvell 1994), which may in turn have implications for abundance and population size. For instance, numerous studies (e.g., Fausch 1984, Fausch and White 1986, Hughes and Dill 1990) have hypothesized that juvenile salmonids select optimal stream positions with abundant drift food supply. When streamflows change there is a shift in spatial patterns of water velocity, and as a consequence, the locations of maximum net energy gain for fish also change (Bravender and Shirvell 1989), which result in fish redistributing themselves to new optimal positions. If habitat with suitable hydraulic characteristics becomes limited in area and distribution, fish may become crowded into the limited available habitat. This crowding of fish into smaller areas may directly reduce abundance through increased competition of limited resources among conspecifics (i.e., extending use beyond the carrying capacity of the habitat). Further, if habitat with suitable hydraulic characteristics is limited to a specific segment of stream, then fish concentrated within this segment could make a large proportion of the population vulnerable to other stressors at once (e.g., localized environmental changes or impacts such as spills, predation, stranding, and icing). Figure 1 describes how extreme flows, which result in decreased habitat availability and increased fish concentration, could result in reduced fish abundance either through competition for limited habitat or due to location-specific impacts. The hypothesized effects of changes in hydraulic habitat availability on fish abundance are dependent on the assumption that availability of suitable hydraulic habitat is a primary limiting factor for adult and juvenile fish abundance, which was assumed for this assessment.

Flow-related changes to fish habitat can result from natural factors (e.g., weather), land use changes, or water withdrawal for mining or other uses. Given the potential effect that stream hydrology (depth and velocity) can have on habitat availability and suitability for fish, flow-related changes in hydraulic habitat availability during the Decline Window have the potential to have caused or contributed to the WCT population decline. An assessment was therefore conducted to determine, first, if there were differences in hydraulic habitat availability (through changes in water depth and velocity) during the Decline Window, and second, if any such differences would be sufficient to explain the observed WCT population decline. It should be noted that this assessment evaluated whether availability of hydraulically suitable habitat was different during the Decline Window relative to prior years, and did not attempt to evaluate the amount of habitat that is sufficient to sustain the WCT population or prescribe a flow regime that is sufficient to sustain this population, and is not intended to assess the effect of Teck Coal water use on availability of hydraulically suitable habitat.

1.1.3. Author Qualifications

Todd Hatfield, Ph.D., R.P.Bio.

This project is being led by Todd Hatfield, Ph.D., a registered Professional Biologist and Principal at Ecofish Research Ltd. Todd has been a practising biological consultant since 1996 and he has focused his professional career on three core areas: environmental impact assessment of aquatic resources, environmental assessment of flow regime changes in regulated rivers, and conservation biology of freshwater fishes. Since 2012, Todd has provided expertise to a wide array of projects for Teck Coal: third party review of reports and studies, instream flow studies, environmental flow needs assessments, aquatic technical input to structured decision making processes and other decision support, environmental impact assessments, water licensing support, fish community baseline studies, calcite effects studies, habitat offsetting review and prioritizations, aquatic habitat management plans, streamflow ramping assessments, development of effectiveness and biological response monitoring programs, population modelling, and environmental incident investigations.

Todd has facilitated technical committees as part of multi-stakeholder structured decision making processes for water allocation in the Lower Athabasca, Campbell, Quinsam, Salmon, Peace, Capilano, Seymour and Fording rivers; he has been involved in detailed studies and evaluation of environmental flows needs and effects of river regulation for Lois River, China Creek, Tamihi Creek, Fording River, Duck Creek, Chemainus River, Sooke River, Nicola valley streams, Okanagan valley streams, and Dry Creek. Todd was the lead author or co-author on guidelines related to water diversion and allocation for the BC provincial government and industry, particularly as related to the determination of instream flow for the protection of valued ecosystem components in BC. He has worked on numerous projects related to water management, fisheries conservation, and impact assessments, and developed management plans and guidelines for industry and government related to many different development types. Todd is currently in his third 4-year term with COSEWIC (Committee on the Status of Endangered Wildlife in Canada) on the Freshwater Fishes Subcommittee.

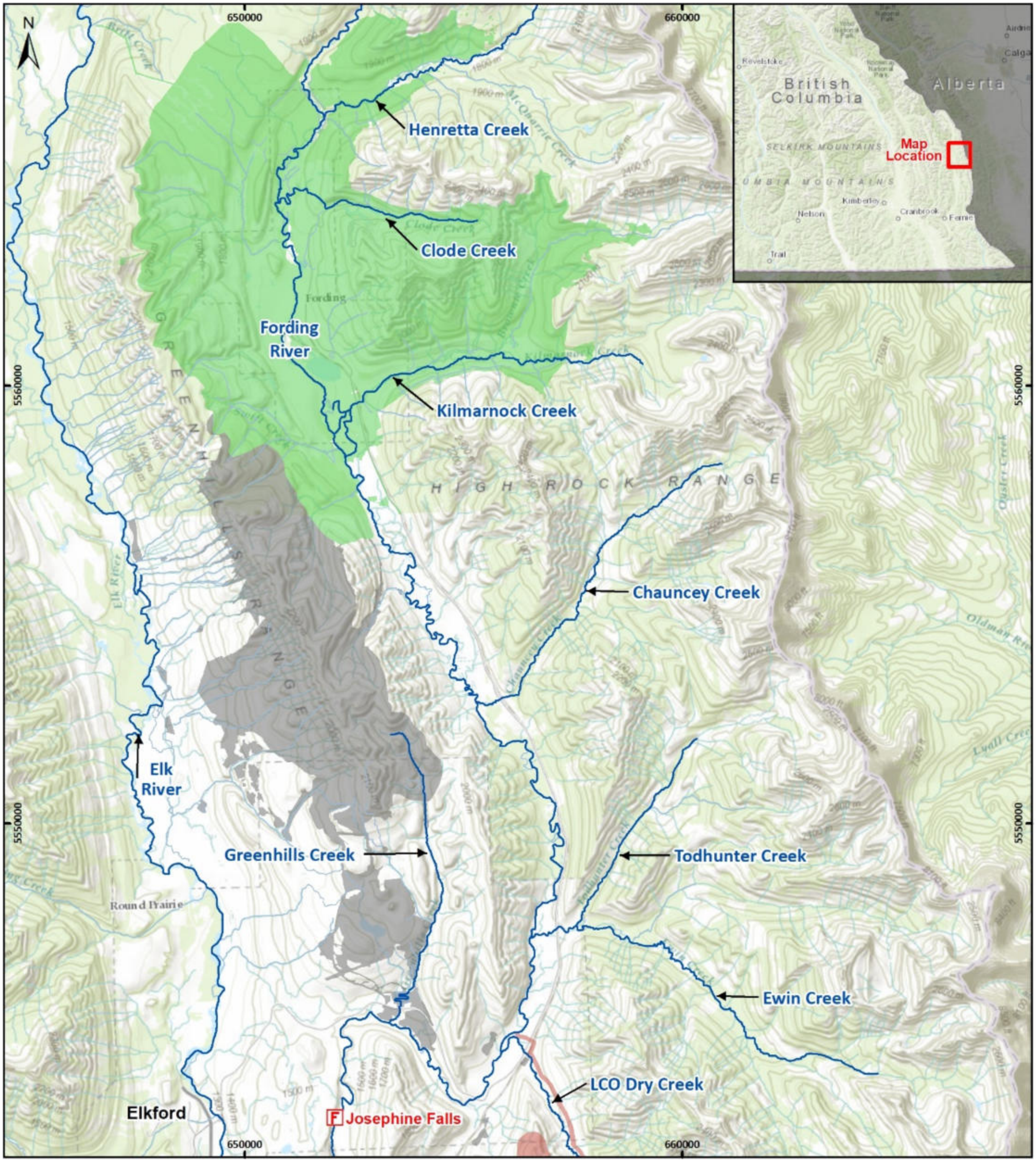
Katie Healey, M.Sc., P. Geo. – Instream Flow Scientist

Katie Healey is a Professional Geoscientist with a Masters in Earth and Ocean Sciences from the University of Victoria. As a Senior Scientist at Ecofish Research Ltd., Ms. Healey has 12 years of experience assessing the effects of water use on fish habitat in British Columbia.

Katie has conducted hydraulic habitat modelling to develop habitat-flow relationships for ~40 streams, completed instream flow effects assessments for these streams according to provincial guidelines, supported proponents in addressing regulatory requirements related to stream flow and flow ramping, and provided third-party technical reviews of instream flow studies. Katie has extensive experience in programming applications for habitat assessment, including instream flow modelling, and development of a desktop application for applying the provincial environmental flow needs (EFN) framework on behalf of BC for Ministry of Environment.

Katie is Technical Lead for instream flow studies on behalf of Teck Coal for all five of the Elk Valley operations: Dry Creek (Line Creek Operations, 2016), Corbin Creek (Coal Mountain Operations, 2019-2020), Fording River (Fording River Operations, 2019-2020), Thompson Creek and Porter Creek (Greenhills Operations, 2019-2020), and Goddard Creek (Elkview Operations, 2019-2020). For Dry Creek, Katie conducted a third-party review of initial hydraulic habitat modelling (2013) and led an instream flow study to develop new habitat-flow relationships (2016) used to evaluate options for the Dry Creek Water Management System (DCWMS). Similarly, on Corbin Creek, Katie conducted a third-party review of government-led hydraulic habitat modelling and environmental flows recommendations (2018) and is leading an instream flow study to develop revised habitat-flow relationships and updated environmental flow targets for Corbin Creek (2019-present). Katie led development of habitat-flow relationships for Fording River (2019-2020) to evaluate the flow requirements attached to water licences held by Teck Coal, and for Goddard Creek (2020) to assess water augmentation alternatives for the Elkview Operations Goddard Creek Tunnel Water Diversion project. Finally, Katie is Technical Lead for current instream flow on Teck Coal's proposed Castle/Turnbull East (TBE) project and Greenhills permitting projects, which include instream flow studies to assess flow-related effects of landscape changes and water use on Fording River, Chauncey Creek, Thompson Creek, and Porter Creek.

Upper Fording River Evaluation of Cause



Legend

Permit Regions

- FRO
- GHO
- LCO
- Falls
- Streams
- Paved Road
- Provincial Border

MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

0 2 4 km

Scale: 1:125,000

NO.	DATE	REVISION	BY
1	2020-06-04	1229_FRD_EvaluationOfCause_3787_20200604	COA
2			
3			
4			
5			

Date Saved: 2020-06-04
Coordinate System: NAD 1983 UTM Zone 11N

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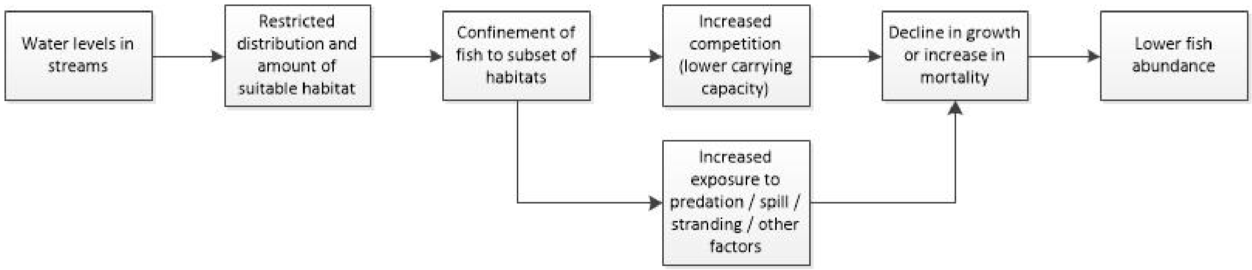
Map 1

Path: M:\Projects-Active\1229_EVWQP\MXD\Overview\1229_FRD_EvaluationOfCause_3787_20200604.mxd

Figure 1. Pathway of effect in which altered stream flows lead to low fish abundance through confinement of fish within a reduced habitat area.



1.2. Objectives

Given the potential effects of streamflow on availability of hydraulically suitable habitat, the objective of this report is to investigate if, and to what extent, changes in hydraulic habitat occurred during the Decline Window that could explain the reduction in abundance of WCT. The results of our assessment of potential effects of changes in habitat availability are intended to support the evaluation of Overarching Hypothesis #1 and Hypothesis #2 (Section 1).

1.3. Approach

We investigated the potential role of changes to hydraulic habitat availability on reduced WCT abundance by first determining whether habitat availability was reduced during critical life history periods of WCT during the Decline Window relative to the years preceding the Decline Window (2014-2016). This involved:

- Developing habitat-flow relationships in the UFR for the life stages of WCT using data collected for the Operational Environmental Monitoring Plan (OEMP) for Fording River Operations (FRO);
- Calculating habitat time series by year based on the habitat-flow relationships and historical flow data for the UFR; and
- Comparing habitat time series during critical periods, as determined by periodicity of WCT in the UFR (i.e., overwintering, spawning, and summer rearing; Table 1) between the Decline Window (2017-2019) and the preceding years (2014 to 2016).
  - Migration between summer rearing habitats and overwintering habitats is also a critical period and evaluated separately in the Fish Passage report (Harwood *et al.* 2021).

The metric used to quantify habitat availability for WCT was weighted usable area (WUA). WUA is a measure of the stream area that represents available habitat for fish based on hydraulic characteristics (velocity and depth) and habitat suitability criteria (HSC), which differ by fish species and life stage.

Once hydraulic habitat availability was quantified, we evaluated whether habitat availability was lower during the Decline Window relative to the preceding years and whether reductions were sufficient to cause (overarching hypothesis #1) or contribute (overarching hypothesis #2) to the decline in WCT abundance. Specifically, we identified requisite conditions that would have to be met for reduced hydraulically suitable habitat to cause or contribute to the observed WCT decline. We identified and evaluated requisite conditions in relation to the following characteristics for any documented reduction in hydraulic habitat availability, as followed.

- Intensity: to what degree was habitat availability reduced (i.e., was the magnitude of the change large enough to potentially result in reduced WCT abundance);
- Timing: when was habitat availability reduced (i.e., was it reduced during the Decline Window and critical WCT time periods (overwintering, spawning, summer rearing) relative to previous years);
- Duration: for how long was habitat availability reduced (i.e., was it reduced for long enough to have the potential to result in reduced abundance);
- Location: where was habitat availability reduced (i.e., was it within the UFR where fish are present); and
- Spatial Extent: over how great an area was habitat availability reduced (i.e., was it within a large proportion of the habitat within the UFR).

Table 1. Periodicity of Westslope Cutthroat Trout in the upper Fording River watershed.

Life Stage	Jan				Feb				Mar				Apr				May				Jun				Jul				Aug				Sep				Oct				Nov				Dec			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Spawning migration													■	■	■	■	■	■	■	■																												
Spawning																			■	■	■	■	■	■	■	■																						
Incubation (egg & alevin)																			■	■	■	■	■	■	■	■	■	■	■	■	■	■																
Summer Rearing (≥7° C)																											■	■	■	■	■	■	■	■	■	■												
Over-wintering migration																																	■	■	■	■	■	■										
Over-wintering	■	■	■	■	■	■	■	■	■	■	■	■																											■	■	■	■	■	■	■	■	■	■
Juvenile migration[1]																																																

[1] No defined periodicity

2. METHODS

2.1. Habitat-Flow Relationships

Habitat-flow relationships were developed to quantify suitable habitat for comparison between the Decline Window and other time periods. These habitat-flow relationships were developed from field sampling and hydraulic modelling that was completed in the instream flow study (IFS) conducted under the OEMP for FRO consumptive water licences (Wright *et al.* 2020a, Healey *et al.* 2021). Detailed methods for the Fording River IFS are provided in Appendix A and are summarized below.

Empirical measurements for the UFR IFS were completed between June and November 2019 following the guidance provided for streams in British Columbia in Lewis *et al.* (2004). Forty cross-sectional habitat transects were established between the Henretta Lake outlet and Chauncey Creek confluence (Map 2). Locations for habitat transects were selected based on information on the types of habitat important for WCT, and locations of such habitat, from Cope *et al.* (2016). Due to the length of river in the study area and the change in river morphology along this length, the UFR was divided into three zones. Henretta Creek downstream of the Henretta Lake outlet received two transects. The Fording River zone between Henretta Creek and Kilmarnock Creek (segments S8 and part of S9 in Cope *et al.* 2016) received 19 transects; this zone is over-widened, riparian vegetation is poor, and the river channel has been disturbed by flooding and mining activities (Cope *et al.* 2016). The zone between Kilmarnock Creek and Chauncey Creek (Segments S6 and S7 in Cope *et al.* 2016) received 19 transects; this zone has less physical disturbance and provides important deep habitat in segment S6, downstream of FRO. Transects were placed within mesohabitats (pool, glide, riffle, run) according to the distribution of the mesohabitats in these zones. For each transect, cross-sectional elevation and substrate data were recorded at a minimum of 20 verticals, and water level loggers were installed to record measurements of water surface elevation during the study period. For each transect, measurements of water depth, velocity, and water surface elevation were recorded at high, moderate and low flow conditions, photographs were taken to document field conditions (Appendix B), and discharge measurements were completed at nearby sites in the UFR during sampling to provide estimates of discharge at the transects.

The IFS transect data were screened for quality (Appendix C) and then used to complete hydraulic habitat modelling for the UFR habitat transects according to the following steps:

1. Stage-discharge relationships were fit to each transect using R statistical software.
2. The IFS data and stage-discharge relationships were input into the System for Environmental Flow Analysis (SEFA) habitat modelling software (Jowett *et al.* 2014).
3. The hydraulic model was run to simulate water depth and transect-average hydraulic properties for simulation flows ranging from 0 to 10 m^3/s, and these simulations were compared to the field measurements to ensure the model was accurately reproducing the observed hydraulics (Appendix D).
4. Cross-sectional velocity profiles were modelled across the range of simulation flows, using the three cross-sectional velocity profiles that were measured in the field (i.e., 3 velocity models for each transect).
5. Habitat suitability criteria (HSC) were applied to the simulated water depth and velocity data, and the observed substrate conditions, across each transect.

6. Weighted usable width (WUW) was calculated for each transect, for each simulation flow, velocity model and HSC:

   $$WUW_{dvs} = \Sigma_i^n (W_i*D_i*V_i*S_i)$$

   Where W_i is the width of computational cell *i* on the transect, D_i is the suitability of depth at cell *i*, V_i is the suitability of velocity at cell *i*, and Si is the suitability of substrate at cell *i*

7. Habitat-flow relationships for individual velocity models were compared to a composite habitat-flow relationship consisting of the average of all three velocity models.

8. The composite (average) WUW-flow relationship was selected for each transect/HSC because:

   a. The shapes of the habitat-flow relationships were found to be relatively insensitive to model choice for the selected HSC (see below), i.e., the habitat-flow relationships for individual transects/HSC had similar shape regardless of velocity model; and

   b. Attempting a more complex blending of velocity models (e.g., using a different velocity model for lowest, moderate, and highest sample flow conditions) introduced irregular and artificial features into the ascending portion of the habitat-flow relationship, changing their shape.

To develop habitat-flow relationships for the EoC, life stage period-specific HSC were identified and calculations were made to account for differences between flow at transects and hydrometric gauges (hydrometric gauges used were FR_HR1 for Henretta Creek and FR_FRNTP for UFR), as summarized below:

1. Selection of HSC – provincially recommended HSC do not exist for WCT and there has been criticism of the HSC specific to UFR WCT (Golder 2014, DFO 2015) so proxy curves needed to be selected (Table 2). WUW-flow relationships were calculated for several HSC (see Appendix A) and the results of these calculations were reviewed to identify HSC suitable for evaluation of WCT habitat availability on the UFR:

   a. For spawning, provincially recommended HSC for Steelhead spawning provided by Ptolemy (2001) were used; these HSC were developed during BC Hydro Water Use Planning (WUP) via a Delphi process and hence reflect the pooling of expert opinion (albeit for a species other than WCT). These HSC predict spawning habitat at deeper water depths than the anadromous Cutthroat Trout criteria from Ptolemy (2001) but predict similar water depth preferences as those in Golder (2014). The selected HSC predict maximum spawning habitat around 3-4 m^3/s at FR_FRNTP, which is similar to post-freshet flows that typically occur late during the spawning period.

   b. For summer rearing, provincially recommended HSC for Steelhead parr provided by Ptolemy (2001) were used; these HSC were also developed under the WUP Delphi process. These velocity HSC are identical to the WCT Adult Holding and Juvenile

HSC in Golder (2014). The depth HSC are identical to the WCT Adult Holding criteria in Golder (2014) but differ from the Golder (2014) WCT Juvenile HSC. The Ptolemy (2001)/Golder (2014) adult Holding criteria were selected to represent rearing preferences for both juvenile and adult WCT.

c. For overwintering, provincially-recommended HSC were not available so HSC were used that were developed by Golder (2014) for WCT overwintering using data collected within the Elk Valley watershed. These HSC produce the greatest WUWs for transects that are suitable for overwintering (i.e., deep pools) and highly suitable habitat is predicted at flows that are typical for overwintering in UFR (i.e., < 1 m^3/s). No provincially-recommended overwintering criteria were available for comparison; we also note that these criteria have not been validated, and have not been accepted by regulators or Ktunaxa Nation Council.

2. Selection of zones for modelling – habitat-flow relationships were developed separately for Fording River between Henretta Creek and Kilmarnock Creek, and Kilmarnock Creek to Chauncey Creek. For overwintering and spawning, habitat use is greatest upstream of Kilmarnock Creek in Clode Flats segments upper S8/lower S9, and downstream of Kilmarnock Creek in the oxbows segment S6, so both Fording River zones (upstream and downstream of Kilmarnock Creek) were selected for modelling. Summer rearing has been observed throughout the UFR and the habitat-flow relationships for both Fording River zones, as well as the Henretta Creek zone, were used for summer rearing analysis.

3. Comparison of flow at transects and hydrometric gauges – habitat-flow relationships are developed based on flow at the transect, which can be different from the flow data available for analysis from the hydrometric gauges due to longitudinal differences along the river channel (e.g., inflow, water withdrawal, areas with substantial hyporheic exchange), or because flow is split between multiple channels. FR_FRNTP is a hydrometric gauge maintained by Teck Coal that has recorded data seasonally since 1997, and year-round since 2014, providing time series of discharge prior to and within the Decline Window. For each transect in the Fording River, the percentage of FR_FRNTP discharge was calculated and used to develop a relationship between discharge at the location of the transect and FR_FRNTP discharge (Appendix D). Flow at the Henretta Creek transects was assumed to be the same as nearby FR_HC1; this assumption was confirmed during field sampling.

4. Combination of transect habitat-flow relationships – For each zone, the average relationship between WUW and hydrometric gauge discharge was calculated for each mesohabitat unit type (pool, riffle, glide/run). Henretta Creek (n=2) and the split channels in S6 (n=3 each) were each treated as single mesohabitat unit types, as there were insufficient transects to allow a stratified approach within these locations. The mesohabitat unit average habitat-flow relationships were multiplied by the corresponding unit lengths to obtain weighted usable area

(WUA, 1000 m²). Where necessary, a linear extrapolation was applied to the habitat-flow relationships beyond the greatest flow modelled (10 m³/s at the transect).

Table 2. Habitat suitability selected for EoC habitat time series analysis.

Life Stage	Age		
	Fry (0+)	Juvenile (1+)	Adult (2+)
Overwintering			Golder (2014)
Spawning			Steelhead Spawning (Ptolemy 2001)
Summer Rearing		Steelhead Parr (Ptolemy 2001)	Steelhead Parr (Ptolemy 2001)[1]

[1] Identical to adult holding HSC in Golder 2014

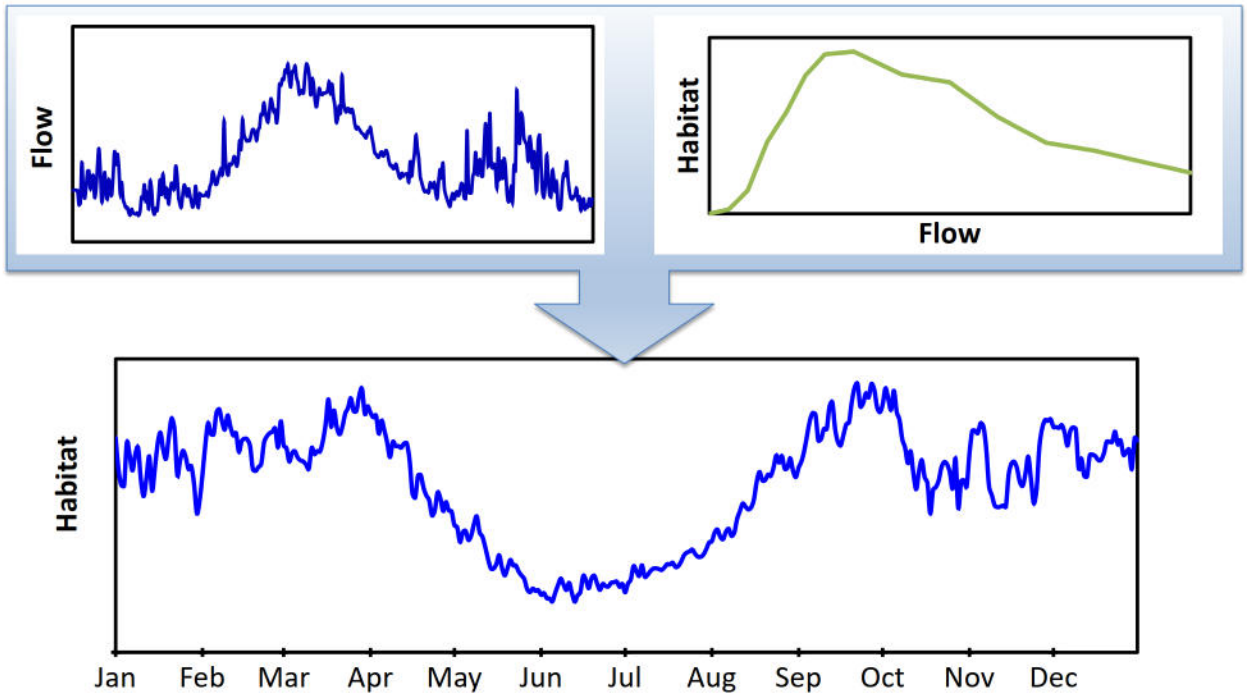
2.2. Evaluation of Cause

2.2.1. Analysis for the Evaluation of Cause

Flow-related changes to habitat availability during the Decline Window were assessed relative to habitat availability in the years preceding the Decline Window (2014-2016) via a habitat time series analysis. Habitat time series were calculated for overwintering, spawning, and summer rearing using the habitat-flow relationships described in Section 2.1, and flow data for hydrometric gauges FR_FRNTP and FR_HC1 provided by Teck Coal. A conceptual diagram illustrating a habitat time series calculation is provided in Figure 2.

For each habitat time series, the average habitat (WUA) during the associated critical period (Table 1) was calculated for each year (2014-2019 for UFR, 2015-2019 for Henretta Creek; 2014 data for Henretta Creek were not available at the time of writing). To characterize habitat availability during the Decline Window relative to other years, the average habitat for each year was tabulated according to life stage and location, and the Decline Window was compared to the average habitat across all years (e.g., each year between 2017-2019 in comparison to all other years).

Figure 2. Conceptual diagram of habitat time series calculation.



2.2.2. Requisite Conditions to Cause or Contribute to the Decline

Requisite conditions were defined as the circumstances that would need to be met for reduction in available habitat to cause or contribute to the observed WCT decline. The analyses described above were used to evaluate habitat availability during critical WCT periods and determine whether requisite conditions were met. As summarized in

Table 3, requisite conditions were based on spatial (extent and location) and temporal (timing and duration) aspects of habitat availability reduction and on its intensity (magnitude). Specifically, for any detected loss of habitat availability to be responsible for the documented WCT decline, a reduction in availability of suitable habitat must have occurred during a critical WCT life history period within the Decline Window (September 2017 to September 2019) and within some or most of the UFR, and it must have been substantive and prolonged (magnitude, spatial extent, and duration must have been sufficient to have caused the observed decrease in abundance). Further, if a reduction in availability of suitable habitat was the cause of the decrease in WCT abundance, the effect (reduced abundance) would be expected to occur within a short time of this reduction (i.e., the mechanisms causing the reduced abundance, such as competition or location-specific impacts, would be fast acting if a substantial part of the population was lost). For the purposes of the EoC, we have assumed that reductions in habitat availability would act quickly though not instantly, and population effects would be proportional to average habitat availability during the relevant life stage period. For example, we assume a reduction in average spawning habitat availability would manifest in lower fry counts during the same year, or that a reduction in average summer rearing habitat availability would manifest as lower adult and juvenile abundance within the same year. This assumption is thought to be conservative, since habitat availability losses likely act more gradually and short-term losses are likely to be more tolerated by fish than longer-term losses of the same magnitude.

A potential reduction in available habitat due to flow could be the single cause (stressor) of the observed reduction in WCT abundance (Overarching Hypothesis #1) but may also be only one of a number of potential causes (Overarching Hypothesis #2). Thus, the greater the extent of any identified reduction of availability of suitable habitat during the September 2017 to September 2019 period compared to pre-September 2017, the more likely it is that flow-related changes to habitat availability contributed to the decline in WCT abundance, provided that this conclusion is consistent with other lines of evidence.

Characterization of the various components of the requisite conditions were identified as follows.

- Intensity – addressed by visually comparing habitat quantity (WUA) between years (in plots) and comparing numerical averages (in table).
- Timing – assessed by focusing on the timing of critical periods for each life stage of WCT.
- Duration – evaluated by calculating a habitat time series from daily flow data from which duration (i.e., number of days) of reduced habitat can be determined.
- Location – explicitly addressed by analyzing three different UFR zones (Henretta Creek, UFR between Henretta and Kilmarnock, UFR downstream of Kilmarnock). Locations assessed represent habitat important for WCT based on Cope *et al.* (2016).
- Spatial extent – addressed implicitly by including multiple transects within each assessment zone (n≥4, except for Henretta Creek where n=2).

Table 3. Requisite conditions for reduction in available habitat due to flow-related changes to cause or contribute to the WCT population decline.

Factors	Requisite Conditions
Intensity	Suitable habitat availability is substantively reduced during the Decline Window relative to previous time periods
Timing	Reduction in suitable habitat availability occurred during the Decline Window (i.e., is temporally consistent with the observed decline) and during critical time periods for WCT
Duration	Suitable habitat availability is reduced for a prolonged period (substantive proportion of time) within critical WCT life history periods
Location	Suitable habitat availability is reduced in locations that are important for WCT within the UFR
Spatial Extent	Suitable habitat availability is reduced over much or most of the UFR

3. RESULTS

3.1. Habitat-Flow Relationships

The estimated relationships between habitat availability (weighted usable area, WUA) and flow for the three identified life stages are presented in Figure 3 to Figure 5. Included are the relationship between transect weighted usable width (WUW) and flow at the transect (top left), relationship between transect WUW and flow at the hydrometric gauge used for habitat assessment (FR_HR1 for Henretta Creek and FR_FRNTP for UFR mainstem; may be different from the transect flow; top right), relationship between average WUW and flow for each mesohabitat unit type (bottom left), and relationship between WUA and flow over the entire zone (bottom right). The habitat-flow relationships in the bottom right plots of Figure 3 to Figure 5 (black lines) were used to complete the habitat time series analysis for Evaluation of Cause (Section 3.2).

Figure 3. **Habitat-flow relationships used to estimate habitat time series for overwintering in Fording River a) between Henretta Creek and Kilmarnock Creek, and b) between Kilmarnock Creek and Chauncey Creek.**

a) Fording River between Henretta Creek and Kilmarnock Creek

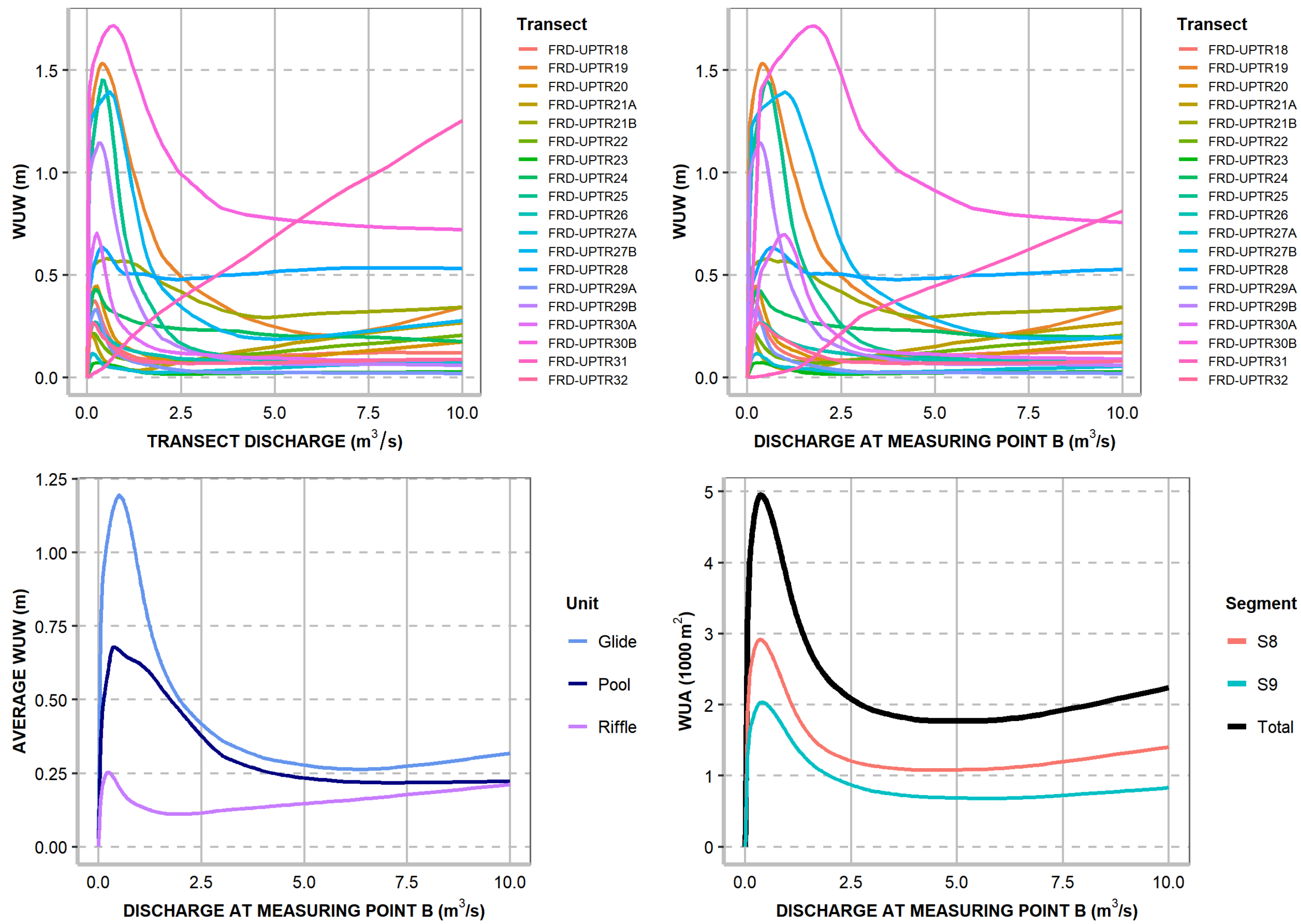


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Figure 3. Continued.

b) Fording River between Kilmarnock Creek and Chauncey Creek

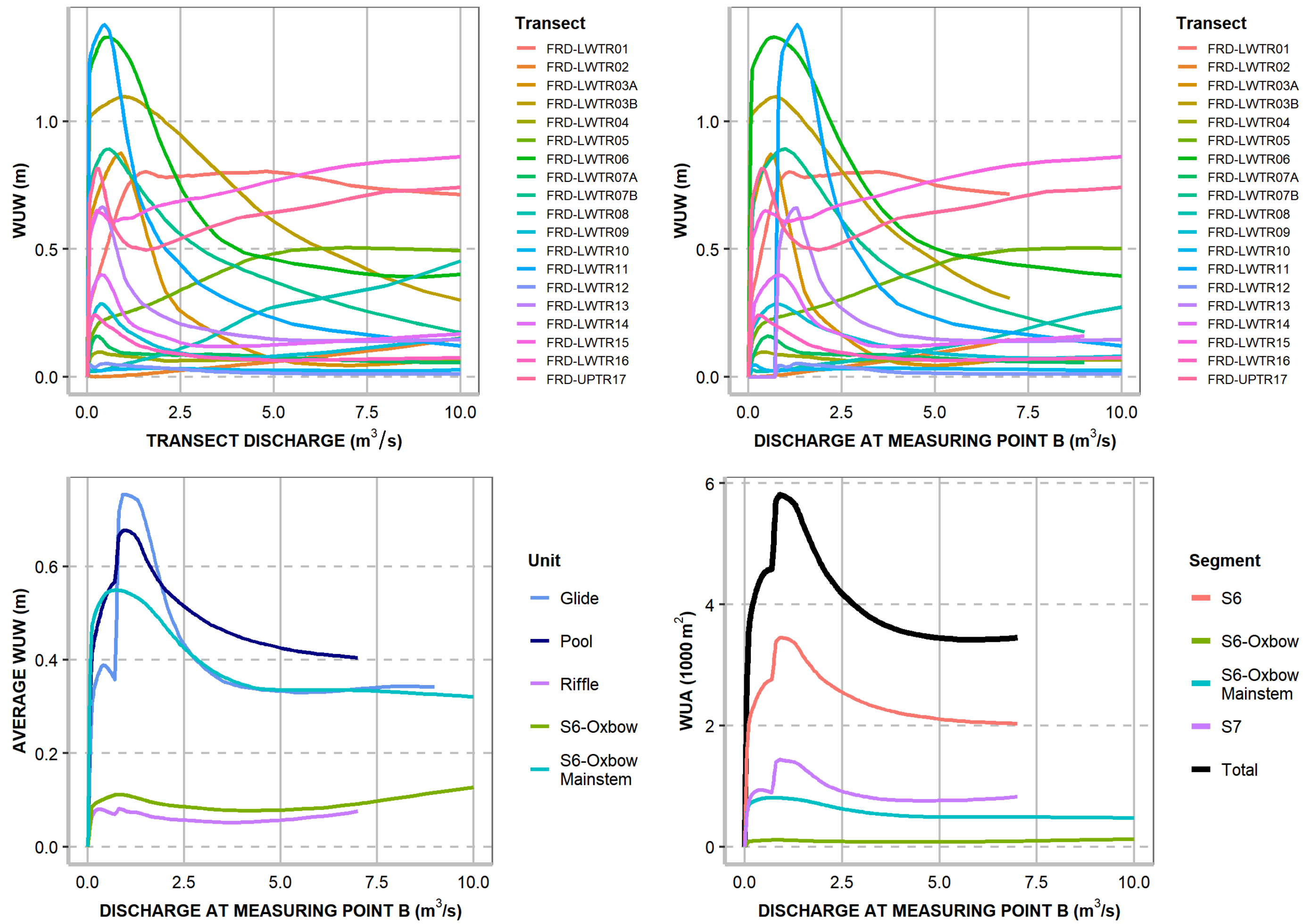

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Figure 4. Habitat-flow relationships used to estimate habitat time series for spawning in Fording River a) between Henretta Creek and Kilmarnock Creek, and b) between Kilmarnock Creek and Chauncey Creek.

a) Fording River between Henretta Creek and Kilmarnock Creek

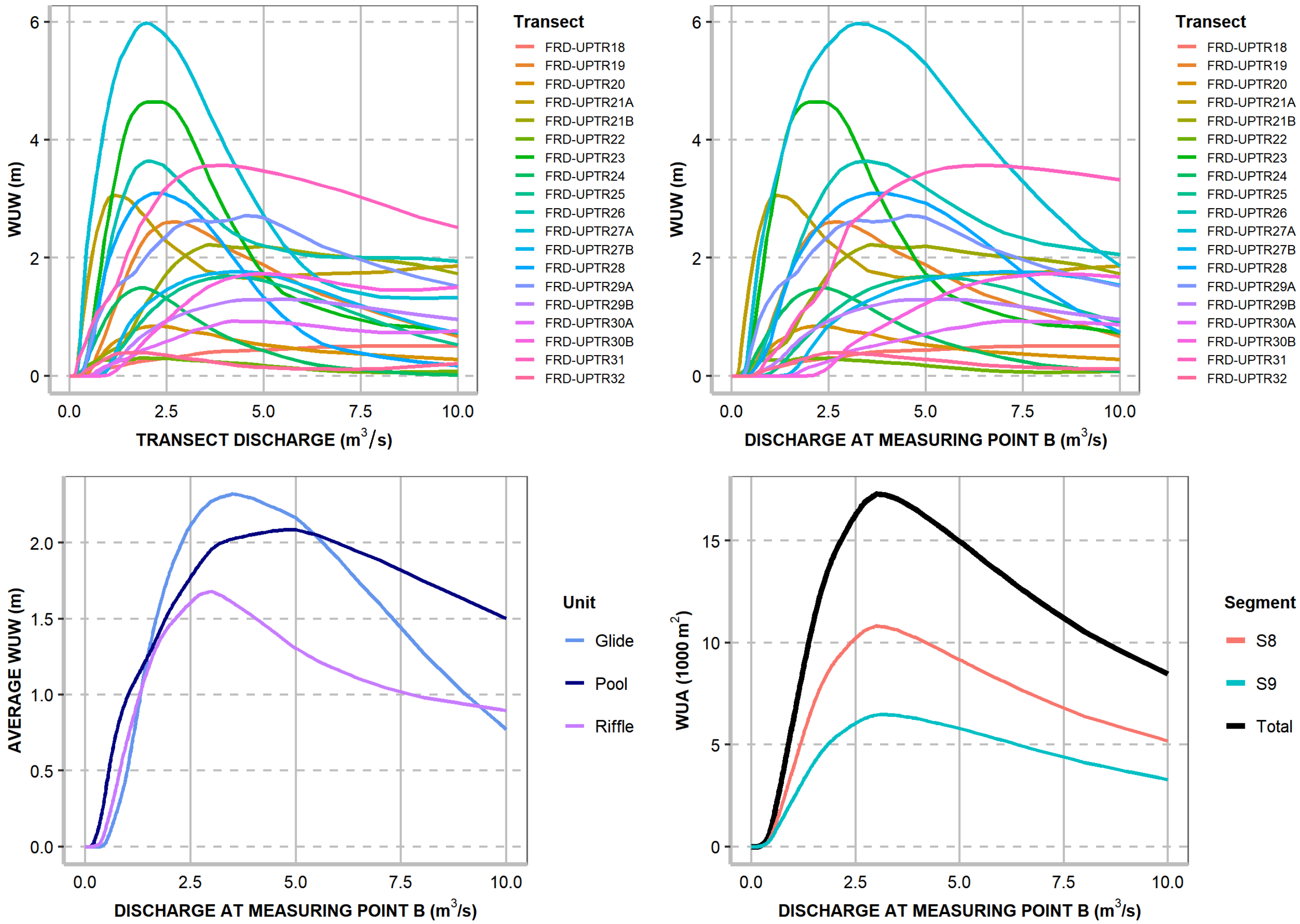


Figure 4. Continued.

b) Fording River between Kilmarnock Creek and Chauncey Creek

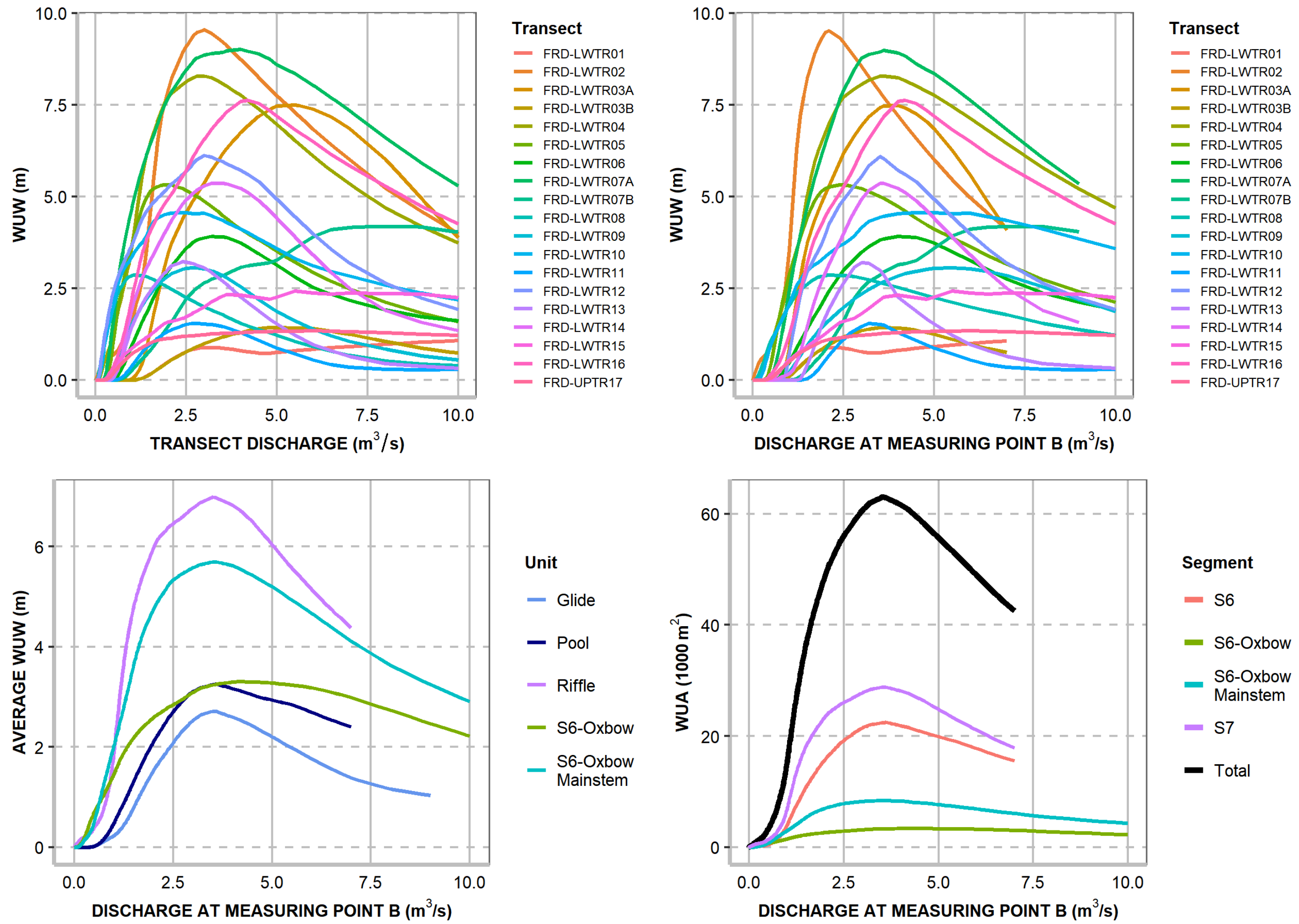


Figure 5. Habitat-flow relationships used to estimate habitat time series for summer rearing in Fording River a) between Henretta Creek and Kilmarnock Creek, b) between Kilmarnock Creek and Chauncey Creek, and c) in Henretta Creek downstream of Henretta Lake outlet.

a) Fording River between Henretta Creek and Kilmarnock Creek

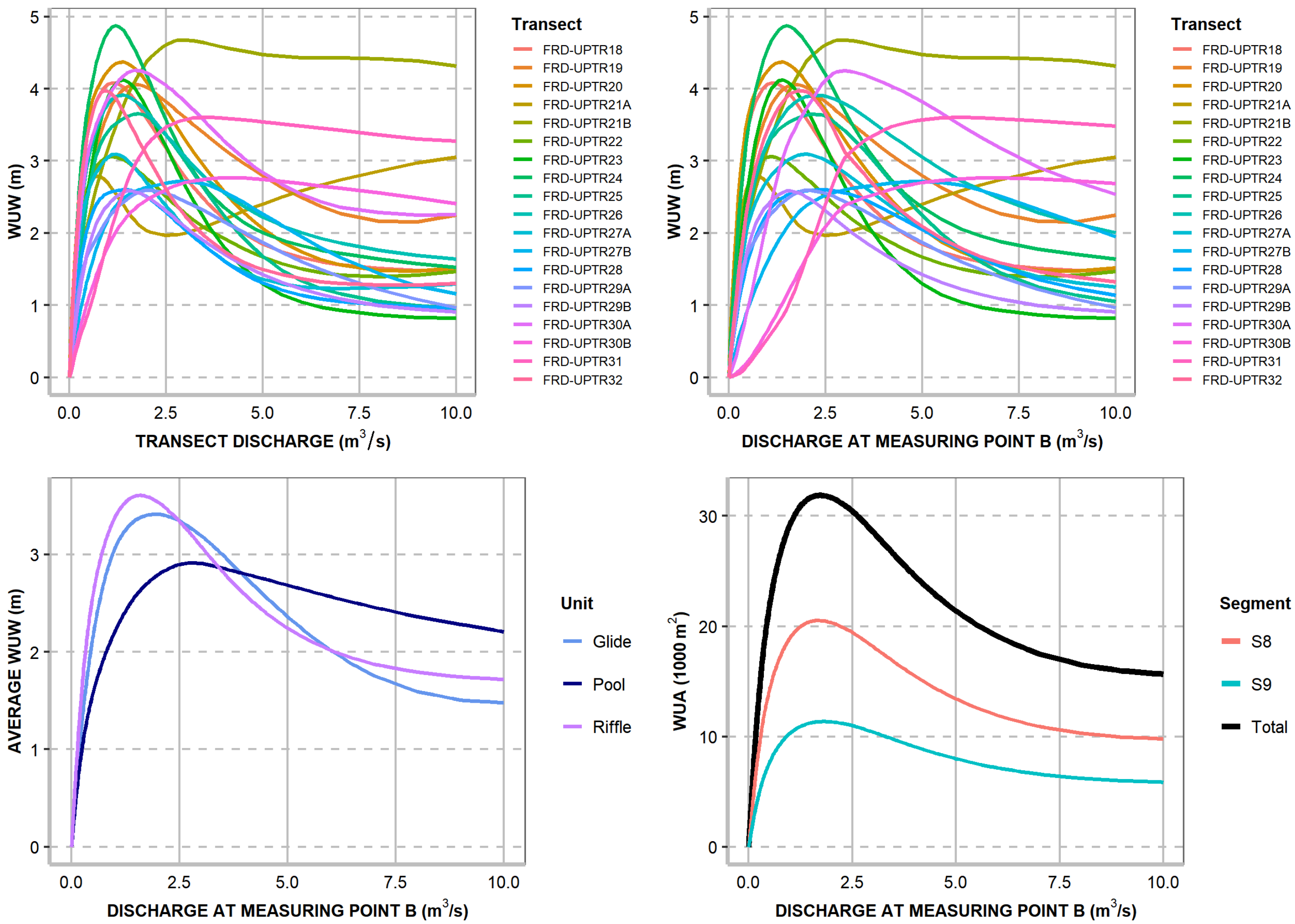


Figure 5. Continued.

b) Fording River between Kilmarnock Creek and Chauncey Creek

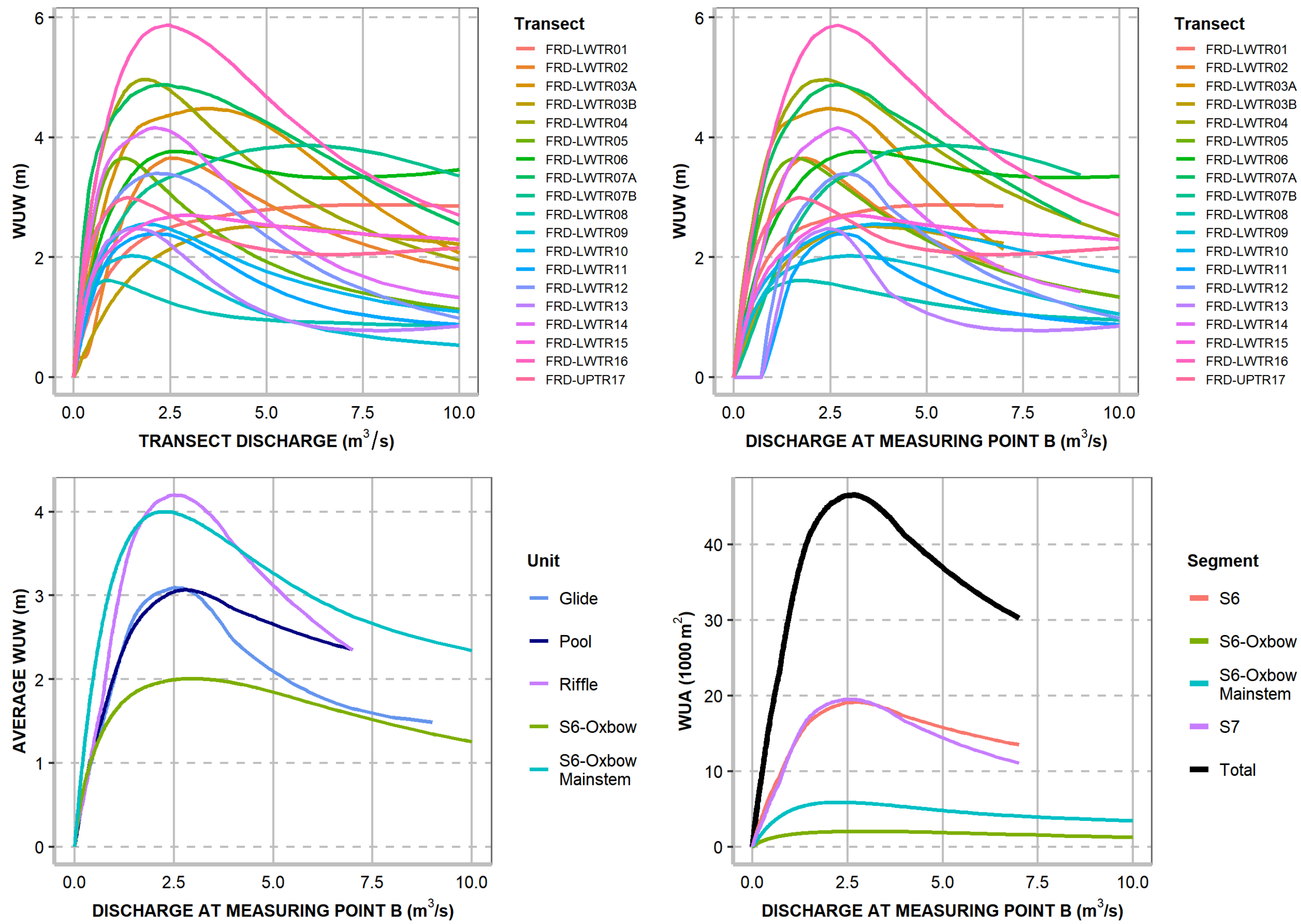
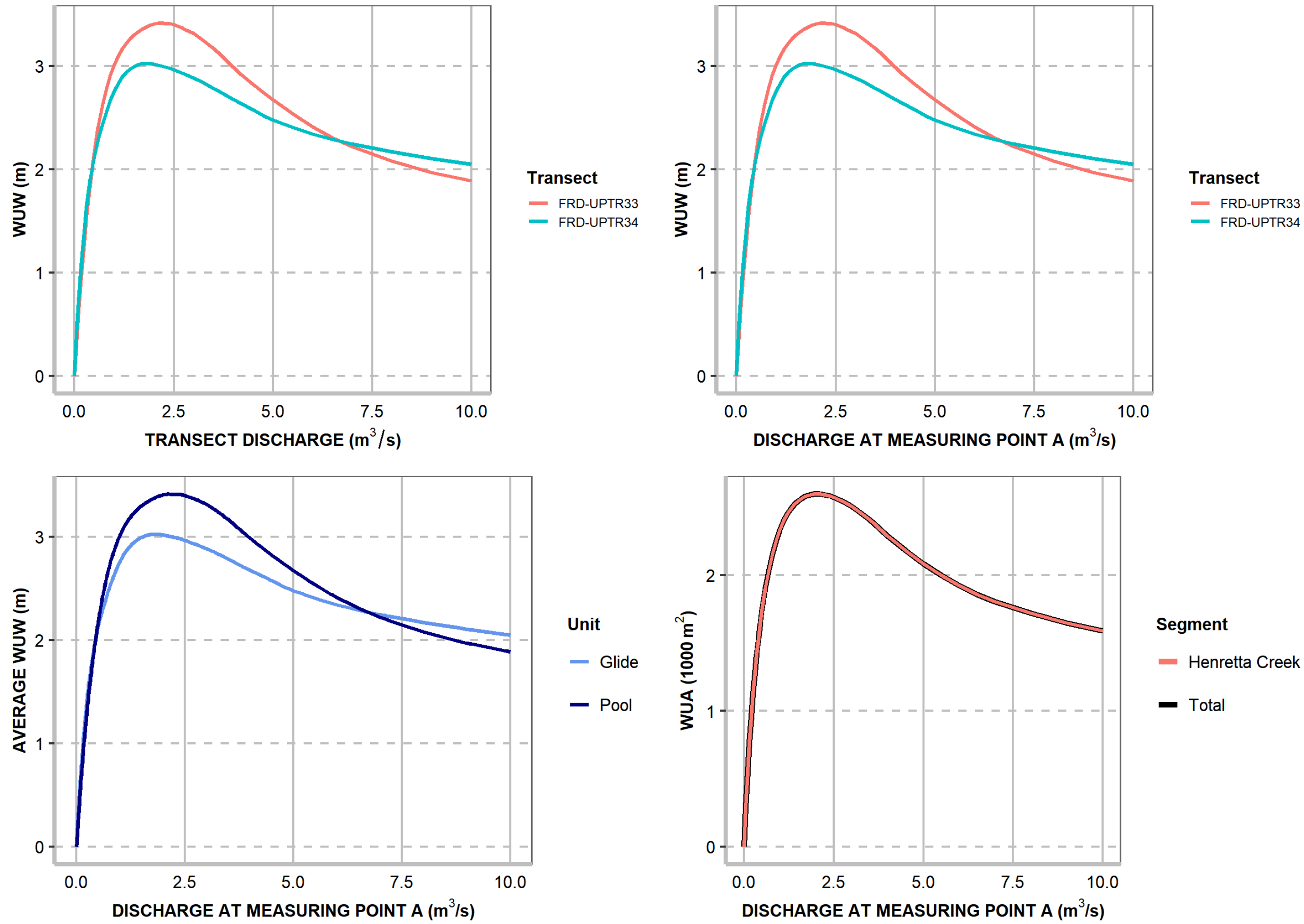


Figure 5. Continued.

c) Henretta Creek downstream of Henretta Lake outlet



3.2. Evaluation of Cause

Time series of habitat availability (WUA) and discharge are provided in Figure 6, Figure 7, Figure 8, and Figure 9. These figures provide a comparison of habitat and discharge during the Decline Window (Sept 2017-Sept 2019) relative to other years. Table 4 provides: a) the average WUA for each life stage, river zone, and year; b) a comparison of the WUA in each year to the average across all years; and c) completeness of the data set used for these calculations.

Overwintering habitat availability during 2017/2018 (Figure 6, grey line) and 2018/2019 (Figure 6, yellow line) were similar to other years for both zones (i.e., upstream and downstream of Kilmarnock Creek; mean availability within years was 95%-106% of average across all years; Table 4b). Upstream of Kilmarnock Creek, the model predicts that overwintering habitat typically increases as flow declines, and remains relatively abundant until the onset of high flows during freshet. For example, upstream of Kilmarnock Creek in 2019 there was a decline in habitat availability in late March due to elevated discharge (Figure 6c). Downstream of Kilmarnock Creek, the model predicts a decline in habitat each fall (Figure 6b) associated with low flow through the seasonally drying section in Segment S7, though it is important to note that the dewatering cannot be estimated from discharge alone, and hence timing of dewatering should not be inferred from this figure (for more information, see the Fish Passage report, Harwood *et al.* 2021). Much of the overwintering data, especially between December and February, are missing due to icing issues at the hydrometric gauge (31-92% complete, Table 4c); including within the Decline Window (December 20, 2017 to March 14, 2018, and November 9, 2018 to January 20, 2019, KWL 2018 and KWL 2019). Habitat availability during the missing periods is unknown but implied by the habitat-flow curves for a given assumed flow (Figure 3).

Spawning habitat availability during the Decline Window was similar to other years for both zones of the Fording River (Figure 7a/b). On average, the spawning habitat available during the Decline Window was 102-109% of the average spawning habitat available across all years (Table 4b). Brief periods with reduced spawning habitat were caused by elevated, rather than low, discharge (Figure 7c); during these high flow periods, fish may delay spawning until more suitable flow conditions are present. Complete data were available for the spawning period (Table 4c).

Summer rearing habitat downstream of Henretta Lake was relatively low in 2017 (the beginning of the Decline Window) compared to all other years (Figure 8a, grey line). Over the entire 2017 summer rearing season, habitat available in Henretta Creek was 75% of the average across all years (Table 4b), which was caused by low discharge in Henretta Creek during late summer 2017 (Figure 8b, grey line). Discharge data for Henretta Creek were mostly complete (91-100%, Table 4c).

Summer rearing habitat in both Fording River zones (upstream and downstream of Kilmarnock Creek) during the Decline Window was generally comparable to other years (Figure 9): on average, summer rearing habitat available during the Decline Window was 93-122% of the average across all years (Table 4b). Some flow data were missing in September 2017 (Table 4c, KWL 2018), including much of the Decline Window for this year. For the portion of September 2017 with complete data, both discharge and habitat were lower than other years between September 23 and 30; the average discharge at FR_FRNTP was 0.51 m^3/s during this period in 2017, compared to 0.77 to 1.22 m^3/s in other years, and discharge was less than 0.51 m^3/s during the summer rearing period in only one other year (July-August 2015) (Figure 9c). We do not provide a comparison of habitat quantity specific to these 8 days, as this value would not be directly comparable to the period-average habitat values provided in Table 4. In summary, while rearing habitat during summer 2017 overall may have been typical, reduced flow and habitat was experienced in September 2017 in both Henretta Creek and UFR mainstem.

Table 4. Average habitat (WUA) for Westslope Cutthroat Trout during critical periods by year, expressed as a) WUA (1000 m²), and b) percentage of the WUA in the year with maximum habitat. The period from September 2017 to September 2019 (Decline Window) is indicated in bold font and outline (summer rearing values for 2017 are calculated across the entire period, including pre-Window from July 15 to August 30, and post-Window from September 1 onward).

a) Weighted usable area (WUA)

Life Stage	Start	End	River Segment	Average Habitat (WUA, 1000 m²)					
				2014	2015	2016	2017	2018	2019[2]
Overwintering[1]	15-Oct	31-Mar	U/S of Kilmarnock	4.57	4.80	4.02	**4.87**	**4.57**	4.67
			D/S of Kilmarnock	4.79	4.34	5.48	**4.46**	**4.53**	4.64
Spawning	15-May	15-Jul	U/S of Kilmarnock	13.54	13.72	13.94	13.70	**14.61**	**14.76**
			D/S of Kilmarnock	44.90	48.10	48.82	48.68	**49.92**	**53.65**
Summer Rearing	15-Jul	30-Sep	Henretta Creek		1.94	2.06	**1.47**	**1.98**	**2.32**
			U/S of Kilmarnock	30.47	26.56	29.17	**28.87**	**29.09**	**29.97**
			D/S of Kilmarnock	36.77	26.87	34.83	**35.32**	**32.08**	**42.17**

[1] Year at beginning overwintering period; e.g., 2014 includes October 15, 2014 to March 30, 2015

[2] Overwintering period for 2019 is limited to October 31 to December 31, 2019

b) Percentage of across-year average WUA

Life Stage	Start	End	River Segment	Average Habitat (% of Average Across Years)					
				2014	2015	2016	2017	2018	2019[2]
Overwintering[1]	15-Oct	31-Mar	U/S of Kilmarnock	100	105	88	**106**	**100**	102
			D/S of Kilmarnock	102	92	116	**95**	**96**	99
Spawning	15-May	15-Jul	U/S of Kilmarnock	96	98	99	98	**104**	**105**
			D/S of Kilmarnock	92	98	100	99	**102**	**109**
Summer Rearing	15-Jul	30-Sep	Henretta Creek		99	105	**75**	**101**	**119**
			U/S of Kilmarnock	105	92	101	**99**	**100**	**103**
			D/S of Kilmarnock	106	78	100	**102**	**93**	**122**

[1] Year at beginning overwintering period; e.g., 2014 includes October 15, 2014 to March 30, 2015

[2] Overwintering period for 2019 is limited to October 31 to December 31, 2019

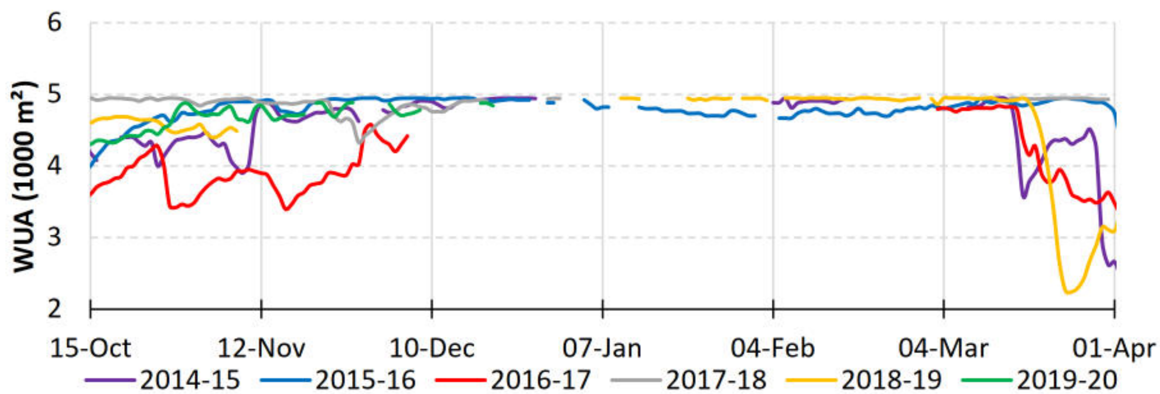
c) Completeness of discharge data used for data for habitat availability calculations

Life Stage	Start	End	River Segment	Discharge Record Completeness (%)					
				2014	2015	2016	2017	2018	2019
Overwintering[1]	15-Oct	31-Mar	Fording River	63	92	49	**51**	**57**	31
Spawning	15-May	15-Jul	Fording River	44	100	100	100	**100**	**100**
Summer Rearing	15-Jul	30-Sep	Henretta Creek		100	100	**91**	**100**	**92**
			Fording River	94	100	100	**79**	**100**	**97**

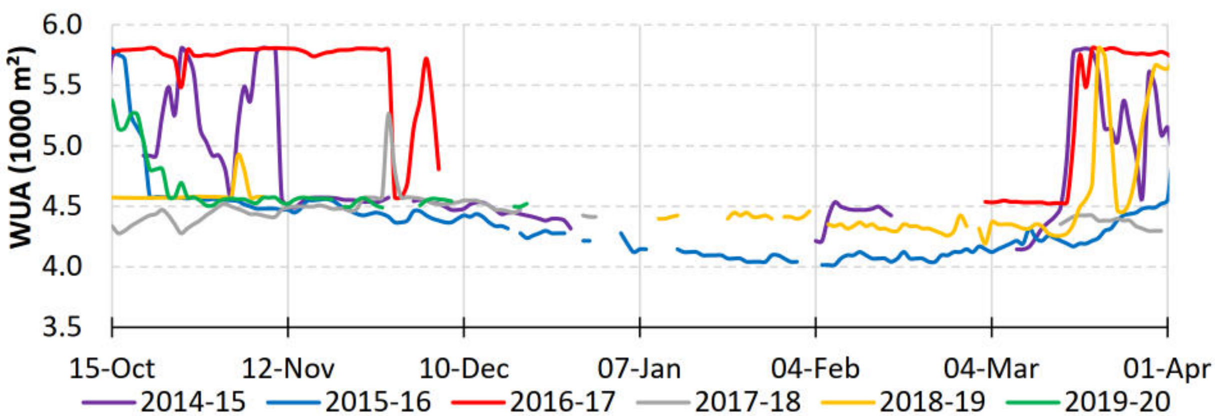
[1] Year at beginning overwintering period; e.g., 2014 includes October 15, 2014 to March 30, 2015

Figure 6. Estimated habitat from 2014-2019 during the Westslope Cutthroat Trout overwintering period (October 15–March 31) for a) between Henretta Creek and Kilmarnock Creek, and b) between Kilmarnock Creek and Chauncey Creek. Discharge (c) at FR_FRNTP provided for reference.

a) Fording River between Henretta Creek and Kilmarnock Creek



b) Fording River between Kilmarnock Creek and Chauncey Creek



c) Discharge at FR_NTP

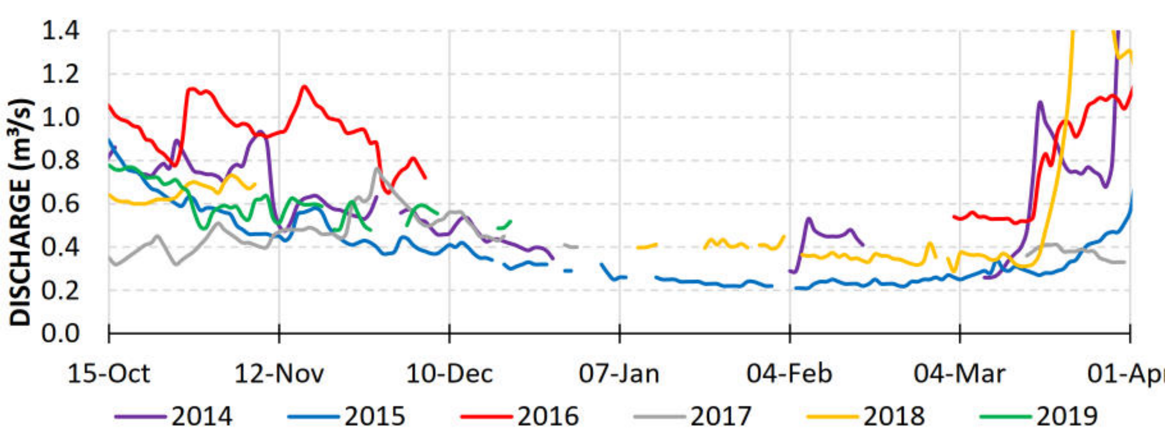
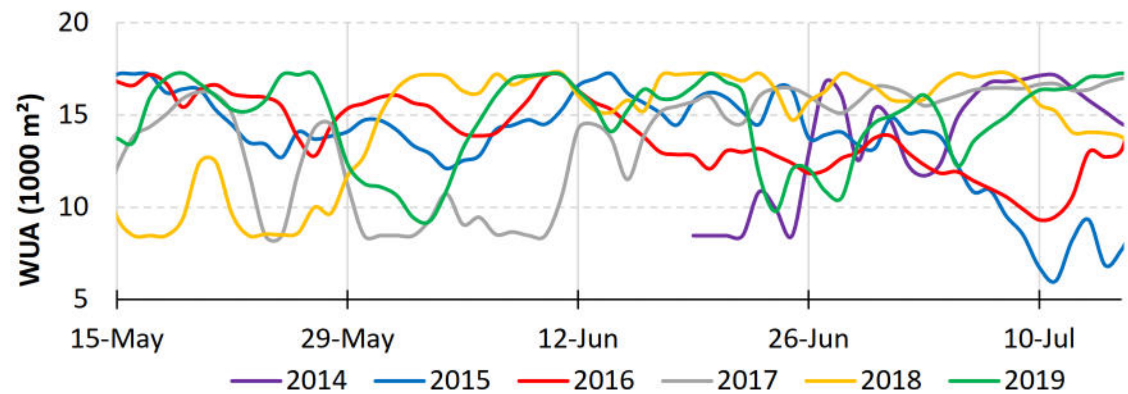
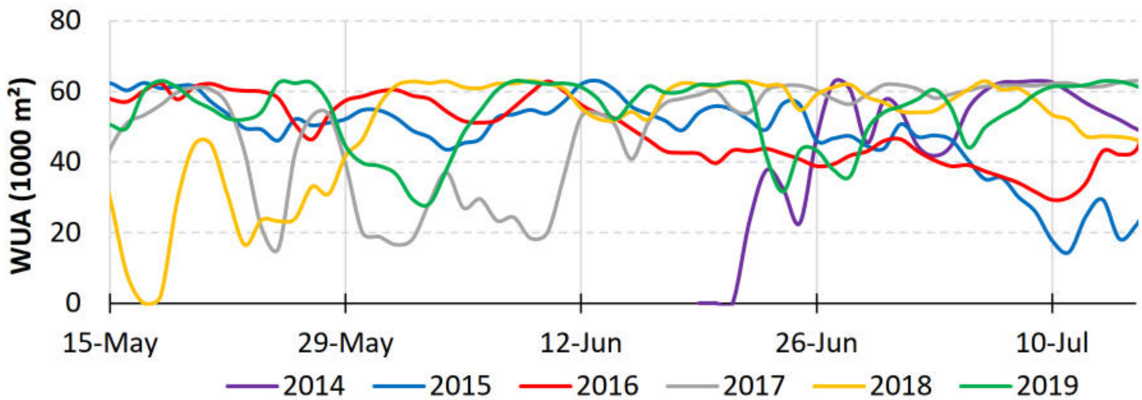


Figure 7. **Estimated habitat from 2014-2019 during the Westslope Cutthroat Trout spawning period (May 15-July 15) for a) between Henretta Creek and Kilmarnock Creek, and b) between Kilmarnock Creek and Chauncey Creek. Discharge (c) at FR_NTP provided for reference.**

a) Fording River between Henretta Creek and Kilmarnock Creek



b) Fording River between Kilmarnock Creek and Chauncey Creek



c) Discharge at FR_NTP

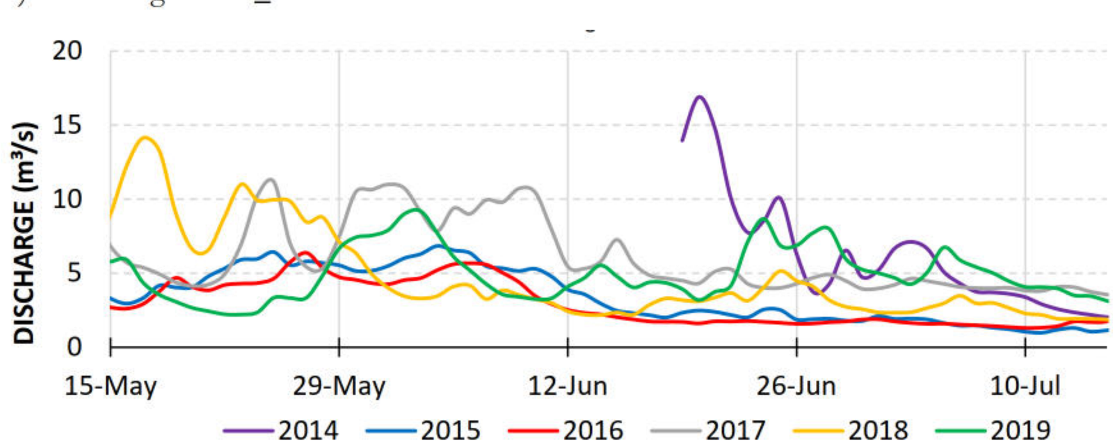
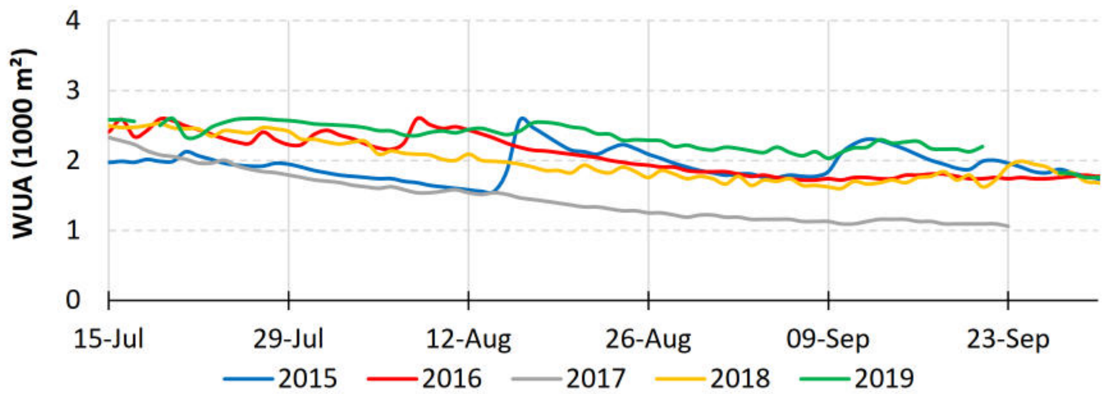


Figure 8. Estimated habitat from 2015-2019 during the Westslope Cutthroat Trout summer rearing period (June 15 to September 30) for a) Henretta Creek downstream of Henretta Lake. Discharge (b) at FR_HC1 provided for reference.

a) Henretta Creek downstream of Henretta Lake.



b) Discharge at FR_HC1.

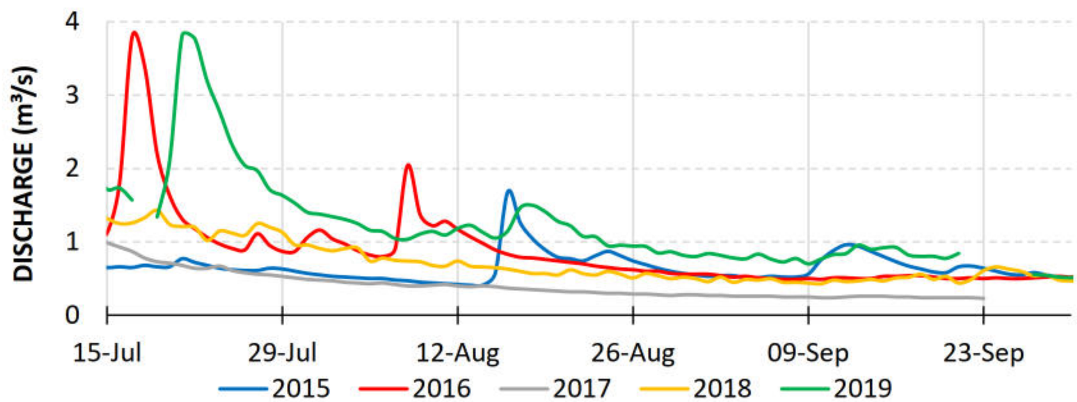
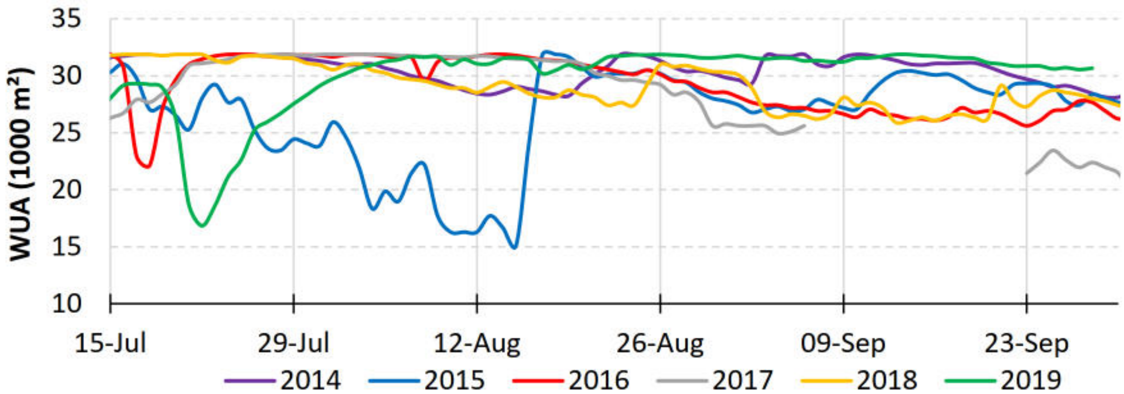
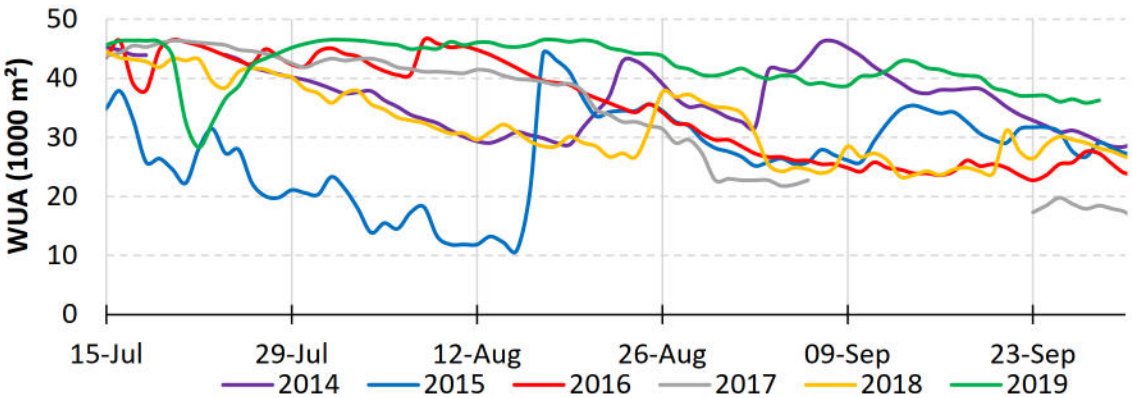


Figure 9. Estimated habitat from 2014-2019 during the Westslope Cutthroat Trout summer rearing period (June 15 to September 30) for a) between Henretta Creek and Kilmarnock Creek, b) between Kilmarnock Creek and Chauncey Creek. Discharge (c) at FR_NTP provided for reference.

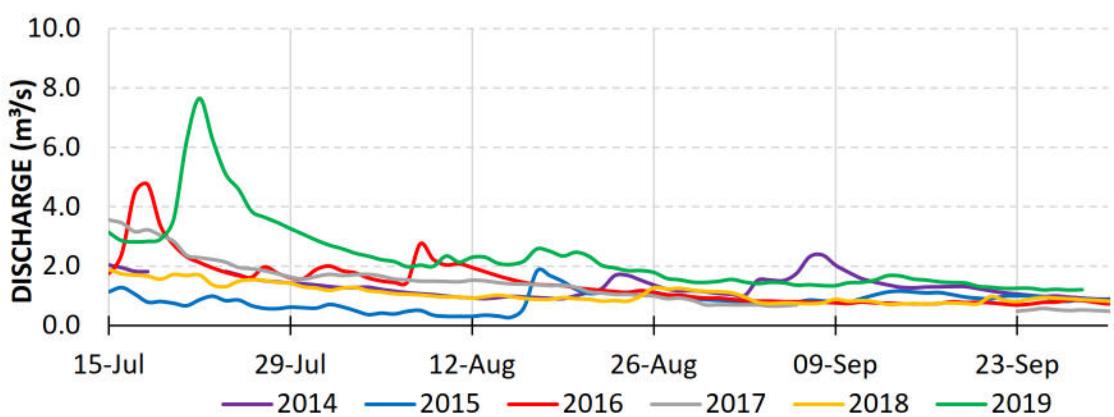
a) Fording River between Henretta Creek and Kilmarnock Creek.



b) Fording River between Kilmarnock Creek and Chauncey Creek.



c) Discharge at FR_NTP.



ECOFISH RESEARCH

4. DISCUSSION

4.1. Habitat-Flow Relationships

Determining if, and the extent to which, flow-related changes to hydraulic habitat availability may be a cause of the observed decline in WCT abundance required that habitat-flow relationships were first developed for the UFR and that these were then used to compare habitat availability during critical WCT time periods within the Decline Window. Several uncertainties were identified that were related to development of the habitat-flow relationships. However, in general, the level of uncertainty related to field work and data analysis associated with this step in the analysis was thought to be low enough to not affect conclusions of the EoC. Identified uncertainties, along with their qualitative evaluation, are:

- Transect placement: Uncertainty associated with the placement of instream flow transects is expected to be low. Spatial heterogeneity was addressed by distributing 40 transects along the ~20km length of the study area stratified by mesohabitat type. Transects were placed in seasonally drying sections, areas with multiple channels, straight and bend sections, and in natural, disturbed, and restored habitat.

- Hydraulic modelling: Uncertainty associated with the hydraulic modelling is expected to be low because there was good agreement between the measured and modelled hydraulics (Appendix C).

- Habitat suitability criteria (HSC): Uncertainty in the selection of HSC depends on life stage. There are no provincially recommended curves for WCT and we needed to use proxies for some HSC. For spawning and summer rearing, uncertainty is assessed as low to moderate; we used HSC for Steelhead (Ptolemy 2001), another large-bodied trout species, and we suggest this approach is useful, at least for determining relative effects of changes to flow. The overwintering criteria are based on data from Golder (2014) and while they produce results that appear reasonable for UFR, the criteria have not been validated or accepted by regulators or Ktunaxa Nation Council; accordingly, uncertainty associated with overwintering HSC is assessed as high.

- Relationship between flow at transects and FR_FRNTP: The greatest source of uncertainty in the habitat-flow relationships is the relationship between transect flow and flow at FR_FRNTP (described in Appendix A). There is substantial longitudinal variation in discharge along UFR; two notable sections of river (within S9 and S7) are considered 'losing' sections at low and moderate discharge (Cope *et al.* 2016), and there are inflows from tributaries, groundwater, and FRO water infrastructure. The estimates of transect to gauge discharge produce a shift in the habitat-flow relationships (i.e., difference between top right and bottom left panels in Figure 3). For locations where the transect discharge is less than the gauge discharge (particularly section S8/S9), this adjustment has the effect of shifting the optimum to a higher flow (e.g., Figure 3a, FRD-UPTR30B) and in some cases expanding or compressing the habitat-flow relationship (i.e., changing the rate of habitat change with flow). Conversely, for locations where transect discharge is greater than the gauge discharge (e.g., section S6), the optimum is shifted to lower discharge (e.g., Figure 3b, FRD-LWT02). This uncertainty is somewhat addressed by completing the EoC separately for two zones of the river (with the hydrometric gauge near the middle) that were each affected by the adjustment in opposite ways, and checking for concurrence between zones.

4.2. Evaluation of Requisite Conditions to Cause or Contribute to the Decline

Comparison of habitat time series during the Decline Window relative to previous years identified little change in spawning, rearing and overwintering WCT hydraulic habitat availability across zones in the UFR (Table 4). Habitat availability varied from 93% to 122% of pre-Window habitat availability depending on the WCT life history time period assessed.

The one WCT time period during which average hydraulic habitat availability was noticeably reduced occurred during the summer rearing period in Henretta Creek in 2017 and to a lesser extent elsewhere in the UFR mainstem in September of 2017 at the beginning of the Decline Window. Specifically, habitat availability was reduced by 25% for the summer rearing period in Henretta Creek relative to average during the pre-Window period. In the UFR mainstem, summer rearing habitat availability was also reduced in September of 2017, albeit to a lesser extent (but see discussion on missing data in Section 3.2). The summer rearing period in 2017 coincides with observations of high WCT density in all river segments in the UFR (Cope 2020). Sharp declines in WCT abundance of adults and juveniles were observed in the subsequent WCT surveys in 2019 and the decline is thought to have occurred most likely during fall 2018 through winter 2019 (Korman 2021). Therefore, a temporary decline in habitat availability in Henretta Creek at the beginning of the broader Decline Window seems unlikely to be a substantive cause or contribution to the observed WCT decline.

The section of Henretta Creek that is predicted to have 25% declines in rearing habitat availability in 2017 corresponds to reach H1 in the Cope (2020) dataset. The H1 reach has had relatively low density of WCT observed throughout the pre-Window time series in comparison to the significantly higher number of WCT adults and juveniles observed in the mainstem UFR, such as in river segments S6 to S10 (Cope 2020). Declines in rearing habitat availability were not observed in other periods within the Decline Window, in Henretta Creek nor in the mainstem UFR. The combination of the high observed WCT densities during the summer 2017 rearing period (see Cope 2020) and the lack of sustained temporal or widespread spatial declines in rearing habitat availability during the Decline Window suggests that it is unlikely that flow-related shifts in rearing habitat availability was the sole cause or a substantive contributor to the WCT decline.

The available flow data also indicate there has been little change in spawning or overwintering habitat availability during the Decline Window period in the UFR compared to the pre-Window period. The requisite conditions for Timing, Duration, Location and Spatial Extent were thus not met for the summer rearing, spawning and overwintering periods (Table 5).

The habitat time series analysis relies on discharge collected under Teck Coal's hydrometric monitoring programs and hence is influenced by any errors or uncertainties within the discharge data or underlying stage data. An important caveat to the above conclusion is that flow data are incomplete for some periods, which introduces uncertainty to the Evaluation of Cause. Specifically, much of the flow data for the overwintering period, especially between December and February, are missing during the Decline Window. A smaller data gap also exists for the summer rearing period in the UFR mainstem during the Decline Window. Thus, the conclusion that hydraulic habitat availability has not contributed to cause of the decline in WCT is based only on existing data. The data gap during the overwintering period of the Decline Window is substantial enough to cause uncertainty regarding our ability to evaluate overwintering habitat availability as a cause of the decline in WCT abundance. Given these gaps in the data record, the potential for flow-related habitat effects during the overwintering period of the Decline Window to have caused or contributed to the decline in WCT abundance is still possible, particularly if evidence from other sources identify potential causes for substantial impacts to flows during this time. Nevertheless, interpolation over gaps of two weeks or less at FR_FRNTP (Measuring Point B) suggested anomalies are unlikely in those periods (i.e., the start and end of gaps of less than two weeks occurred at flows that are not notably anomalous). Likewise, flows during longer gaps occurred in winter when flows are stable, so large fluctuations in flow-related habitat availability are unlikely. There was a longer, 17-day gap in September 2017 at FR_FRNTP. Flows were trending lower before and after this data gap but flows at FR_HC1 (Measuring Point A) were stable and not anomalous, which suggests that flows at FR_FRNTP followed a similar trend. Although we could not reliably infill the various gaps, it seems unlikely that flow-related habitat availability was markedly different during the gaps.

The evaluation of changes to habitat availability in this report only considers suitability of hydraulic habitat for fish, and hence only reflect flow-related changes to habitat availability in locations where fish are expected to be overwintering, rearing, and spawning. This analysis was completed assuming open water conditions (effects of ice formation on fish habitat are addressed in Whelan *et al.* 2021), and does not consider changes in habitat availability due to access (e.g., connectivity associated with shallow water depths at low flow or physical barriers such as culverts; addressed in the Fish Passage report, Harwood *et al.* 2021) or physical changes to the UFR watershed (e.g., infilling of tributaries; addressed in EoC Team 2021), and does not evaluate potential stranding due to water level fluctuations (addressed in Faulkner *et al.* 2021a). Water temperature is also an important factor in habitat usability, which is addressed in Wright *et al.* (2021b). Synthesis of results across multiple potential stressors or factors will be completed as part of the broader EoC report (EoC Team 2021).

In summary, the available evidence indicates that this stressor was not the sole cause of the decline. We are unable to rule out this stressor as a contribution to the decline; however, the evidence suggests the contribution is likely to be minor.

Table 5. Evaluation of Cause for habitat availability in relation to flow (assessed based on WUA time series) by WCT life stage period.

Factor	Overwintering[1]	Spawning	Summer Rearing
Intensity	Habitat availability typical for both zones of UFR mainstem during periods with available flow data	Habitat availability typical for both zones of UFR mainstem	Rearing habitat availability was typical in summer 2018 and 2019 in Henretta Creek and both zones of the UFR mainstem. Average Henretta Creek habitat availability in 2017 was 25% less than average across all years; UFR mainstem habitat availability was also somewhat less in September 2017 than previous years (estimates not provided due to data gaps).
Timing	Not applicable – no substantial reduction in habitat (based on available flow data)	Not applicable - no substantial reduction in habitat	Rearing habitat availability was typical in summer 2018 and 2019 in Henretta Creek and both zones of the UFR mainstem. Reduced habitat availability occurred in Henretta Creek for the 2017 summer rearing period (beginning of the Decline Window); reduced habitat availability in the UFR also occurred during the Decline Window for the summer rearing period (September 2017).
Duration	Not applicable – no substantial reduction in habitat (based on available flow data)	Not applicable - no substantial reduction in habitat	Rearing habitat availability was typical in summer 2018 and 2019 in Henretta Creek and both zones of the UFR mainstem. Reduced habitat availability occurred through much of the summer rearing period in 2017 for Henretta Creek; reduced habitat availability in the UFR was greatest during one month of the Decline Window (September 2017). Note that missing data in 2017 for the UFR mainstem limit our ability to assess duration.

[1] Data were missing for much of the Decline Window during the overwintering period which introduced uncertainty into potential for evaluation.

Table 5. Continued (2 of 2).

Factor	Overwintering[1]	Spawning	Summer Rearing
Location	Not applicable – no substantial reduction in habitat (based on available flow data)	Not applicable - no substantial reduction in habitat	Rearing habitat availability was typical in summer 2018 and 2019 in Henretta Creek and both zones of the UFR mainstem. Reduced habitat availability during the Decline Window occurred in Henretta Creek and in both zones of UFR mainstem.
Spatial Extent	Not applicable – no substantial reduction in habitat (based on available flow data)	Not applicable - no substantial reduction in habitat	Rearing habitat availability was typical in summer 2018 and 2019 in Henretta Creek and both zones of the UFR mainstem. Reduced habitat availability during the Decline Window occurred in Henretta Creek and, to a lesser extent, in both zones of UFR mainstem.

[1] Data were missing for much of the Decline Window during the overwintering period which introduced uncertainty into potential for evaluation.

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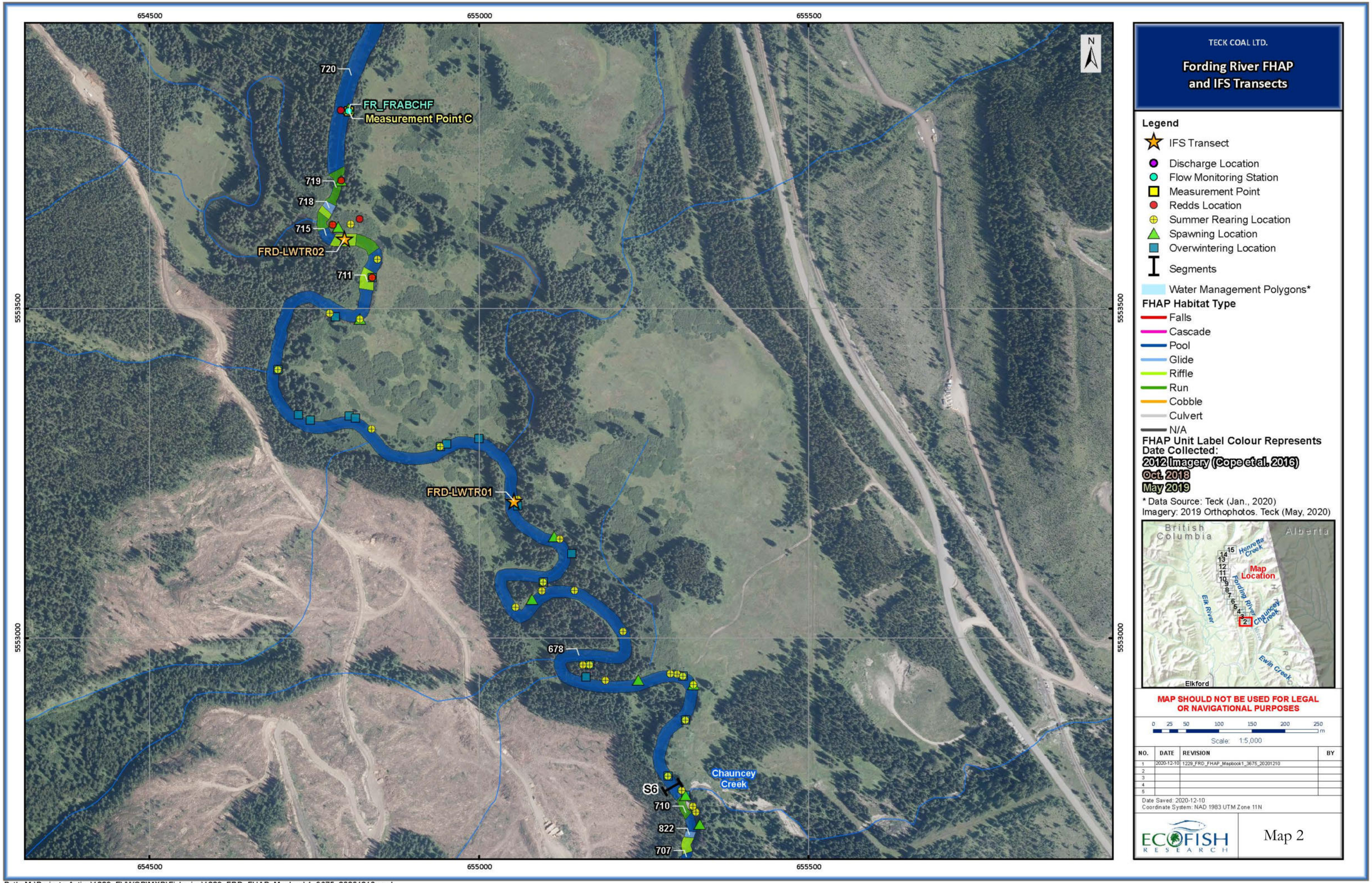
PROJECT MAPS



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APPENDICES

Appendix A. Fording River Instream Flow Study Methods

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1. INSTREAM FLOW STUDY METHODS

Instream flow field data collection, analysis, and modelling were completed under the Fording River Operations consumptive water licences Operational Environmental Monitoring Plan (Healey *et al.* 2020). Data collected between June 10 and November 8, 2019 were used as input to System for Environmental Flow Analysis (SEFA) habitat modelling software (Jowett *et al.*, 2014) to build relationships of habitat vs. stream flow.

1.1. Methods

1.1.1. Field Data Collection

Habitat transects were placed in three zones: Henretta Creek downstream of the Henretta Lake outlet, an upper zone from Fording River near Kilmarnock Creek to Henretta Creek, and an upper zone from Fording River confluence with Chauncey Creek to near Kilmarnock Creek. These zones were selected to develop habitat-flow relationships considering the location of permanent hydrometric gauges (i.e., one zone corresponding to each of Measuring Point A, B, and C), inflows and FRO water management infrastructure (e.g., Kilmarnock Creek, Swift Creek, and AWTF-S are located near the boundary between the two Fording River zones), and heterogeneity (e.g., the lower zone has less physical alteration by mining activities). For the purpose of transect selection, each zone was subdivided into 3 to 4 reaches to account for spatial heterogeneity within the zone, and to concentrate sampling effort in important habitat areas identified in Cope *et al.* 2016.

Transects were placed in each reach according to a stratified sampling approach considering the relative distribution of mesohabitats (i.e., channel units) that are present. Mesohabitat information was inferred from aerial habitat mapping completed by Cope *et al.* (2016) and data collected by Ecofish using a fish habitat assessment procedure (FHAP, Johnston and Slaney 1996) in May 2019. Within each of the reaches, transects were distributed according to the relative distribution of habitat units within the reach (i.e., proportion of length comprised of pool, riffle, glide/run). Some transects were placed specifically within river bends to assess the difference between river bends and straights. Two transects were placed in some of the pools to characterize both deep and shallow habitat within the pool. Transects sampled in the Fording River are summarized in Table 1.

Table 1. Instream flow transects sampled in Fording River in 2019.

Zone	Segment	Transect	Habitat Unit	Channel Type	Discharge Section	Bend Or Straight
Kilmarnock to Chauncey (S6 & S7)	S6	FRD-LWTR01	Pool	Single	FRUSCH	Bend
		FRD-LWTR02	Riffle	Single	FRUSCH	Bend
		FRD-LWTR03A	Pool	Single	FRUSCH	Bend
		FRD-LWTR03B	Pool	Single	FRUSCH	Bend
		FRD-LWTR04	Riffle	Multiple (Primary)	MSSC	Straight
		FRD-LWTR05	Glide	Multiple (Primary)	MSSC	Straight
		FRD-LWTR06	Pool	Multiple (Primary)	MSSC	Bend
		FRD-LWTR07A	Pool	Single	DSDRY	Bend
		FRD-LWTR07B	Pool	Single	DSDRY	Bend
		FRD-LWTR08	Glide	Multiple (Secondary)	LWSC	Bend
		FRD-LWTR09	Glide	Multiple (Secondary)	LWSC	Bend
		FRD-LWTR10	Riffle	Multiple (Secondary)	LWSC	Straight
	S7	FRD-LWTR11	Glide	Single	DRY	Straight
		FRD-LWTR12	Riffle	Single	DRY	Bend
		FRD-LWTR13	Pool	Single	DRY	Bend
		FRD-LWTR14	Glide	Single	LWTR14	Straight
		FRD-LWTR15	Pool	Single	LWTR15	Straight
		FRD-LWTR16	Riffle	Single	DSNTP	Straight
		FRD-UPTR17	Glide	Single	DSNTP	Straight
Henretta to Kilmarnock (S8 & S9)	S8	FRD-UPTR18	Riffle	Single	NTP	Straight
		FRD-UPTR19	Glide	Single	NTP	Straight
		FRD-UPTR20	Riffle	Single	NTP	Straight
		FRD-UPTR21A	Pool	Single	NTP	Straight
		FRD-UPTR21B	Pool	Single	NTP	Straight
		FRD-UPTR22	Riffle	Single	NTP	Straight
		FRD-UPTR23	Riffle	Single	NTP	Straight
		FRD-UPTR29A	Pool	Single	NTP	Straight
		FRD-UPTR29B	Pool	Single	NTP	Straight
		FRD-UPTR24	Riffle	Single	DSCC1	Bend
		FRD-UPTR25	Glide	Single	DSCC1	Straight
		FRD-UPTR26	Riffle	Multiple (Primary)	USCC	Bend
		FRD-UPTR27A	Pool	Multiple (Primary)	USCC	Bend
		FRD-UPTR27B	Pool	Multiple (Primary)	USCC	Bend
	S9	FRD-UPTR28	Glide	Single	USCC	Straight
		FRD-UPTR30A	Pool	Single	FR1	Bend
		FRD-UPTR30B	Pool	Single	FR1	Bend
		FRD-UPTR31	Riffle	Single	FR1	Bend
		FRD-UPTR32	Riffle	Single	USFR1	Bend
Henretta Creek		FRD-UPTR33	Pool	Single	HC1	Straight
		FRD-UPTR34	Glide	Single	HC1	Straight

Instream flow data were collected at each transect location over three periods in 2019: June 10-17, August 30-September 4, and November 4-8; the specific information collected during each trip is described in the following paragraphs. These sampling dates roughly correspond to highest, moderate, and lowest sample flow conditions, respectively, and reflect the range of wadeable open-water flow conditions in UFR. Data collection was completed following the methods outlined in the BC Instream Flow Methodology (BCIFM; Appendix A in Lewis *et al.* 2004), with water depth and velocity data collected following procedures in the "Manual of British Columbia Hydrometric Standards" (RISC 2018). Digital photographs were taken during sampling at each transect to document field conditions (Appendix B).

Prior to conducting field measurements, transects were named, georeferenced, and marked with flagging tape. Pins were installed at the ends of each transect, ensuring that the transect was perpendicular to the direction of flow, and benchmarks (e.g., a spike in tree or bolt in rock) were installed for each transect. Pins were either 8" or 10" galvanized spikes or rock-climbing anchors.

During the first sampling trip (June), streambed topography data were collected using a rod and level. Verticals were positioned based on streambed topography, taking into account expected changes in water surface elevation over the range of metered flows; a minimum of 20 verticals were established for each transect. Cover data were collected for each vertical. Additional site data were also collected, including the D95 substrate particles, the local channel slope, the roughness height, and whether each transect spanned a single channel or multiple channels. Substrate data were collected at each vertical during the second (August-September) sampling trip. Substrate coverage was visually estimated and expressed as a percentage using size classes defined within the "Reconnaissance (1:20 000) Fish and Fish Habitat Inventory Standards and Procedures" (RISC 2001). Solinst Leveloggers were installed at each transect location to monitor stage change over the course of the study (June 10 to November 4, 2019). Solinst Barologgers were installed at two locations within the study area to collect barometric pressure data and compensate the recorded water level data for barometric pressure: a Barologger installed near FRD-UPTR27 and FRD-UPTR26 was used to compensate all Leveloggers in the upper section and a Barologger near FRD-LWTR13 was used for the Leveloggers in the lower section.

During the second and third trips, a subset of stations were resurveyed for each transect to measure water surface elevation; these stations included the permanent benchmark, pins, wetted edges, and a subset of wetted verticals. Surveys were also completed for each Levelogger (bed, water surface, sensor elevation). The surveys of wetted stations are used to measure water surface elevation (relative to an assumed benchmark elevation of 10 m), and pin and benchmark surveys are used for a series of calculations to assess for survey error and/or movement of pins or benchmark.

During each trip, depth and velocity were sampled across each transect at a minimum of 18 wetted verticals, (with the exception of FRD-LWTR11 and FRD-LWTR13, which had extensive ice cover during the low flow trip in November), using a Swoffer (Model 2100, 8.5 cm diameter propeller) or Pygmy velocity meter (5 cm propeller) and a 140 cm top-set rod. All velocity measurements were taken following the standard operating procedures for hydrometric surveys in BC (RISC 2018). Velocity measurements were generally taken at 60% depth from the water surface (0.6D), which represent average water column velocity, and recorded using the long averaging function on the Swoffer equipment (when this equipment was used). If depth exceeded 0.75 m, additional measurements were obtained at 20% and 80% of the water column depth to obtain more precise estimates of average water column velocity. Prior to collecting data for each flow sampling trip, the Swoffer equipment was calibrated according to manufacturer's guidelines in still water. Alignment with the correct calibration number was confirmed at each transect prior to collecting data. Likewise, the batteries in the Swoffer units were also checked with a voltmeter and replaced if the voltage was lower than 9.1 V, as this could affect velocity measurements. Finally, velocities were estimated visually in areas where flows were too low or depths were too shallow to use the velocity meter (e.g., undercut banks, locations where the propeller assembly could not be fully or partly submerged).

While the depth and velocity information collected at each transect can be used to estimate discharge, the transect locations were selected to represent fish habitat rather than suitable discharge measurement conditions; important habitats often contain bed features that make the location unsuitable for accurate discharge measurement, sometimes resulting in estimates of discharge that would be considered "Unknown data quality" under RISC (2018) standards. To ensure reliable estimates of discharge were available during the time of sampling, discharge measurements were completed at suitable measurement sites near the transects during each sampling trip. We note that ultimately, the depth and velocity profiles for many instream flow transects produced reasonable estimates of discharge (meeting RISC Grade B or C standards, and discharge values corroborated between adjacent transects), and many of these discharge estimates were retained for use in modelling; these decisions are described further in Section 1.1.2 below.

Transect data were entered into spreadsheets and reviewed in detail following Ecofish QA/QC processes (see Appendix C).

1.1.2. Habitat Model Calibration

Physical habitat modelling requires a water surface elevation model (i.e., stage-discharge relationship), which ultimately determines the hydraulics at each transect (wetted width, depth, velocity). Stage-discharge relationships were derived for each transect considering both discrete measurements of water surface elevation and discharge (collected during field sampling) and continuous measurements of water surface elevation and discharge (collected passively by water level recorders and nearby hydrometric gauges). The discrete estimates of stage and discharge, measured in the field, are the primary data source for the water surface model, while the continuous data provide estimates of stage for discharge conditions that were not sampled in the field. This design exceeds the provincial guidance for instream flow data collection (Lewis *et al.* 2004), which recommend sampling a minimum of three discrete sample flow conditions and do not require passive, continuous data collection.

The estimated discharge rates (discrete and continuous) depend on location within the Fording River. For the discrete discharge estimates (i.e., during each sampling trip), discharge was measured at several locations chosen specifically for stream gauging along the Fording River. For each transect measurement, corresponding estimates of discharge were obtained from these nearby field measurements when possible, or if a suitable field measurement was not available discharge was estimated either from transect velocity-area data, or from nearby continuous flow monitoring gauges (Table 2). Specifically, if a discharge measurement was recorded at a suitable nearby location on the same day as transect measurements, this was used as the discharge estimate for that transect on the sample date. If a measurement was recorded at a suitable location on a different day during the multiday sampling visit, the discharge measurement was prorated based on flow change seen at a nearby continuous monitoring gauge. For some transects, on some trips, the dedicated flow measurement was determined to be suitable to represent transect conditions, these issues became apparent during analysis of the data due to unforeseen complexities in the hydrology of the Fording River (i.e., longitudinal decreases in flow along drying sections, and inflow from water management infrastructure). In these situations, if velocity and area data from the IFS transect were deemed suitable for flow estimation (meeting RISC Grade B or C standards, corroboration between multiple transects where possible) these discharge values were used to estimate discharge for the transect. For some transects, an average of transect-measured discharge at a group of proximal transects was used to estimate discharge at the time of sampling for a grouping of transects within a specific reach. Finally, for some transects located very close to continuous monitoring gauges (e.g., FR_FRNTP or FR_HC1) the gauge discharge was used as the discharge estimate for the transect.

Continuous estimates of discharge (used as a secondary source for the water surface model) were estimated at each transect from hydrometric gauges that were determined to be representative of transect discharge conditions, considering operational water management and natural variations within reaches (i.e., due to hyporheic exchange).

For each transect measurement, the average water surface elevation was calculated from the surveyed bed elevation and water depth measurements that were taken at a subset of the wetted verticals. Anomalies in the data were reviewed; some stations were removed from the averaging calculations, and two measurements were removed from the November dataset due to ice cover; details of these adjustments are summarized in Appendix D. The final water surface elevations were used to adjust the continuous water level data to provide a continuous time series of water surface elevation over the study period (Appendix D Figure 1-40, top left plots).

Stage-discharge relationships were fit for each transect considering both the discrete and continuous estimates of water surface elevation and discharge. Initial relationships were fit via a nonlinear regression; if the discrete and continuous data produced relationships that were substantially different, adjustments were made to the relationships in consideration of the confidence in the two data sources (generally, confidence was greater in the discrete measurements because they are based on direct measurements of water surface elevation and on flow measurements at or near the transects on the day of sampling). Stage-discharge relationships are shown in Appendix D, top right plot.

Physical habitat modelling assumes a flat water surface, which is seldom true in many streams. For two transects (FRD-UPTR29A and FRD-UPTR31), there is a bar along the river margin that contains a wetted depression with a water surface that is not level with the primary channel. The topography of these portions of the transects were adjusted to reasonably simulate the water depths that were measured in the field (see Appendix D, Table 1). For transects with undercut banks (e.g., FRD-LWTR02), a vertical bank was assumed at the farthest extent of the undercut.

Stage-discharge relationships, bed elevation data, substrate data, and velocity data for the three sampling trips were imported into the SEFA habitat modelling software (Jowett *et al.* 2014). The water surface model was configured in SEFA and adjusted so that the model reproduces the measured hydraulic geometry (wetted width, average depth, and average velocity) for all transects (Appendix D Figure 1-40, center right, bottom left, and bottom right plots).Three separate velocity models were configured for habitat simulation; one model calibrated from each set of velocity data. Adjustments were made to the velocity data to ensure that the measured velocity conditions were accurately reproduced at the calibration flows and that extrapolations to higher flow conditions are reasonable. The three model runs were completed and habitat suitability criteria (HSC; these provide depth, velocity, and substrate preference for relevant species) were evaluated (Figure 1).

Modelling was completed using several habitat suitability criteria because site-specific and species specific HSC do not exist for all life stages of WCT, or existing HSC have not been finalized. Some WCT criteria are available from Golder (2014); however, these criteria have not been approved by provincial biologists. To test the sensitivity of the model results to the choice of HSC, and to evaluate the relationship of other commonly modelled life history stages and ecological attributes to flow, we modelled the following five habitat suitability criteria:

- Fry:
    - Bioenergetics-based habitat suitability criteria (Rosenfeld *et al.* 2016) were selected to model habitat changes taking into account bioenergetics (drift of prey, foraging); these criteria for Coho fry are the only bioenergetics-based HSC for salmonids that we are aware of. These habitat suitability criteria specify greater minimum depth and velocity requirements than other criteria for fry.
    - Steelhead Fry criteria (WUP Delphi; Ptolemy 2001) were selected to provide a reference point, as these criteria are frequently applied on instream flow studies in BC.
    - Westslope Cutthroat Trout Fry criteria developed by Golder (2014).
- Juvenile rearing and Adult holding:
    - Steelhead parr criteria (WUP Delphi; Ptolemy 2001) were selected to provide a reference point, as these criteria are frequently applied on instream flow studies in BC. These criteria are sometimes used as a proxy for juveniles of large-bodied trout.
    - Westslope Cutthroat Trout juvenile and adult holding criteria developed by Golder (2014).

- Spawning:
    - Cutthroat Trout spawning criteria (Ptolemy 2001).
    - Steelhead spawning (WUP Delphi; Ptolemy 2001) were selected to provide a reference point, as these criteria are frequently applied on instream flow studies in BC.
    - Westslope Cutthroat Trout spawning criteria developed by Golder (2014).
- Overwintering criteria developed by Golder (2014).
- Macroinvertebrate criteria from Ptolemy (pers. comm. 2009) developed for swiftwater specialists.

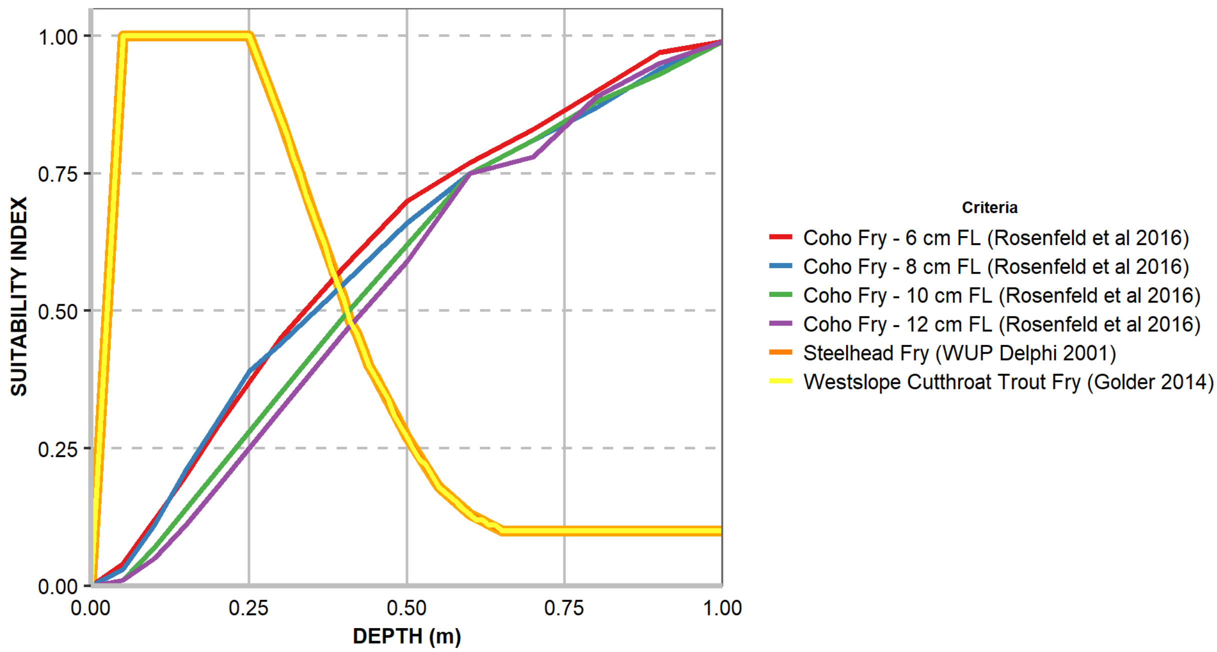
For each transect and flow, modelled wetted width, average velocity, and average depth were validated against the measured values (Appendix D) to confirm that the model accurately simulated transect hydraulics. Discrepancies were analyzed to determine the source of errors and develop solutions to any issues; however, some small discrepancies could not be reconciled either due to poor measurement conditions at transects or other nuances (e.g., undercut banks).

Table 2. Source of discharge estimates for transects during field sampling.

Transect	Source for Discharge Estimate		
	Trip 1	Trip 2	Trip 3
FRD-LWTR01	Average of transect measurements (1-3; 5.37 to 5.58)	TRQ8 from yesterday x 97%	TRQ8 from tomorrow x 94%
FRD-LWTR02	Average of transect measurements (1-3; 5.37 to 5.58)	TRQ8	TRQ8 from tomorrow x 94%
FRD-LWTR03A	Average of transect measurements (1-3; 5.37 to 5.58)	TRQ8 from yesterday x 97%	TRQ8
FRD-LWTR03B	Average of transect measurements (1-3; 5.37 to 5.58)	TRQ8 from yesterday x 97%	TRQ8
FRD-LWTR04	Average of transect measurements (4-5, 3.55 to 3.45)	TRQ7	TRQ7
FRD-LWTR05	Average of transect measurements (4-5, 3.55 to 3.45)	TRQ7	TRQ7
FRD-LWTR06	Transect measurement	TRQ7	TRQ7
FRD-LWTR07A	Transect measurement	TRQ10	TRQ10
FRD-LWTR07B	Measurement for 7A	TRQ10	TRQ10
FRD-LWTR08	Average of transect measurements (8-10, 1.74-1.92)	TRQ1	TRQ1 from yesterday * 110%
FRD-LWTR09	Average of transect measurements (8-10, 1.74-1.92)	TRQ1	TRQ1
FRD-LWTR10	Average of transect measurements (8-10, 1.74-1.92)	TRQ1	TRQ1
FRD-LWTR11	Value from 7A, 13, 14 (4.55 to 4.56)	TRQ9	not used (frozen)
FRD-LWTR12	Value from 7A, 13, 14 (4.55 to 4.56)	Average of Transect 11 and Transect 13	not used (frozen)
FRD-LWTR13	Value from 7A, 13, 14 (4.55 to 4.56)	Transect measurement	not used (frozen)
FRD-LWTR14	Value from 7A, 13, 14 (4.55 to 4.56)	TRQ6	Transect measurement
FRD-LWTR15	Value from 7A, 13, 14 (4.55 to 4.56)	Transect measurement	Transect measurement
FRD-LWTR16	Transect measurement	Transect measurement	Transect measurement
FRD-UPTR17	Transect measurement	Transect measurement	Transect measurement
FRD-UPTR18	FR_NTP	FR_NTP	FR_NTP
FRD-UPTR19	FR_NTP	FR_NTP	FR_NTP
FRD-UPTR20	FR_NTP	FR_NTP	FR_NTP
FRD-UPTR21A	FR_NTP	FR_NTP	FR_NTP
FRD-UPTR21B	FR_NTP	FR_NTP	FR_NTP
FRD-UPTR22	FR_NTP	FR_NTP	FR_NTP
FRD-UPTR23	Transect measurement	Transect measurement	Transect measurement
FRD-UPTR24	Transect measurement	TRQ5	TRQ5
FRD-UPTR25	Transect measurement	TRQ5	TRQ5
FRD-UPTR26	Average of transect measurements (26-27, 1.85-2.10)	TRQ4 from yesterday * 109.7%	TRQ4
FRD-UPTR27A	Average of transect measurements (26-27, 1.85-2.10)	TRQ4	TRQ4
FRD-UPTR27B	Average of transect measurements (26-27, 1.85-2.10)	TRQ4	TRQ4
FRD-UPTR28	Transect measurement	TRQ3	TRQ3
FRD-UPTR29A	Transect measurement	Transect measurement (29A/B, 1.22-1.29)	Transect measurement (29A/B, 0.55-0.59)
FRD-UPTR29B	Transect measurement (29A)	Transect measurement (29A/B, 1.22-1.29)	Transect measurement (29A/B, 0.55-0.59)
FRD-UPTR30A	Transect measurement (30A)	Transect measurement (30A)	Transect measurement (30A)
FRD-UPTR30B	Transect measurement (30A)	Transect measurement (30A)	Transect measurement (30A)
FRD-UPTR31	Transect measurement (30A)	Transect measurement (30A)	Transect measurement
FRD-UPTR32	Transect measurement	Transect measurement	Transect measurement
FRD-UPTR33	HC1	HC1	HC1
FRD-UPTR34	HC1	HC1	HC1

Figure 1. Habitat suitability criteria used in the Fording River instream flow study for a) fry, b) juveniles/adults, c) spawning, d) overwintering, and e) macroinvertebrates (drift of food).

a) Fry



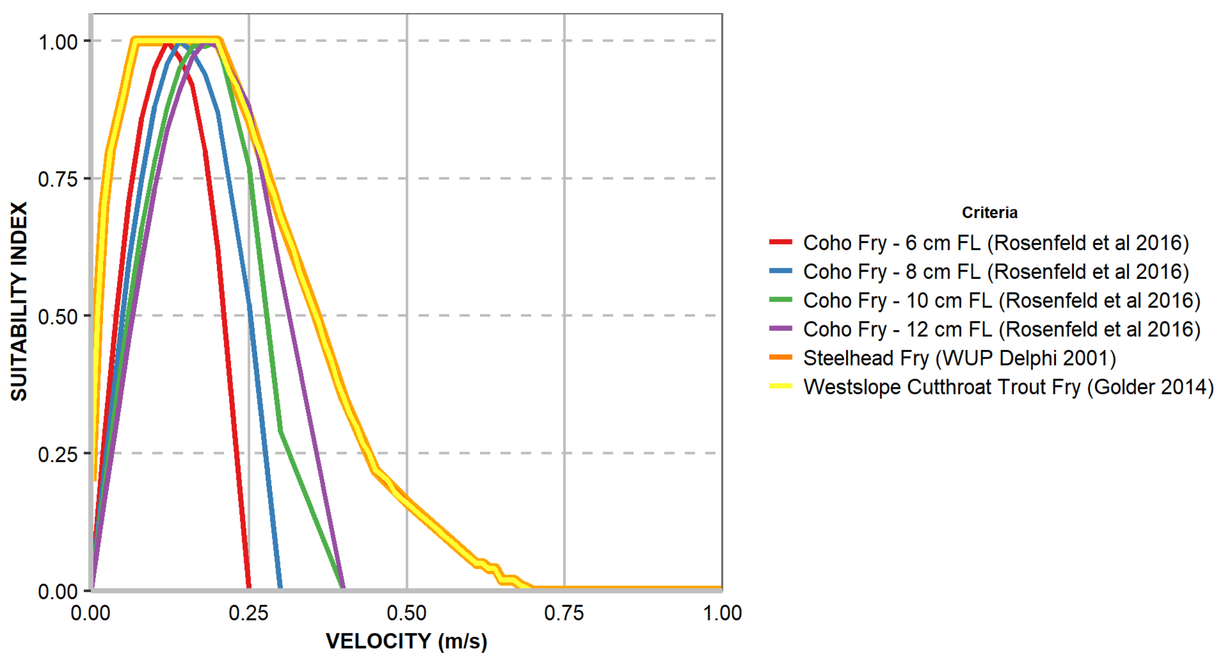
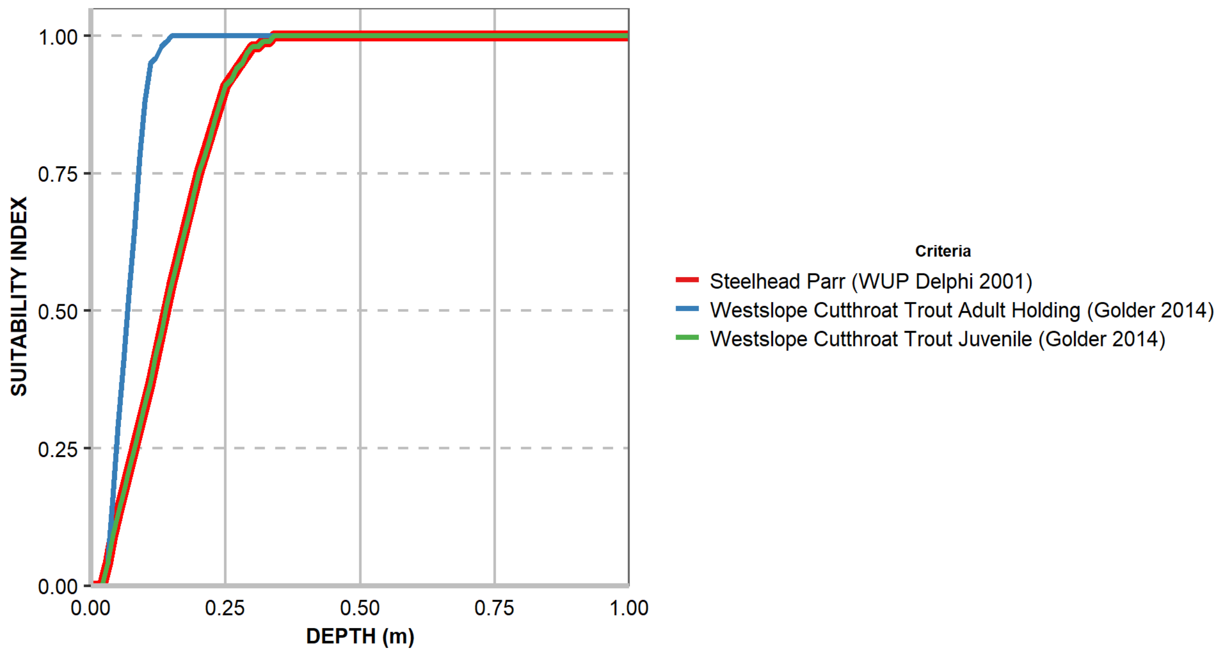


Figure 1. Continued.

b) Juveniles/Adults



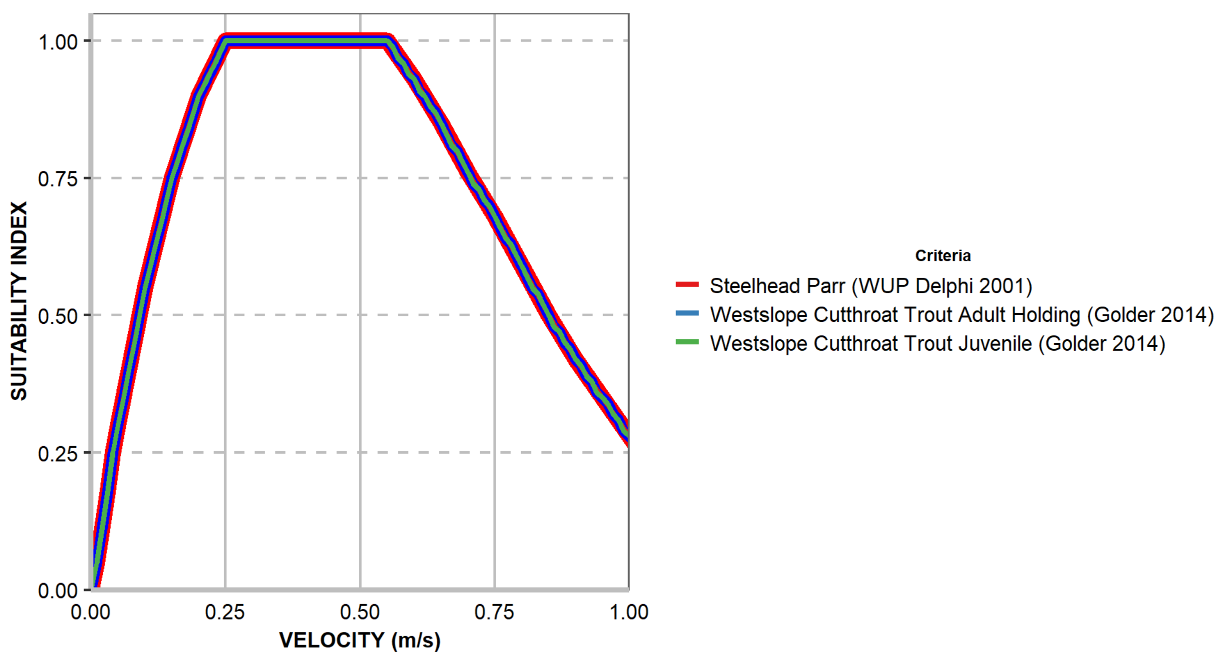
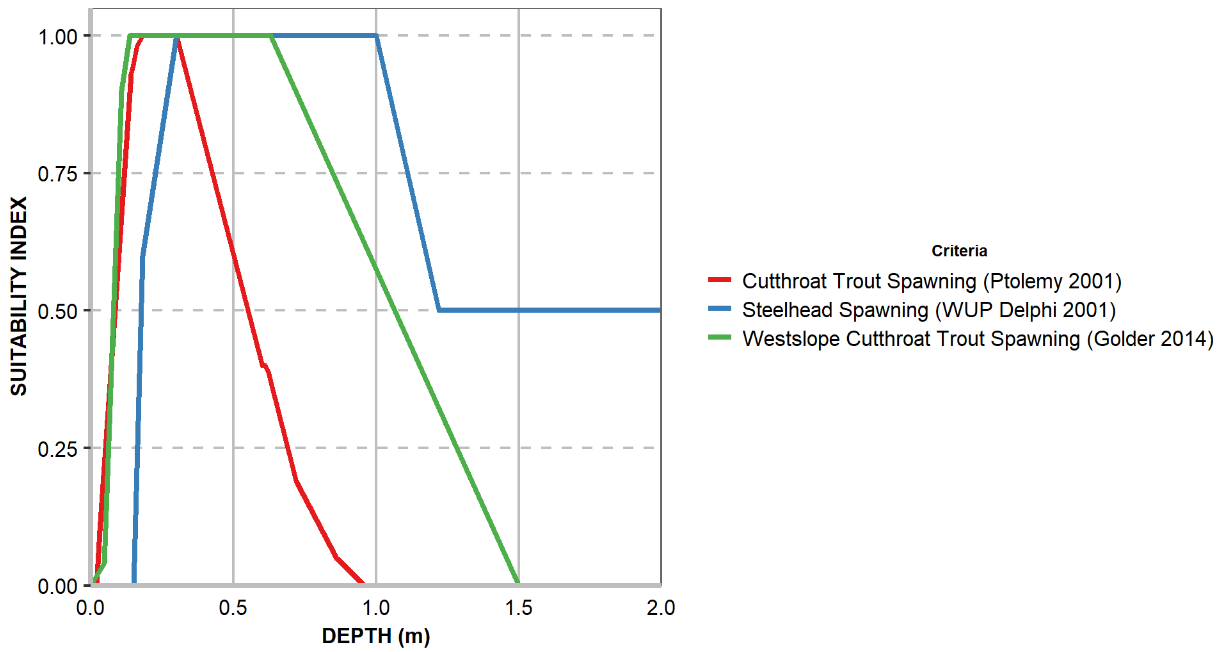


Figure 1. Continued.

c) Spawning



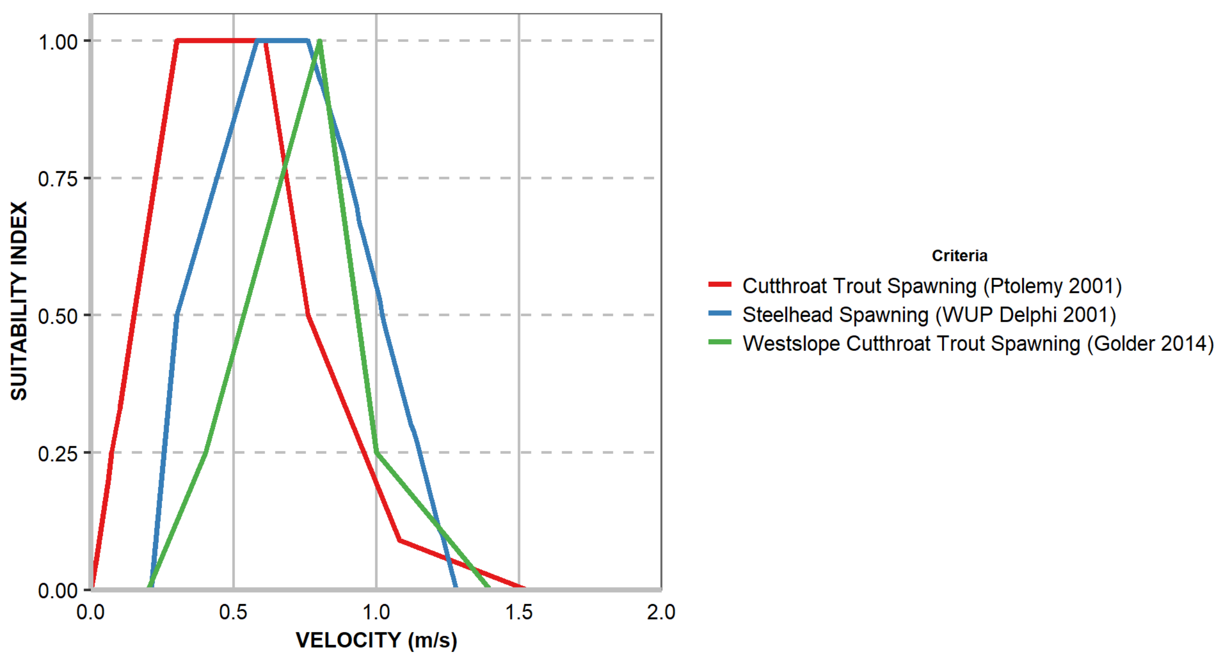
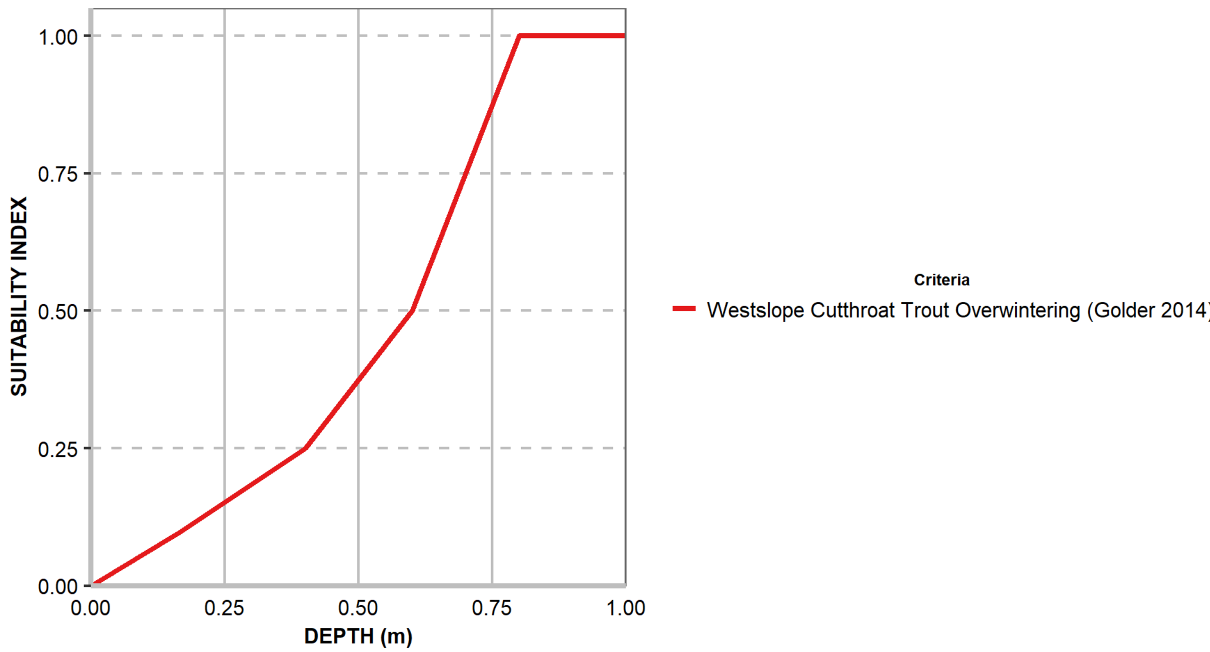


Figure 1. Continued.

d) Overwintering



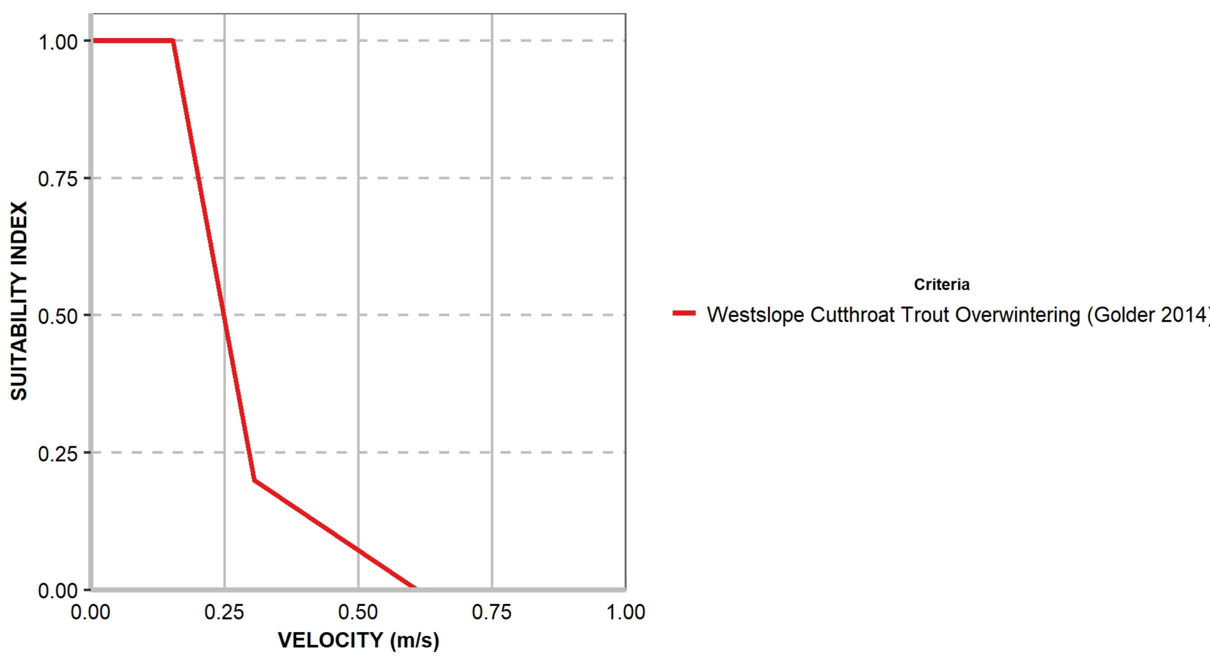
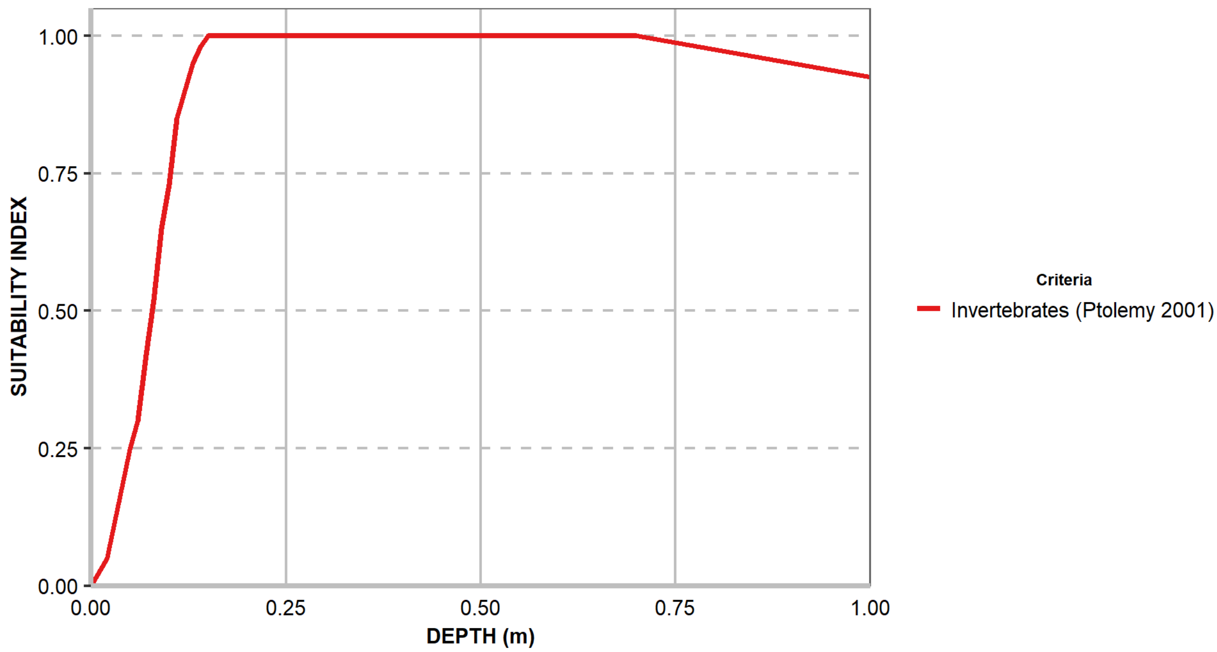
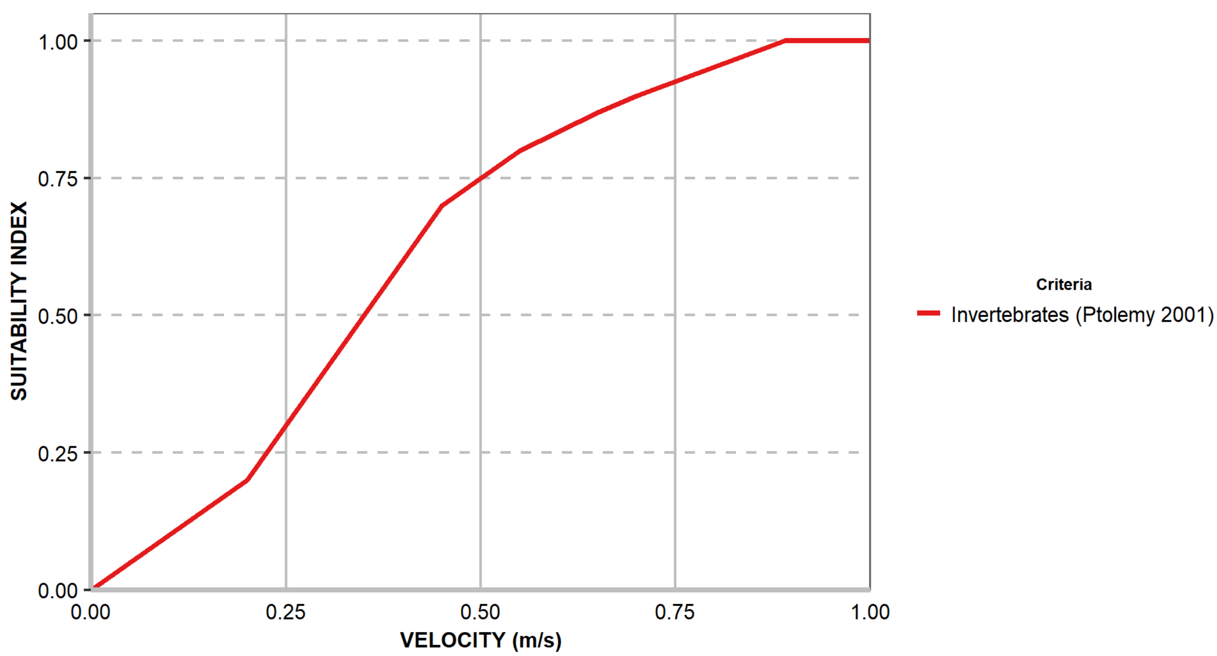


Figure 1. Continued.

e) Macroinvertebrates





1.1.3. Habitat Model Post-Processing

The raw outputs from the SEFA model were imported into the R statistical software (R Core Team 2019) and further processed to create habitat-flow relationships according to the following steps:

WUW-Transect Flow Relationships

Relationships between WUW and flow through the transects were derived as follows:

1. For each transect, three Weighted Usable Width (WUW)-transect flow relationships were created, each corresponding to one of three separate sets of velocity calibration data. The three velocity sets correspond to highest, moderate, and lowest sample flow conditions (June, August-September, and November sampling trips, respectively). Weighted usable width (WUW) was calculated for each transect, for each simulation flow, velocity model and HSC as:

$$WUW_{dvs} = \Sigma_i^n (W_i*D_i*V_i*S_i)$$

   where W_i is the width of computational cell *i* on the transect, D_i is the suitability of depth at cell *i*, V_i is the suitability of velocity at cell *i*, and Si is the suitability of substrate at cell *i*. Suitability values range from 0 (not suitable) to 1.0 (highest suitability) and are defined in Figure 1 above.

2. Habitat-flow relationships for individual velocity models were compared to a composite habitat-flow relationship consisting of the average of all three velocity models.

3. The composite (average) WUW-flow relationship was selected for each transect/HSC because:

   a. The shape of the habitat-flow relationships were found to be relatively insensitive to model choice for the selected HSC (see below), i.e., the habitat-flow relationships for individual transects/HSC had similar shape regardless of velocity model, and

   b. Attempting a more complex blending of velocity models (e.g., using a different velocity model for lowest, moderate, and highest sample flow conditions) introduced irregular and artificial features into the ascending portion of the habitat-flow relationship, changing their shape.

WUW-Measuring Point Discharge Relationships

The WUW-flow relationships described above are developed based on flow through the transect. Discharge along the UFR varies longitudinally (e.g., due to groundwater interaction, tributary inputs, or water management infrastructure). To calculate habitat-flow relationships for a large section of river (i.e., weighted usable area, or WUA), it is necessary to relate habitat to discharge at a specific location. For Fording River, the three continuous streamflow monitoring stations (FR_HC1, FR_FRNTP, and FR_FRABCHF) were selected as locations for developing WUA versus flow relationships.

These locations were selected because:

1. The FRO water licences specify minimum IFRs at these locations;
2. Continuous streamflow data are recorded at these locations; the WUA-flow relationships can be applied directly to these data to calculate habitat time series;
3. There is one monitoring station within each zone; and
4. Discharge in the immediate vicinity of these locations does not vary longitudinally.

FR_HC1 (Measuring Point A) was selected to represent Henretta Creek downstream of the Henretta Lake outlet. For the purpose of Evaluation of Cause (EoC), FR_FRNTP (Measuring Point B) was selected to represent Fording River because this location is located in the center of Fording River operations and has a long-term discharge record; the data record for FR_FRABCHF (Measuring Point C), between Kilmarnock Creek and Chauncey Creek, begins in November 2017 and hence does not provide data for the years prior to the Decline Window, limiting its utility for EoC analysis.

The flow at the Henretta Creek transects was assumed to be the same as nearby FR_HC1 as there is minimal distance between the locations. For the Fording River transects, the relationship between flow at each transect FR_FRNTP was examined to estimate the percentage of gauge flow that is present at the transect. In both zones, multiple relationships were required to translate transect flow to measuring point discharge, as both zones contain split channels, downwelling sections, and inflows (Figure 2). For each transect, 3 discrete measurements (supplemented by level logger data) were examined. If the transect discharge was judged to be materially different than the FR_FRNTP discharge, then we evaluated whether the transect discharge could be approximated by a simple percentage of the FR_FRNTP discharge, considering the quality of the FR_FRNTP data over the study period. Where this assumption was not reasonable, we approximated simple relationships (constant above and below some threshold with a linear increase in between) in consideration of longitudinal trends (i.e., increases/decreases) in streamflow.

For each Fording River transect (Table 1), the estimated relationship between transect flow and flow at the associated measuring point (Figure 2), was applied to the WUW-transect flow relationships to create relationships between transect WUW and measuring point discharge.

WUA-Measuring Point Discharge Relationships

Overall relationships between WUA and measuring point discharge were developed by aggregating the WUW-measuring point discharge for each zone.

1) For each zone, the average relationship between WUW and measuring point discharge was calculated for each mesohabitat unit type (pool, riffle, glide/run):
    a) Henretta Creek (n=2) and the split channel at the oxbow in S6 (n=3 each) were each treated as single mesohabitat unit types, as there were insufficient transects to allow a stratified approach within these locations; and

2) The mesohabitat unit average habitat-flow relationships were multiplied by the corresponding unit lengths in Table 4 to obtain WUA (1000 m²).

Table 3. Number of transects used to develop habitat-flow relationships.

Zone	Segment	Habitat Unit Length (km)			Mesohabitats used for WUA Calculation?[2]
		Glide	Pool[1]	Riffle	
Kilmarnock to Chauncey (S6 & S7)	S6 - Single Channel	0	5	1	Yes
	S7	2	2	2	Yes
	S6 & S7 Total (Single Channel)	**5**	**8**	**5**	**Yes**
	S6 - Mainstem with Side Channel	1	1	1	No
	S6 - Lower Side Channel	2	0	1	No
Henretta to Kilmarnock (S8 & S9)	S8[4]	2	6	6	Yes
	S9	1	2	2	Yes
	S8 & S9 Total	**4**	**8**	**8**	**Yes**
Henretta Creek		1	1	0	No
All		**10**	**17**	**13**	

[1]Two transects were placed in some pool mesohabitat units and treated as a single transect in post-processing

[2]WUA calculated by averaging habitat-flow relationships by mesohabitat across the zone, and then multiplying by mesohabitat unit lengths. Some locations had insufficient transects (< 3 per unit) for this approach and average across all transects was used for these locations (i.e., no stratification).

Table 4. Distribution of mesohabitat units in the upper Fording River, based on percentages in Table 3.4.1 of Cope *et al.* (2016) and stream length information from Teck Coal and FHAP data collected by from Ecofish in 2018.

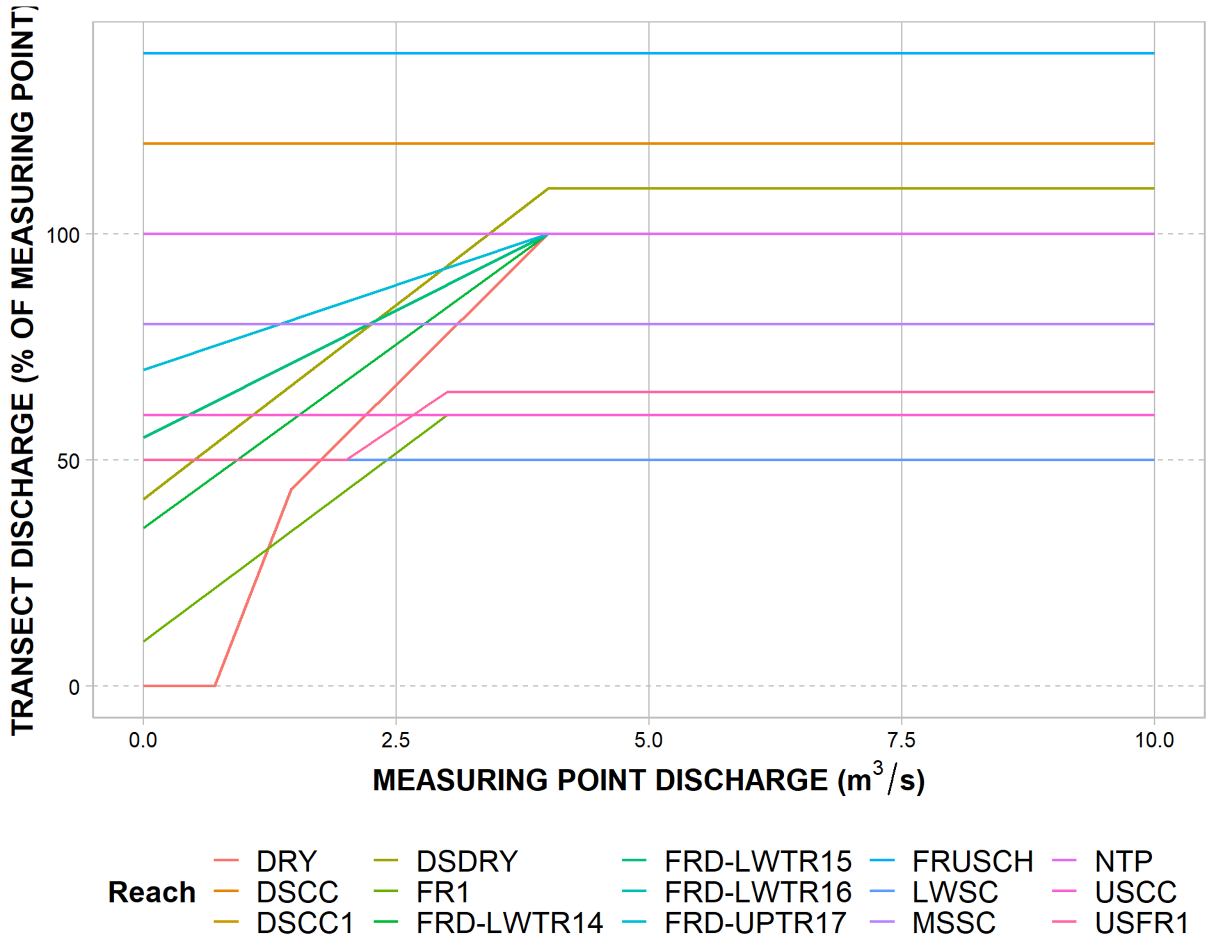
Zone	Segment	Habitat Unit Length (km)					
		Glide	Pool	Riffle	Run[1]	Cascade[2]	Total
Kilmarnock to Chauncey (S6 & S7)	S6 - Single Channel	0.27	4.45	0.96	0.21	0.00	5.89
	S6 - Multi Channel (Primary)	0.17	0.73	0.50	0.08	0.00	1.48
	S6 - Multi Channel (Secondary)	0.40	0.08	0.10	0.45	0.00	1.02
	S7	1.18	0.40	3.48	0.00	0.00	5.07
	Total	**2.02**	**5.67**	**5.03**	**0.74**	**0.00**	**13.45**
Henretta to Kilmarnock (S8 & S9)	S8[3]	1.56	0.24	4.05	0.00	0.00	5.85
	S9	0.47	0.65	1.69	0.56	0.00	3.38
	Total	**2.03**	**0.89**	**5.74**	**0.56**	**0.00**	**9.22**
Henretta Creek		**0.15**	**0.19**	**0.34**	**0.11**	**0.02**	**0.81**
All		**4.20**	**6.75**	**11.11**	**1.41**	**0.02**	**23.49**

[1]Habitat-flow relationships for glides assumed to represent run habitats in IFS

[2]Cascade habitats not sampled due to limited distribution (~200 m)

[3]Glide length adjusted by +625 m and riffle length adjusted by -625 m to account for addition of 20 riffle structures

Figure 2. Estimated relationship between flow at Fording River transects and Measuring Point B (FR_NTP). Underlying data are provided in Appendix D.



1.2. Discussion of Uncertainties

The prediction of habitat-flow relationships through an instream flow study typically includes consideration of sources of uncertainty. Uncertainty occurs with all transect-based instream flow models (Turner *et al.* 2015) because:

- Models are based on data collected at specific locations and extrapolated to a larger stream segment (i.e., spatial heterogeneity);
- Models may be informed by imperfect data (i.e., measurement error);
- Models require application of habitat suitability criteria that relate physical parameters (depth/velocity) to biotic response; and
- Data are collected at specific flow conditions and used to predict habitat conditions at other flows (i.e., interpolation and extrapolation).

We provide a brief discussion of key sources of uncertainty below in Table 5 and note efforts that were made to minimize these uncertainties. This table describes how the uncertainties were addressed, ordered by the anticipated effect on the habitat-flow relationships. The effects of the uncertainties are assessed qualitatively based on professional judgment and could be further considered quantitively if warranted under a specific decision context. We emphasize that the inclusion of this discussion does not imply uncertainties that are atypical for an instream flow study. This study adhered to current guidelines for conducting this type of study (Lewis *et al.* 2004), and these guidelines were developed to reduce uncertainties in the resulting habitat-flow relationships to within acceptable bounds.

Table 5. Evaluation of uncertainties associated with UFR habitat-flow relationships, ordered from least to greatest effect on the habitat-flow relationships.

Uncertainty	Section	Description
Measurement Error	1.1.1	Survey measurements were checked by relating all surveys to three fixed locations (Appendix C). Velocity meters were calibrated for each trip; close agreement between discharge estimates at adjacent transects suggests velocity measurements are representative of mean column velocity.
Velocity Model	1.1.2	Habitat-flow relationships were developed with 3 velocity models; the shapes of habitat-flow relationships were similar for all models with a few exceptions for specific transects/HSC. Average of all 3 velocity models was used to develop final habitat-flow relationships, so error in any model should have little effect on habitat-flow relationships.
Water Surface Model	1.1.2	Stage-discharge relationships produced simulated hydraulics in close agreement with measurements. There is some uncertainty in discharge estimates at time of sampling. Hydrometric gauge data, transect measurements, discrete measurements, and longitudinal variation in flow considered in discharge estimates. Uncertainty in discharge estimates is greatest for highest flow trip in Segment S6 because transects were sampled on different dates, discharge estimates from the instream flow transects are consistently greater than FR_FRABCHF estimates at high flow conditions, and discrete flow measurements were not taken on the same date as sampling. Uncertainty for moderate and low flow trips is greatest in and around the two seasonally drying sections.
Sampling Design	1.1.1	Spatial heterogeneity was addressed by distributing 40 transects along the ~20km length of the study area stratified by mesohabitat type. Transects were placed in seasonally drying sections, areas with multiple channels, straight and bend sections, and in natural, disturbed, and restored habitat. Uncertainty associated with heterogeneity was evaluated via bootstrap analysis; widths of confidence intervals is similar to our findings on other streams.

Table 5. Continued (2 of 3).

Uncertainty	Section	Description
HSC	1.1.2	Where available, multiple HSC were evaluated for each life stage to assess sensitivity to HSC selection. While the HSC specific to WCT (Golder 2014) were developed with regulatory input, it is unclear if these criteria have been fully accepted by regulators (DFO 2015). Suitability of HSC should be considered when selecting habitat-flow relationships to assess water management scenarios and EFN.
Sampled Flow Range	1.1.1	Confidence in habitat-flow relationships is greatest within the sampled flow range (~1 m^3/s to 5.5 m^3/s near Measuring Point C, 0.6 m^3/s to 4 m^3/s near Measuring Point B, 0.4 m^3/s to 2.5 m^3/s near Measuring Point A). There is greater uncertainty in the model extrapolation to low flow vs high flow conditions, especially considering the two seasonally drying sections. Sampling at lower flow conditions was not completed because these low flows occur in the winter when ice formation at the transects affects the channel hydraulics, limiting the utility of the data.
Aggregation	1.1.3	For each Fording River zone, the habitat-flow relationships for each mesohabitat type (pool, riffle, glide/run) were estimated; S6 and S7 were combined, and S8 and S9 were combined. The segments do not reflect morphological breaks (Cope *et al.* 2016). There are longitudinal changes in stream morphology along each zone, as well as variation in streamflow, as there would be under other delineation schemes. Accordingly, the aggregate habitat-flow relationships are sensitive to the specific placement of transects within each zone. This uncertainty was considered in the sampling design and placement of transects to avoid giving too much weight to an individual location; in the Chauncey to Kilmarnock zone, each mesohabitat type was assigned a minimum of 5 transects, and in the Kilmarnock to Henretta zone, 8 pool and riffle transects and 4 glide transects were assigned.

Table 5. Continued (3 of 3).

Uncertainty	Section	Description
Transect to Gauge Discharge	1.1.3	Measuring points are located in segments S8 and in Henretta Creek; confidence in translation of transect to gauge discharge is greatest in these segments. Confidence in the translation of transect to gauge discharge is lowest in and around the seasonally drying sections of S9 and S7; the greatest uncertainty is the estimated minimum gauge flow at which the transects become wetted, estimated from water level logger data. Transect to measuring point relationships are based on 3 discrete measurements supplemented by level logger data; simple relationships (constant, or where necessary constant above and below some threshold with a linear increase in between) were fit to these points and longitudinal increases/decreases in streamflow were considered.
Winter conditions		The habitat-flow relationships developed in this report are for ice-free conditions. Ice is present in the Fording River each winter (regardless of Project water use) and affects channel hydraulics (e.g., due to backwatering or constriction of flow). Effects of ice should be considered when applying these habitat-flow relationships to overwintering conditions.

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Appendix B. Photographs of Instream Flow Transects.

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b) September 4, 2019

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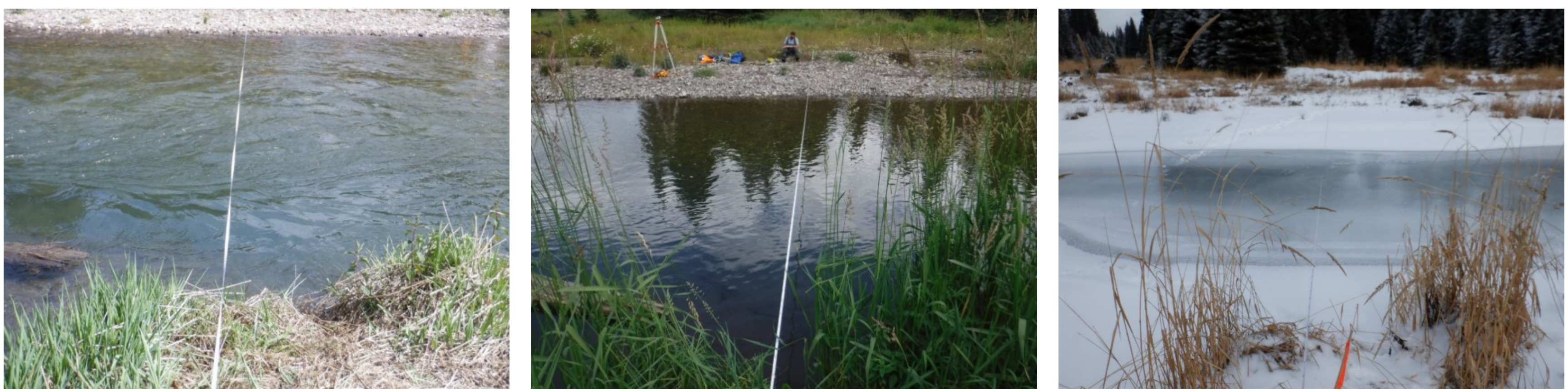


Figure 46. Looking upstream at transect FRD-LWTR14

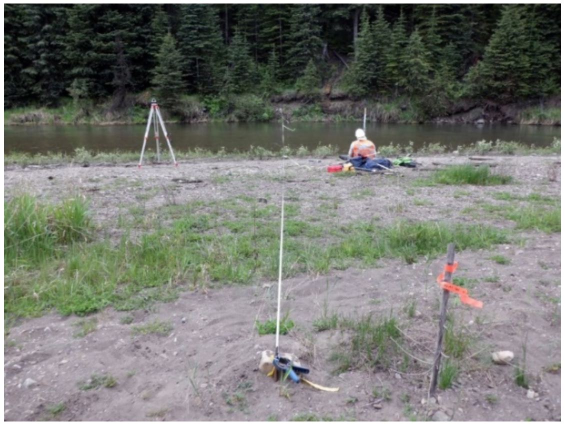
a) June 13, 2019

b) September 2, 2019

c) November 6, 2019

Figure 47. Looking RL to RR at transect FRD-LWTR14

a) June 13, 2019



b) September 2, 2019

c) November 6, 2019

Figure 48. Looking RR to RL at transect FRD-LWTR14

a) June 13, 2019

b) September 2, 2019

c) November 6, 2019

Figure 49. Looking upstream at transect FRD-LWTR15

a) June 13, 2019

b) September 2, 2019

c) November 6, 2019

Figure 50. Looking RL to RR at transect FRD-LWTR15

a) June 13, 2019 b) September 2, 2019 c) November 6, 2019

Figure 51. Looking RR to RL at transect FRD-LWTR15

a) June 13, 2019 b) September 2, 2019 c) November 6, 2019

Figure 52. Looking upstream at transect FRD-LWTR16

a) June 14, 2019

b) September 2, 2019

c) November 7, 2019

Figure 53. Looking RL to RR at transect FRD-LWTR16

a) June 14, 2019

b) September 2, 2019

c) November 7, 2019

Figure 54. Looking RR to RL at transect FRD-LWTR16

a) June 14, 2019

b) September 2, 2019

c) November 7, 2019

Figure 55. Looking upstream at transect FRD-UPTR17

a) June 13, 2019

b) No photo

c) November 6, 2019

Figure 56. Looking RL-RR at transect FRD-UPTR17

a) June 13, 2019 b) September 2, 2019 c) November 6, 2019

Figure 57. Looking RR-RL at transect FRD-UPTR17

a) June 13, 2019 b) September 2, 2019 c) November 6, 2019

Figure 58. Looking upstream at transect FRD-UPTR18

a) June 12, 2019

b) September 2, 2019

c) November 5, 2019

Figure 59. Looking RL to RR at transect FRD-UPTR18

a) June 12, 2019

b) September 2, 2019

c) November 5, 2019

Figure 60. Looking RR at RL at transect FRD-UPTR18

a) June 12, 2019

b) September 2, 2019

c) November 5, 2019

Figure 61. Looking upstream at transect FRD-UPTR19

a) June 13, 2019

b) September 2, 2019

c) November 5, 2019

Figure 62. Looking RL to RR at transect FRD-UPTR19

a) June 13, 2019 b) September 2, 2019 c) November 5, 2019



Figure 63. Looking RR to RR at transect FRD-UPTR19

a) June 13, 2019 b) September 2, 2019 c) November 5, 2019



Figure 64. Looking upstream at transect FRD-UPTR20

a) June 12, 2019

b) September 2, 2019

c) November 5, 2019

Figure 65. Looking RL to RR at transect FRD-UPTR20

a) June 12, 2019 b) September 2, 2019 c) November 5, 2019

Figure 66. Looking RR to RL at transect FRD-UPTR20

a) June 12, 2019 b) September 2, 2019 c) November 5, 2019

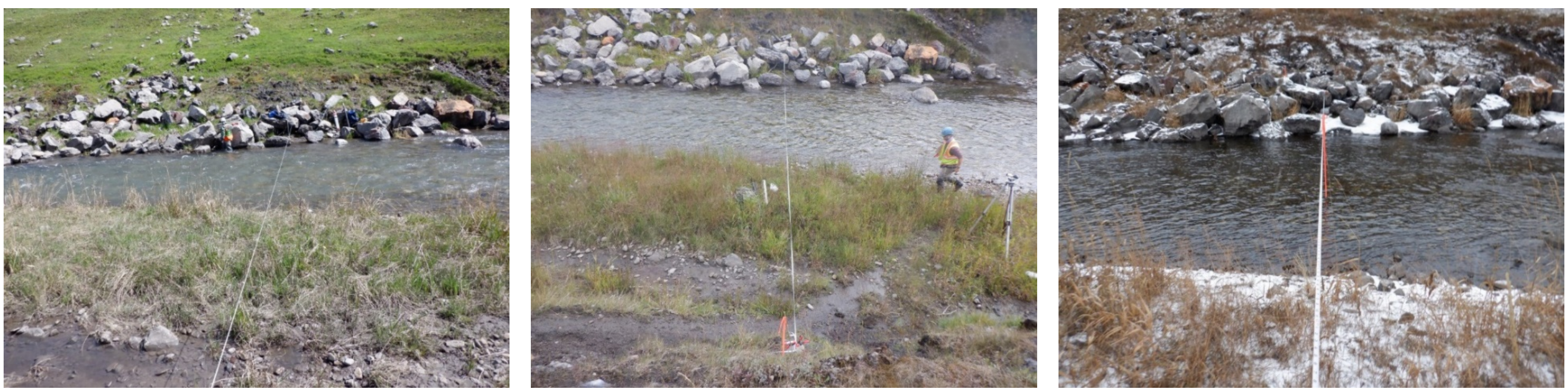


Figure 67. Looking upstream at transect FRD-UPTR21A

a) June 12, 2019

b) September 1, 2019

c) November 5, 2019

Figure 68. Looking RL to RR at transect FRD-UPTR21A

a) June 12, 2019 b) September 1, 2019 c) November 5, 2019

Figure 69. Looking RR to RL at transect FRD-UPTR21A

a) June 12, 2019 b) September 1, 2019 c) November 5, 2019

Figure 70. Looking upstream at transect FRD-UPTR21B

a) June 12, 2019

b) September 1, 2019

c) November 5, 2019

Figure 71. Looking RL to RR at transect FRD-UPTR21B

a) June 12, 2019

b) September 1, 2019

c) November 5, 2019

Figure 72. Looking RR to RL at transect FRD-UPTR21B

a) June 12, 2019

b) September 1, 2019

c) November 5, 2019

Figure 73. Looking upstream at transect FRD-UPTR22

a) June 12, 2019

b) September 1, 2019

c) November 5, 2019

Figure 74. Looking RL to RR at transect FRD-UPTR22

a) June 12, 2019

b) September 1, 2019

c) November 5, 2019

Figure 75. Looking RR to RL at transect FRD-UPTR22

a) June 12, 2019

b) September 1, 2019

c) November 5, 2019

Figure 76. Looking upstream at transect FRD-UPTR23

a) June 11, 2019

b) September 1, 2019

c) November 5, 2019

Figure 77. Looking RL to RR at transect FRD-UPTR23

a) June 11, 2019 b) September 1, 2019 c) November 5, 2019

Figure 78. Looking RR to RL at transect FRD-UPTR23

a) June 11, 2019 b) September 1, 2019 c) November 5, 2019

Figure 79. Looking upstream at transect FRD-UPTR24

a) June 11, 2019

b) September 1, 2019

c) November 5, 2019

Figure 80. Looking RL to RR at transect FRD-UPTR24

a) June 11, 2019 b) September 1, 2019 c) November 5, 2019

Figure 81. Looking RR to RL at transect FRD-UPTR24

a) June 11, 2019 b) September 1, 2019 c) November 5, 2019

Figure 82. Looking upstream at transect FRD-UPTR25

a) June 11, 2019

b) September 1, 2019

c) November 5, 2019

Figure 83. Looking RL to RR at transect FRD-UPTR25

a) June 11, 2019 b) September 1, 2019 c) November 5, 2019

Figure 84. Looking RR to RL at transect FRD-UPTR25

a) June 11, 2019 b) September 1, 2019 c) November 5, 2019

Figure 85. Looking upstream at transect FRD-UPTR26

a) June 10, 2019

b) September 1, 2019

c) November 4, 2019

Figure 86. Looking RL to RR at transect FRD-UPTR26

a) June 10, 2019

b) September 1, 2019

c) November 4, 2019

Figure 87. Looking RR to RL at transect FRD-UPTR26

a) June 10, 2019

b) September 1, 2019

c) November 4, 2019

Figure 88. Looking upstream at transect FRD-UPTR27A

a) June 10, 2019

b) August 31, 2019

c) November 4, 2019

Figure 89. Looking RL to RR at transect FRD-UPTR27A

a) June 10, 2019 b) August 31, 2019 c) November 4, 2019

Figure 90. Looking RR to RL at transect FRD-UPTR27A

a) June 10, 2019 b) August 31, 2019 c) November 4, 2019

Figure 91. Looking upstream at transect FRD-UPTR27B

a) June 10, 2019

b) August 31, 2019

c) November 4, 2019

Figure 92. Looking RL to RR at transect FRD-UPTR27B

a) June 10, 2019 b) August 31, 2019 c) November 4, 2019

Figure 93. Looking RR to RL at transect FRD-UPTR27B

a) June 10, 2019 b) August 31, 2019 c) November 4, 2019

Figure 94. Looking upstream at transect FRD-UPTR28

a) June 11, 2019

b) August 30, 2019

c) November 4, 2019

Figure 95. Looking RL to RR at transect FRD-UPTR28

a) June 10, 2019 b) August 30, 2019 c) November 4, 2019

Figure 96. Looking RR to RL at transect FRD-UPTR28

a) June 10, 2019 b) August 30, 2019 c) November 4, 2019

Figure 97. Looking upstream at transect FRD-UPTR29A

a) June 14, 2019

b) September 1, 2019

c) November 5, 2019

Figure 98. Looking RR to RL at transect FRD-UPTR29A

a) June 14, 2019 b) September 1, 2019 c) November 5, 2019

Figure 99. Looking RL to RR at transect FRD-UPTR29A

a) June 14, 2019 b) September 1, 2019 c) November 5, 2019

Figure 100. Looking upstream at transect FRD-UPTR29B

a) June 14, 2019

b) September 1, 2019

c) November 5, 2019

Figure 101. Looking RL to RR at transect FRD-UPTR29B

a) June 14, 2019

b) September 1, 2019

c) November 5, 2019

Figure 102. Looking RR to RL at transect FRD-UPTR29B

a) June 14, 2019

b) September 1, 2019

c) November 5, 2019

Figure 103. Looking upstream at transect FRD-UPTR30A

a) June 12, 2019

b) August 30, 2019

c) November 4, 2019

Figure 104. Looking RL to RR at transect FRD-UPTR30A

a) June 12, 2019

b) August 30, 2019

c) November 4, 2019

Figure 105. Looking RR to RL at transect FRD-UPTR30A

a) June 12, 2019

b) August 30, 2019

c) November 4, 2019

Figure 106. Looking upstream at transect FRD-UPTR30B

a) June 12, 2019

b) August 20, 2019

c) November 4, 2019

Figure 107. Looking RL to RR at transect FRD-UPTR30B

a) June 12, 2019 b) August 30, 2019 c) November 4, 2019

Figure 108. Looking RR to RL at transect FRD-UPTR30B

a) June 12, 2019 b) August 30, 2019 c) November 4, 2019

Figure 109. Looking upstream at transect FRD-UPTR31

a) June 11, 2019

b) August 30, 2019

c) November 4, 2019

Figure 110. Looking RL to RR at transect FRD-UPTR31

a) June 11, 2019

b) August 30, 2019

c) November 4, 2019

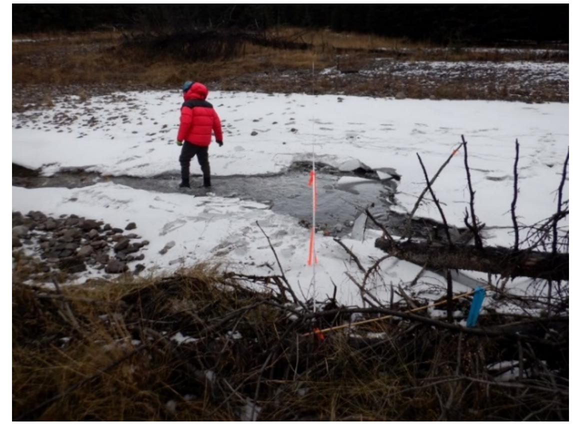


Figure 111. Looking RR to RL at transect FRD-UPTR31

a) June 11, 2019

b) August 30, 2019

c) November 4, 2019

Figure 112. Looking upstream at transect FRD-UPTR32

a) June 11, 2019

b) August 31, 2019

c) November 4, 2019

Figure 113. Looking RL-RR at transect FRD-UPTR32

a) June 11, 2019 b) August 31, 2019 c) November 4, 2019

Figure 114. Looking RL-RR at transect FRD-UPTR32

a) June 11, 2019 b) August 31, 2019 c) November 4, 2019

Figure 115. Looking upstream at transect FRD-UPTR33

a) June 12, 2019

b) August 31, 2019

c) November 4, 2019

Figure 116. Looking RL-RR at transect FRD-UPTR33

a) June 12, 2019 b) August 31, 2019 c) November 4, 2019

Figure 117. Looking RR-RL at transect FRD-UPTR33

a) June 12, 2019 b) August 31, 2019 c) November 4, 2019

Figure 118. Looking upstream at transect FRD-UPTR34

a) June 12, 2019

b) August 31, 2019

c) November 4, 2019

Figure 119. Looking RL-RR at transect FRD-UPTR34

a) June 12, 2019 b) August 31, 2019 c) November 4, 2019


Figure 120. Looking RR-RL at transect FRD-UPTR34

a) June 12, 2019 b) August 31, 2019 c) November 4, 2019


Appendix C. Transect Quality Assurance Reports

Definitions:

LB Pin: Left Bank Pin

RB Pin: Right Bank Pin

BM: Benchmark

BM-LB Pin: Benchmark Elevation Minus Left Bank Pin Elevation

BM-RB Pin: Benchmark Elevation Minus Right Bank Pin Elevation

LB Pin - RB Pin: Left Bank Pin Elevation Minus Right Bank Pin Elevation

Q: Discharge

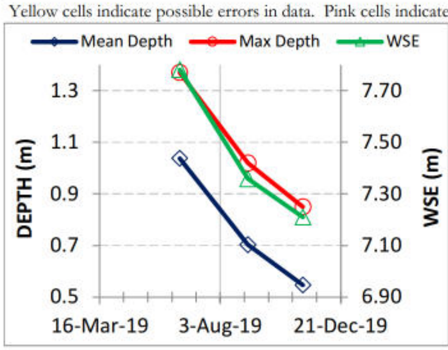
WSE: Water Surface Elevation

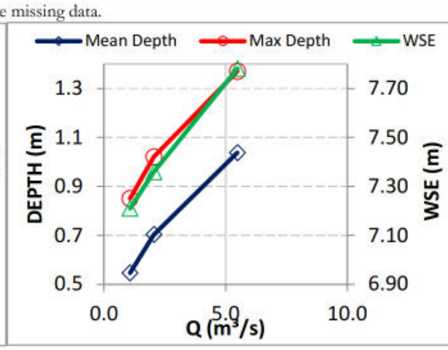
Transect Quality Assurance Report

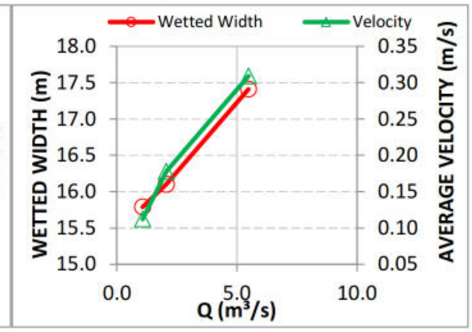
	Stream **Fording River** **FRD-LWTR01**
Static: Tol: 0.01m	No missing data Possible Errors: (06/17/2019, LB Pin)
Dynamic Tol: 0.05m	No missing data Possible Errors: (06/17/2019, WSE)

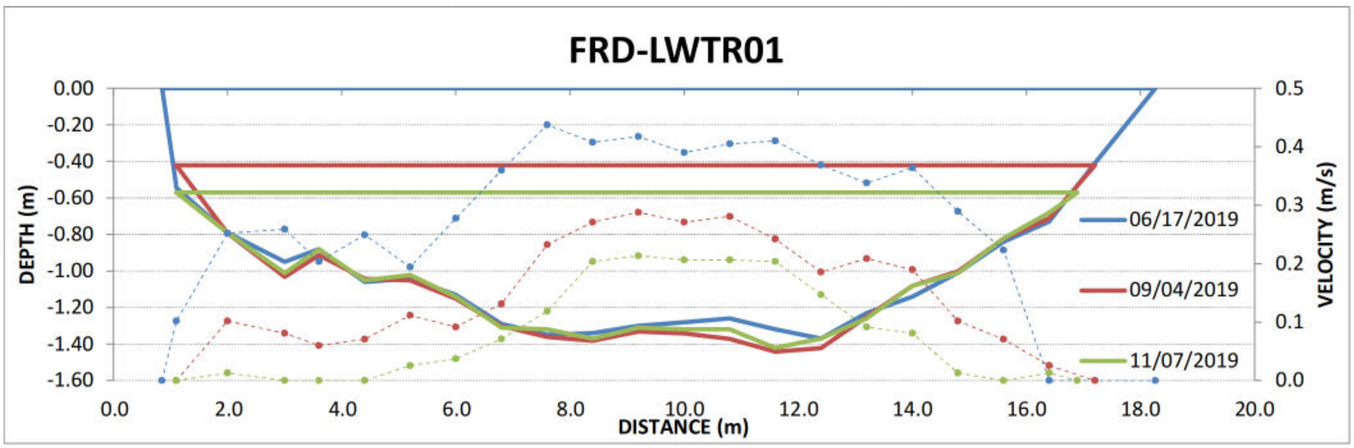
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/17/19	0.825	0.704	0.121	5.482	1.037	1.370	7.781	0.309	17.410	MGL, RLL
09/04/19	0.837	0.704	0.133	2.053	0.703	1.020	7.359	0.178	16.100	AMT, TRS
11/07/19	0.839	0.707	0.132	1.071	0.547	0.850	7.210	0.112	15.790	AMT, JEF

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







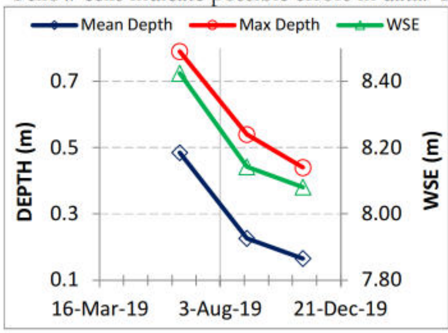


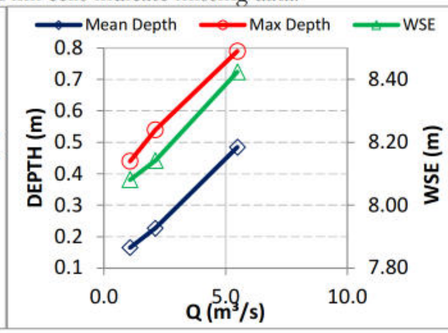
Transect Quality Assurance Report

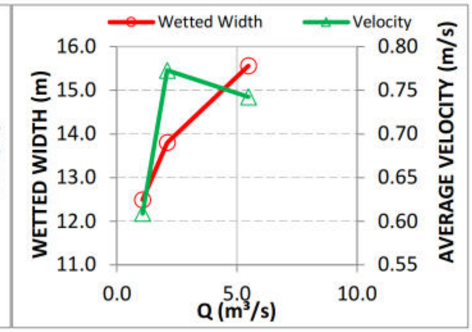
	Stream **Fording River**	**FRD-LWTR02**
Static: Tol: 0.01m	No missing data No errors found	
Dynamic Tol: 0.05m	No missing data No errors found	

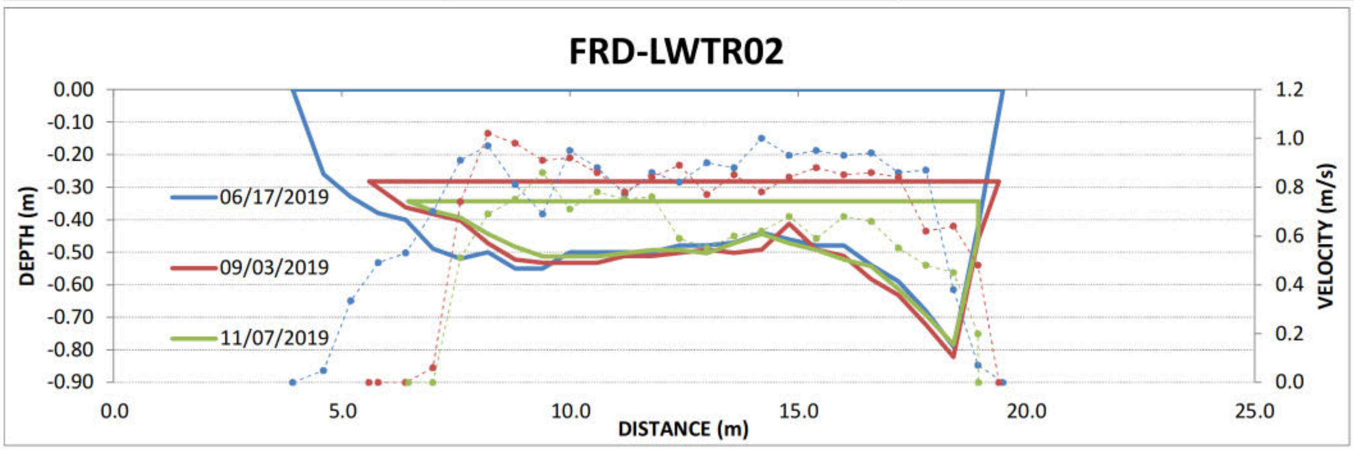
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/17/19	0.465	0.411	0.054	5.482	0.485	0.790	8.424	0.742	15.560	CCF, RLL
09/03/19	0.464	0.407	0.057	2.108	0.226	0.540	8.142	0.773	13.800	AMT, TRS
11/07/19	0.465	0.408	0.057	1.071	0.165	0.440	8.081	0.609	12.490	AMT, JEF

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







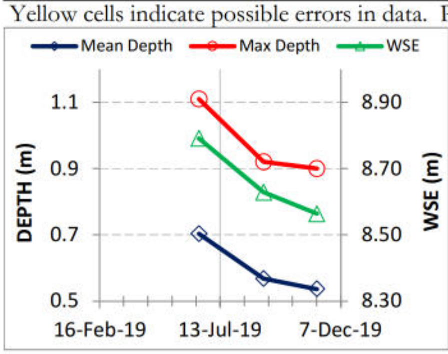


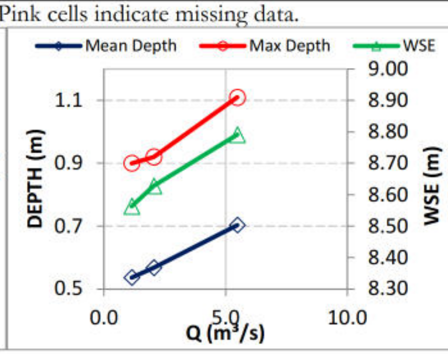
Transect Quality Assurance Report

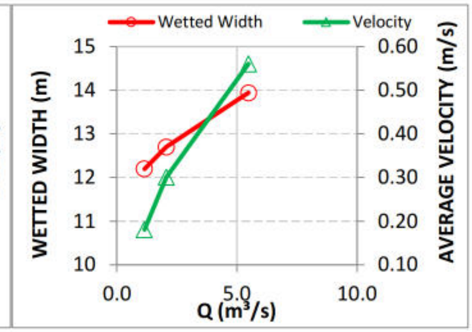
	Stream **Fording River** **FRD-LWTR03A**
Static: Tol: 0.01m	No missing data No errors found
Dynamic Tol: 0.05m	No missing data No errors found

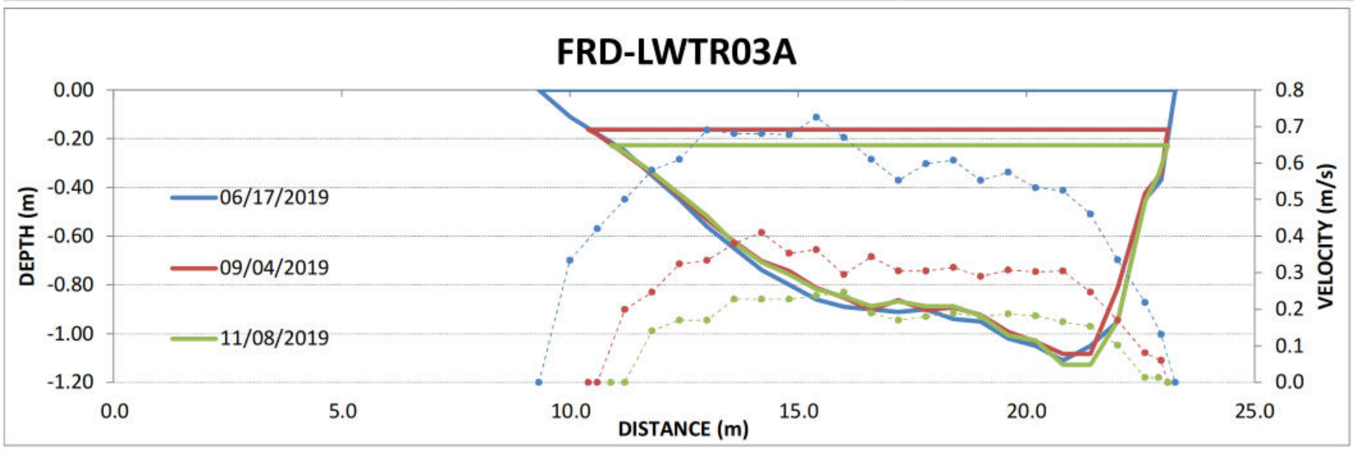
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/17/19	0.091	0.030	0.121	5.482	0.704	1.110	8.791	0.561	13.940	MGL, TRS
09/04/19	0.096	0.027	0.123	2.053	0.568	0.920	8.629	0.301	12.700	MGL, SMS
11/08/19	0.099	0.026	0.125	1.146	0.537	0.900	8.564	0.181	12.200	DJM, MGL

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







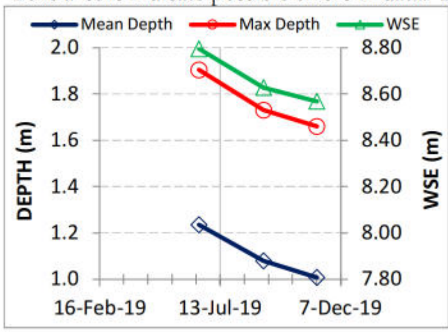


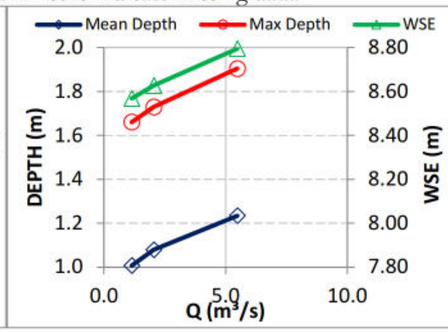
Transect Quality Assurance Report

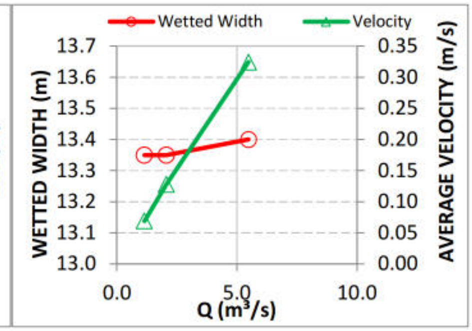
	Stream **Fording River** **FRD-LWTR03B**
Static: Tol: 0.01m	No missing data No errors found
Dynamic Tol: 0.05m	No missing data No errors found

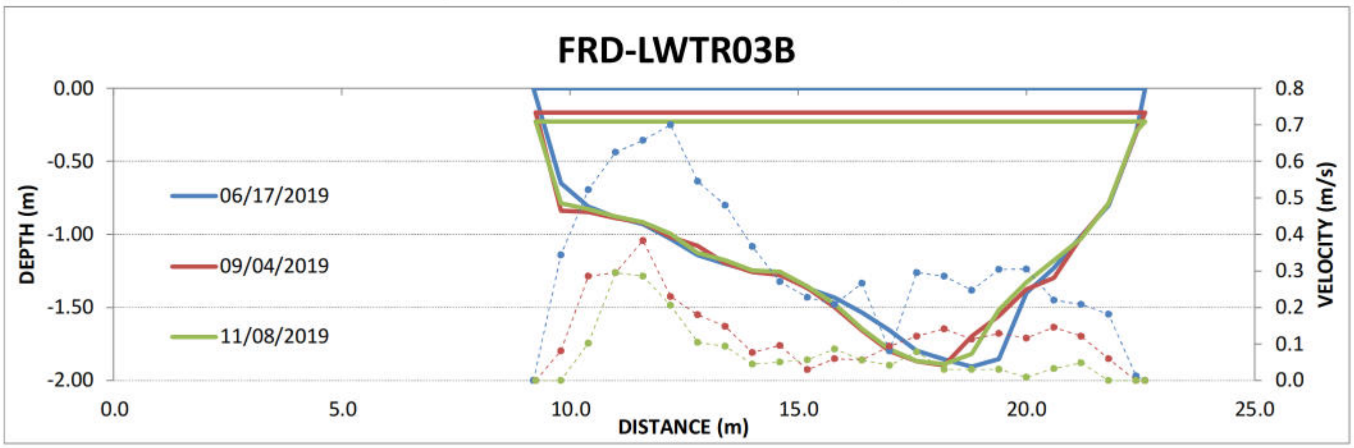
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/17/19	0.080	0.094	0.014	5.482	1.235	1.904	8.795	0.324	13.400	MGL, TRS
09/04/19	0.081	0.086	0.005	2.053	1.079	1.730	8.628	0.128	13.350	AMT, SMS
11/08/19	0.087	0.089	0.002	1.146	1.007	1.660	8.568	0.069	13.350	DJM, MGL

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







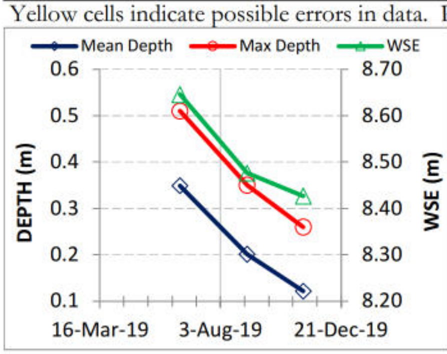


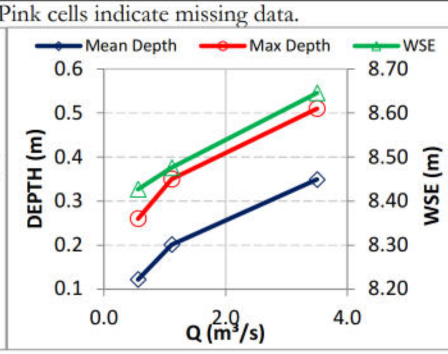
Transect Quality Assurance Report

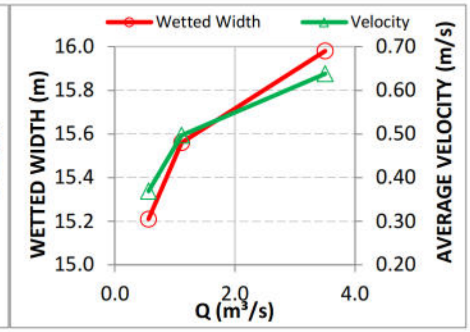
	Stream **Fording River**	**FRD-LWTR04**
Static: Tol: 0.01m	No missing data Possible Errors: (11/07/2019, RB Pin)	
Dynamic Tol: 0.05m	No missing data No errors found	

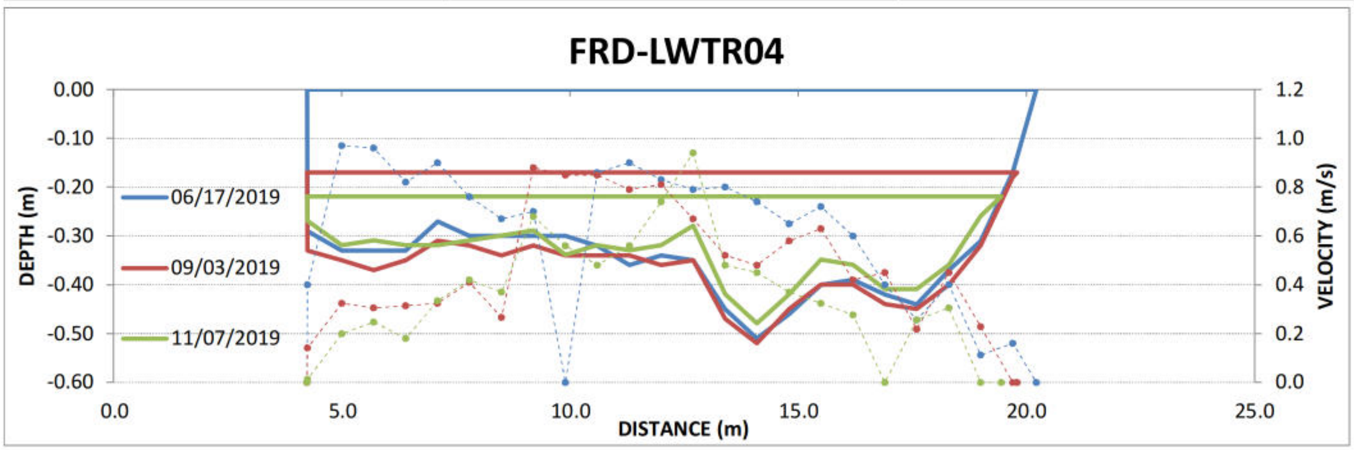
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/17/19	0.360	0.186	0.174	3.502	0.349	0.510	8.646	0.638	15.980	CCF, TRS
09/03/19	0.360	0.187	0.173	1.115	0.201	0.350	8.476	0.497	15.560	AMT, TRS
11/07/19	0.355	0.000	0.355	0.561	0.122	0.260	8.427	0.369	15.210	DJM, MGL

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







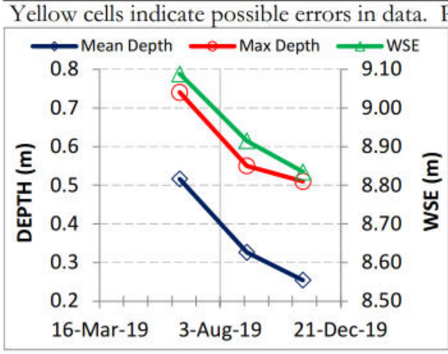


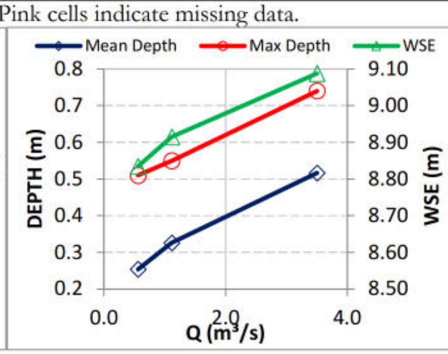
Transect Quality Assurance Report

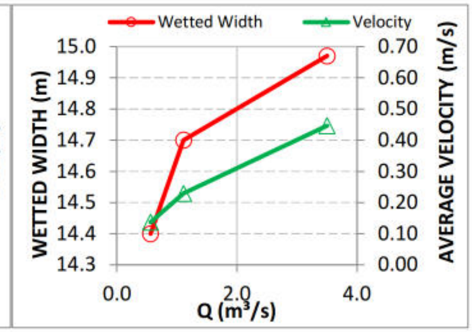
	Stream **Fording River**	**FRD-LWTR05**
Static: Tol: 0.01m	No missing data No errors found	
Dynamic Tol: 0.05m	No missing data No errors found	

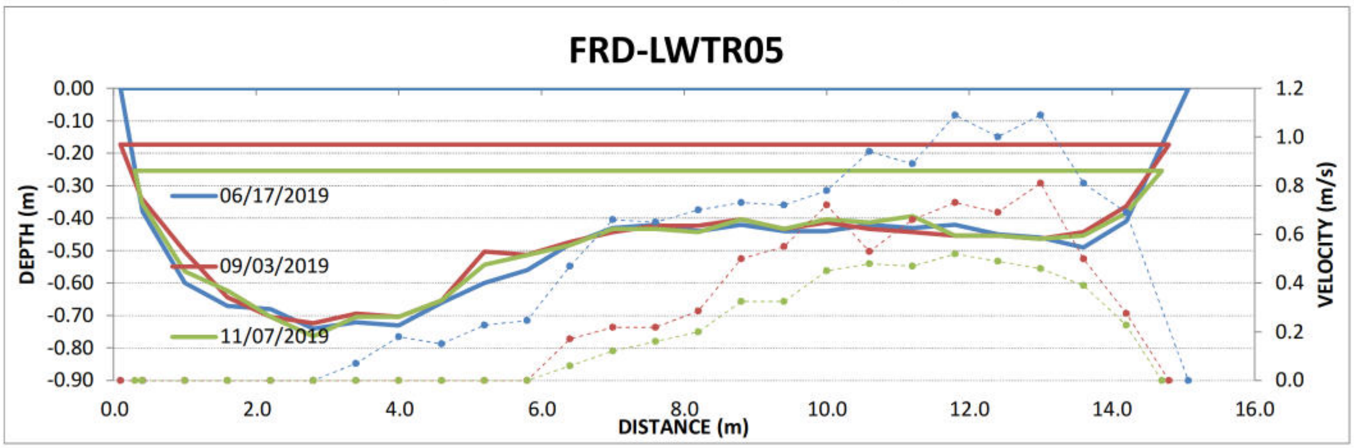
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/17/19	0.209	0.312	0.103	3.502	0.516	0.740	9.088	0.446	14.970	CCF, TRS
09/03/19	0.213	0.312	0.099	1.115	0.326	0.550	8.915	0.229	14.700	MGL, SMS
11/07/19	0.206	0.308	0.102	0.561	0.254	0.510	8.834	0.137	14.400	DJM, MGL

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







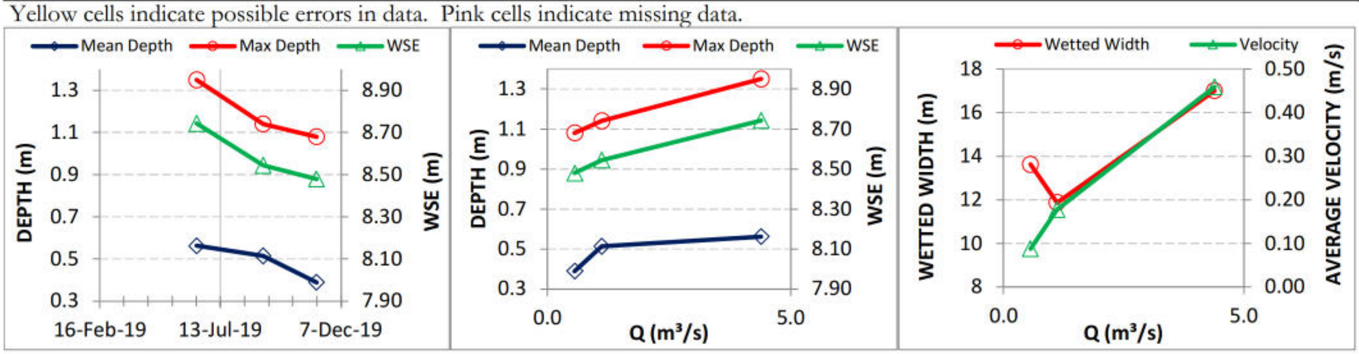


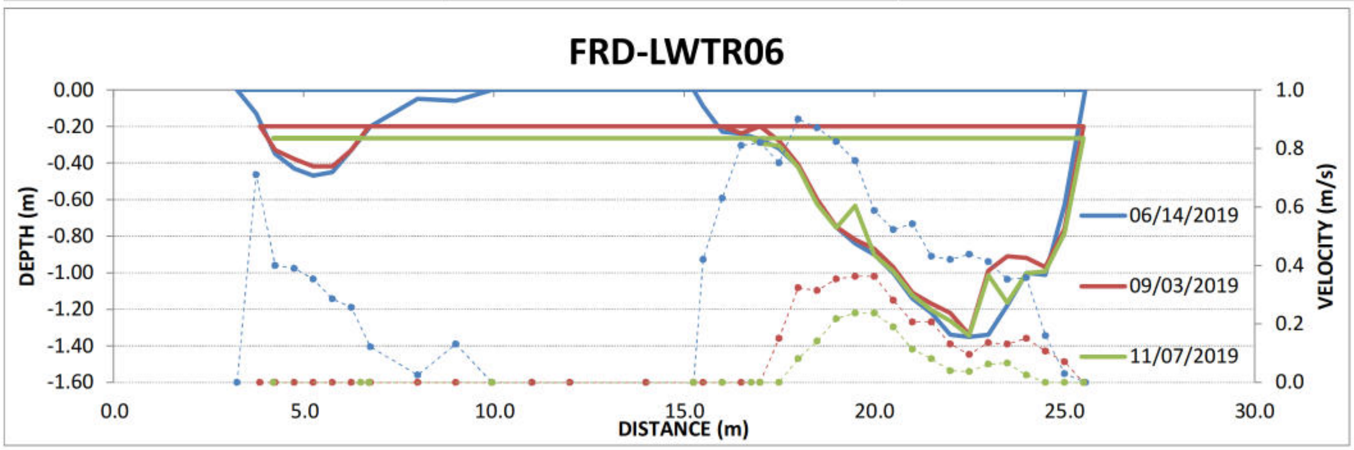
Transect Quality Assurance Report

	Stream **Fording River**	**FRD-LWTR06**
Static: Tol: 0.01m	No missing data No errors found	
Dynamic Tol: 0.05m	No missing data Possible Errors: (06/14/2019, Mean Depth) (09/03/2019, Mean Depth) (11/07/2019, Mean Depth)	

Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/14/19	0.428	0.366	0.062	4.387	0.563	1.350	8.743	0.459	17.000	CCF, TRS
09/03/19	0.428	0.366	0.062	1.115	0.514	1.140	8.544	0.178	11.870	MGL, SMS
11/07/19	0.427	0.356	0.071	0.561	0.389	1.080	8.479	0.088	13.615	DJM, MGL

Yellow cells indicate possible errors in data. Pink cells indicate missing data.



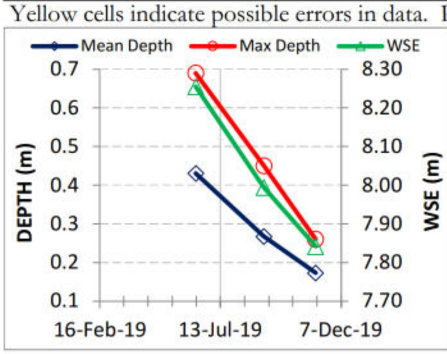


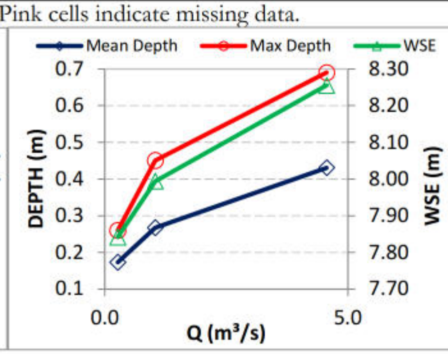
Transect Quality Assurance Report

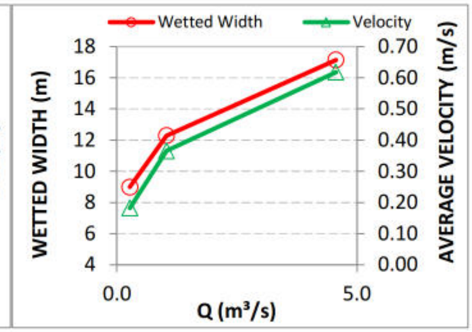
	Stream **Fording River**	**FRD-LWTR07A**
Static: Tol: 0.01m	No missing data Possible Errors: (06/13/2019, RB Pin)	
Dynamic Tol: 0.05m	No missing data Possible Errors: (06/13/2019, Mean Depth) (09/04/2019, Mean Depth) (11/06/2019, Mean Depth)	

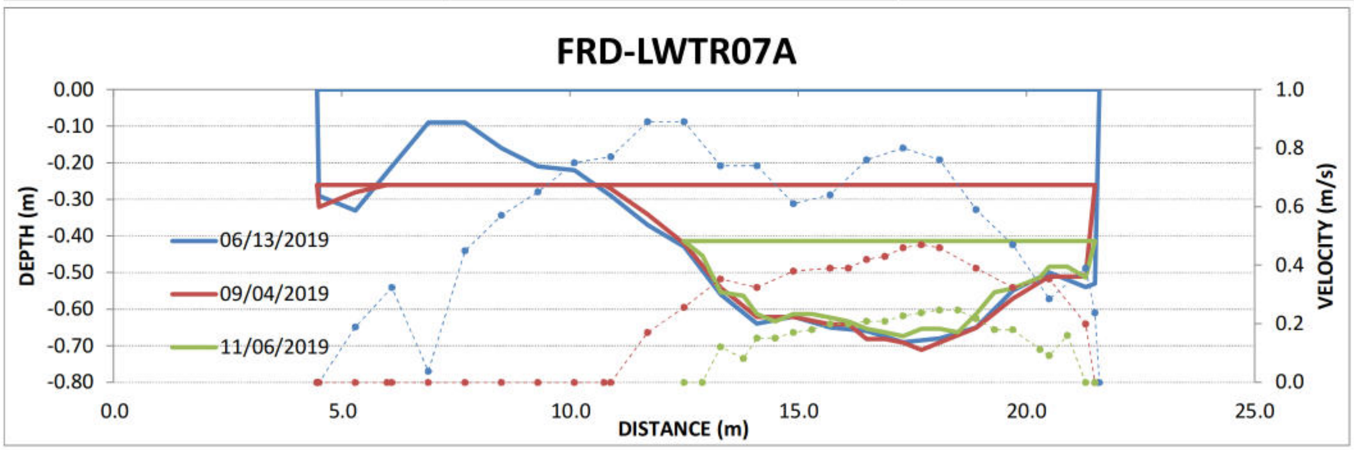
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/13/19	0.441	0.582	0.141	4.560	0.431	0.690	8.255	0.618	17.140	MGL, RLL
09/04/19	0.440	0.594	0.154	1.037	0.267	0.450	7.994	0.366	12.290	AMT, TRS
11/06/19	0.441	0.594	0.153	0.270	0.173	0.260	7.842	0.183	9.000	DJM, MGL

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







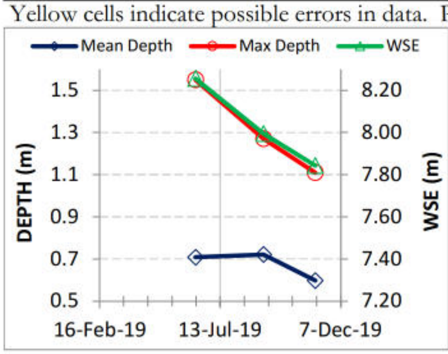


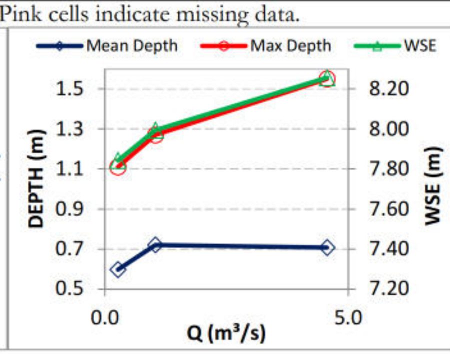
Transect Quality Assurance Report

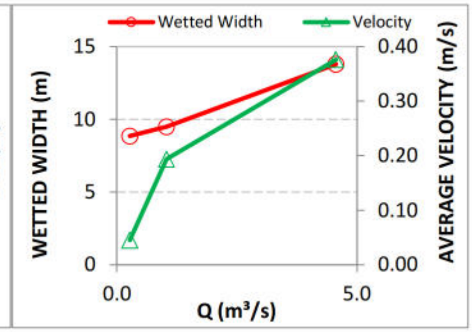
	Stream **Fording River**	**FRD-LWTR07B**
Static: Tol: 0.01m	No missing data No errors found	
Dynamic Tol: 0.05m	No missing data Possible Errors: (06/13/2019, Mean Depth)	

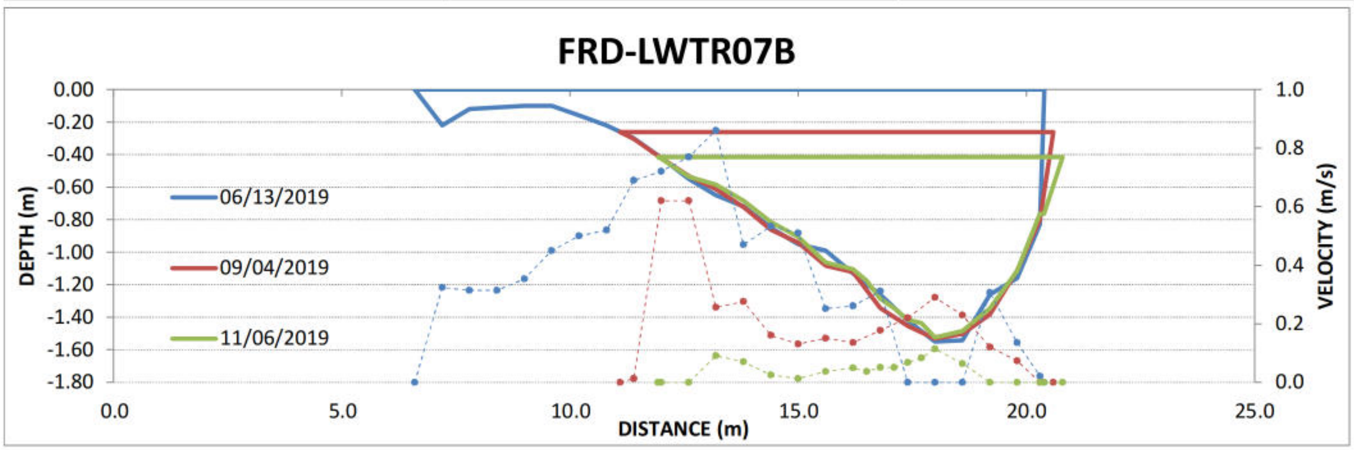
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/13/19	0.047	0.233	0.280	4.560	0.708	1.550	8.256	0.376	13.790	MGL, RLL
09/04/19	0.046	0.237	0.283	1.037	0.721	1.270	7.995	0.194	9.490	AMT, TRS
11/06/19	0.046	0.235	0.281	0.270	0.597	1.110	7.842	0.046	8.860	DJM, MGL

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







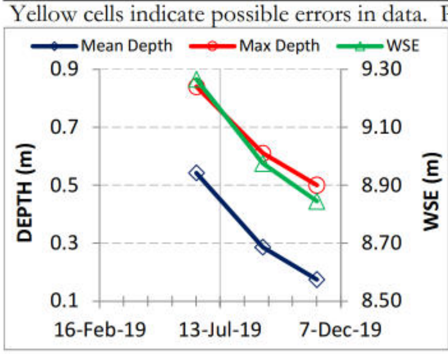


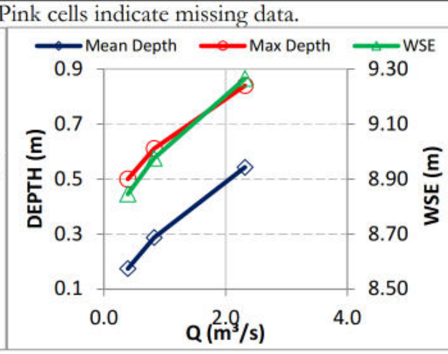
Transect Quality Assurance Report

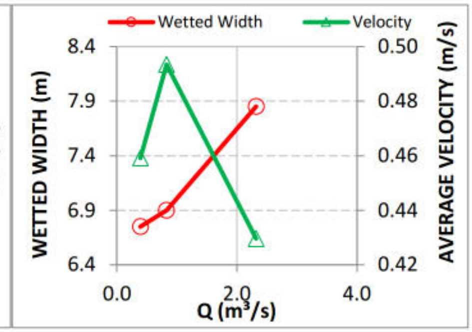
	Stream **Fording River** **FRD-LWTR08**
Static: Tol: 0.01m	No missing data Possible Errors: (06/14/2019, BM) (06/14/2019, LB Pin) (06/14/2019, RB Pin)
Dynamic Tol: 0.05m	No missing data Possible Errors: (06/14/2019, WSE)

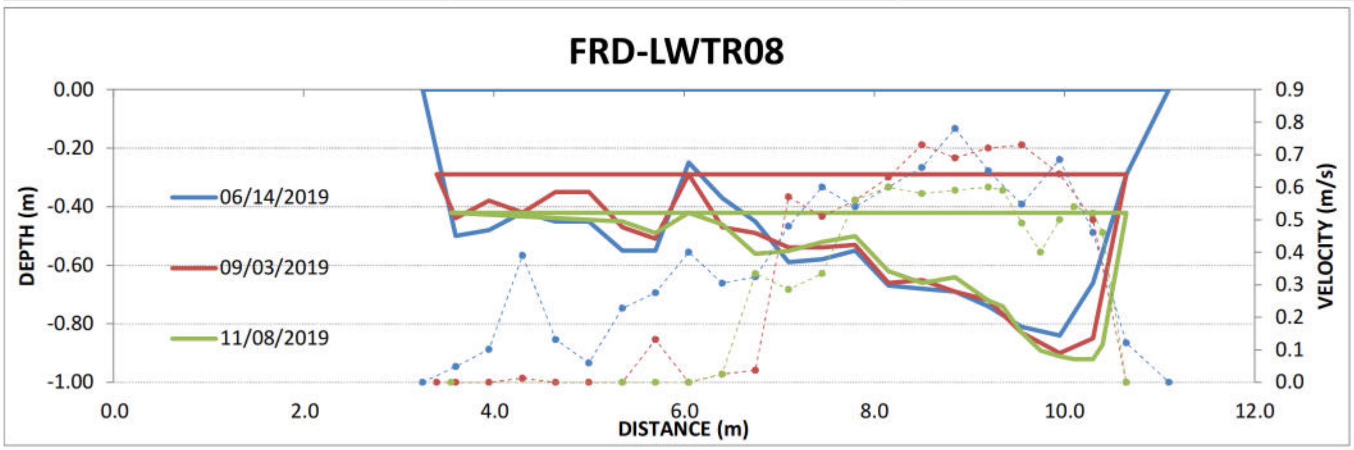
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/14/19	0.862	0.111	0.751	2.320	0.542	0.840	9.266	0.430	7.850	CCF, TRS
09/03/19	0.292	0.137	0.155	0.827	0.287	0.610	8.976	0.493	6.900	AMT, TRS
11/08/19	0.294	0.141	0.153	0.393	0.174	0.500	8.845	0.459	6.750	AMT, JEF

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







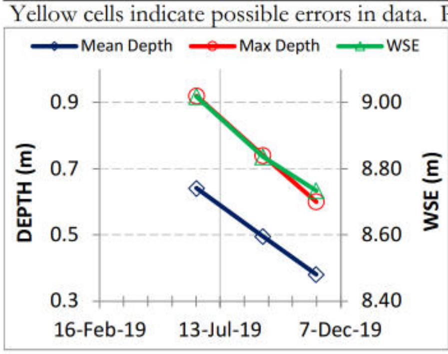


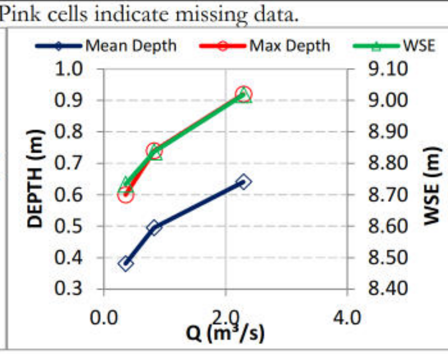
Transect Quality Assurance Report

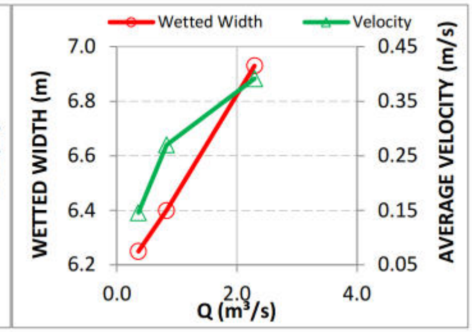
	Stream **Fording River**	**FRD-LWTR09**
Static: Tol: 0.01m	No missing data No errors found	
Dynamic Tol: 0.05m	No missing data No errors found	

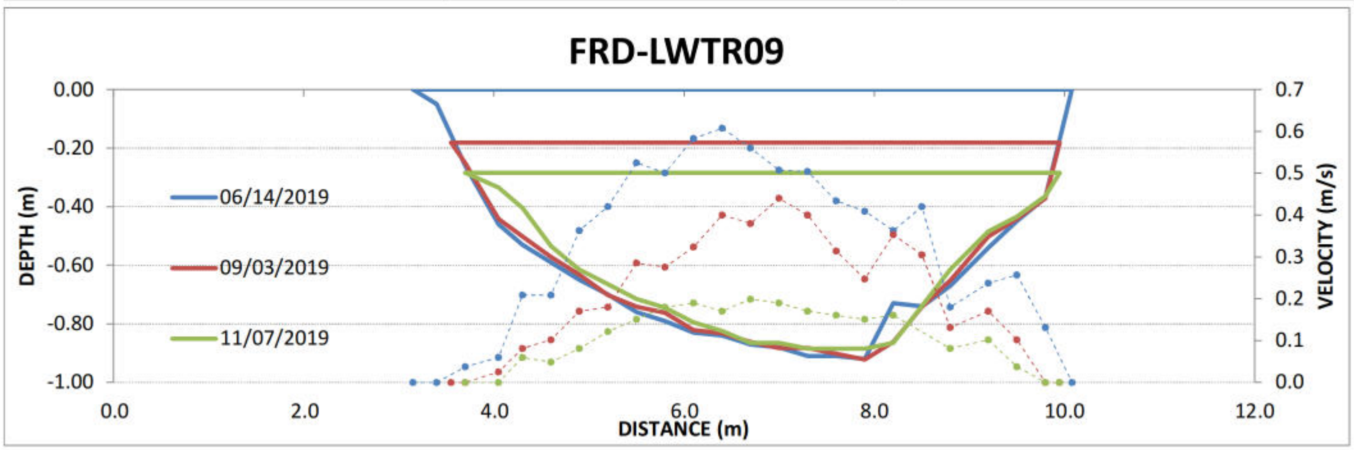
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/14/19	0.497	0.290	0.207	2.294	0.641	0.920	9.018	0.391	6.930	TRS, CCF
09/03/19	0.496	0.290	0.206	0.827	0.496	0.740	8.836	0.270	6.400	AMT, TRS
11/07/19	0.496	0.285	0.211	0.357	0.381	0.600	8.733	0.146	6.250	AMT, JEF

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







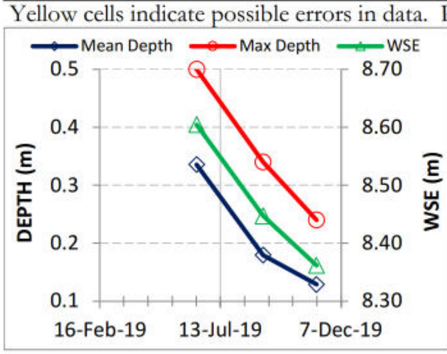


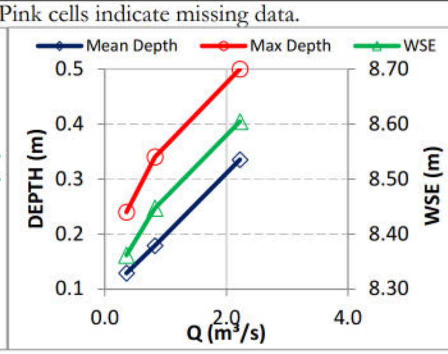
Transect Quality Assurance Report

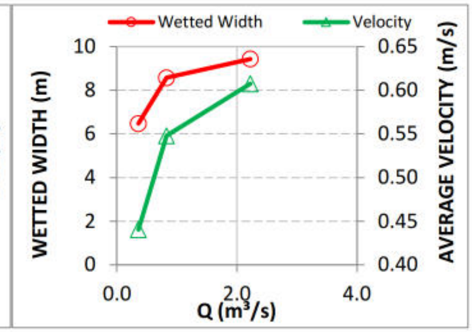
	Stream **Fording River** **FRD-LWTR10**
Static: Tol: 0.01m	No missing data No errors found
Dynamic Tol: 0.05m	No missing data No errors found

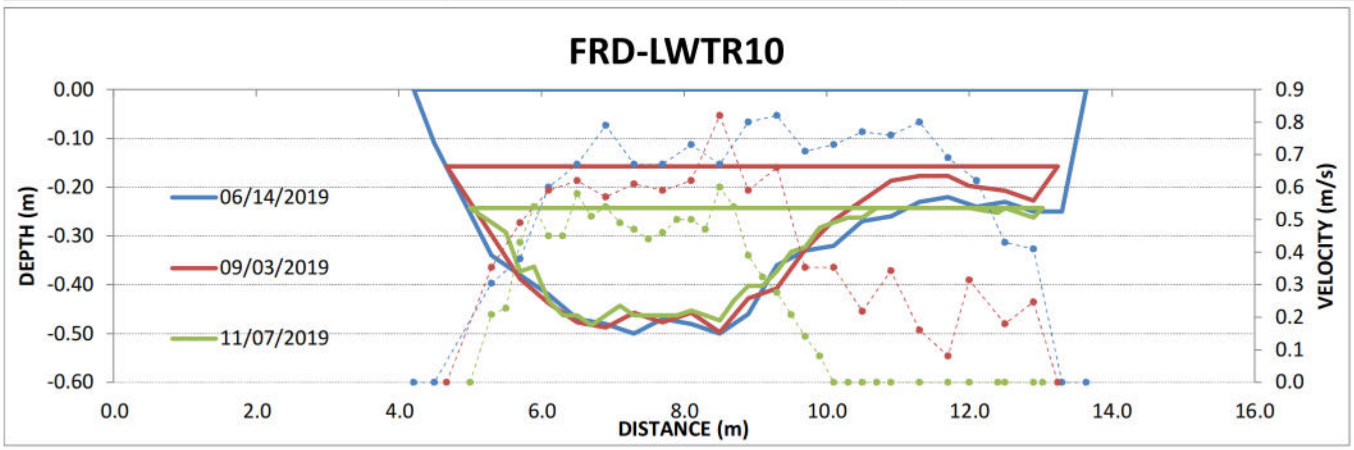
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/14/19	0.120	0.185	0.065	2.223	0.335	0.500	8.604	0.608	9.430	CCF, TRS
09/03/19	0.117	0.184	0.067	0.827	0.179	0.340	8.447	0.548	8.570	MGL, SMS
11/07/19	0.119	0.181	0.062	0.357	0.129	0.240	8.362	0.441	6.480	DJM, MGL

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







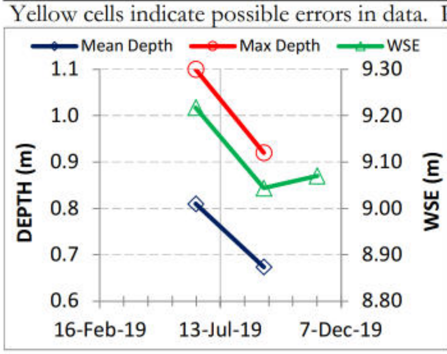


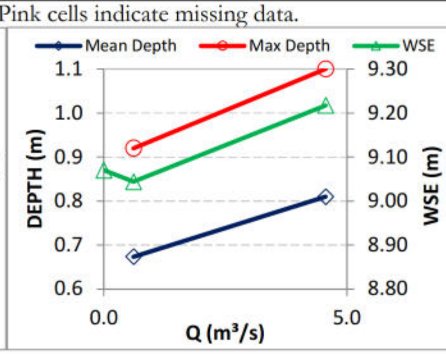
Transect Quality Assurance Report

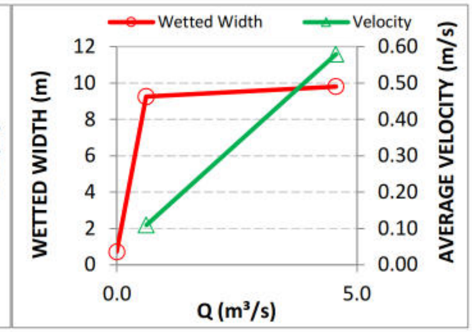
	Stream **Fording River**	**FRD-LWTR11**
Static: Tol: 0.01m	No missing data No errors found	
Dynamic Tol: 0.05m	Missing Information: (11/08/2019, Mean Depth) (11/08/2019, Max Depth) No errors found	

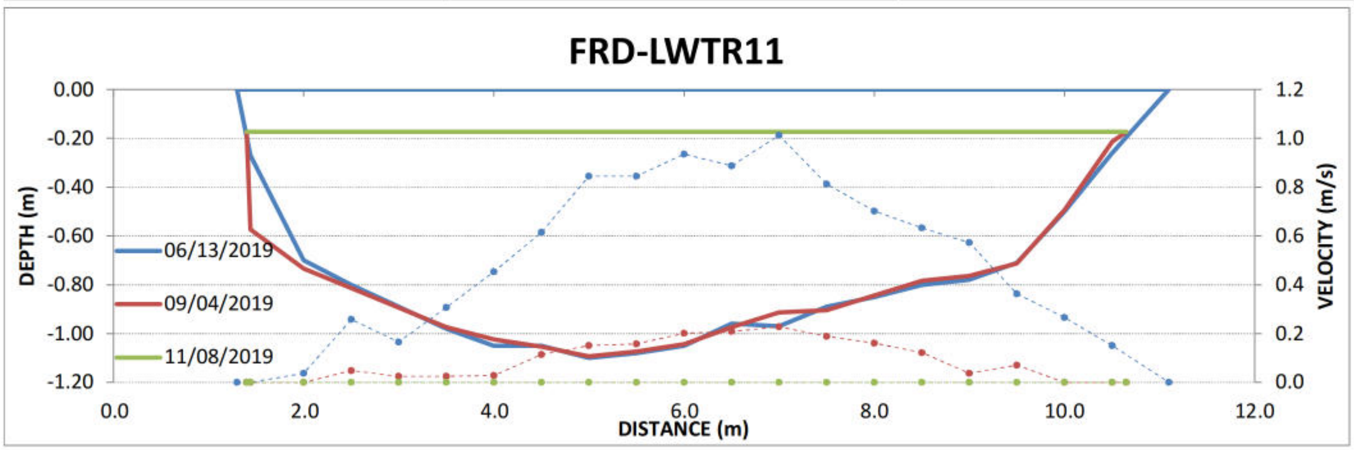
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/13/19	0.283	0.360	0.077	4.560	0.810	1.100	9.217	0.579	9.800	MGL, RLL
09/04/19	0.277	0.350	0.073	0.613	0.674	0.920	9.044	0.110	9.250	TRS, AMT
11/08/19	0.271	0.346	0.075	0.000	0.000	0.000	9.070	0.000	0.720	AMT, JEF

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







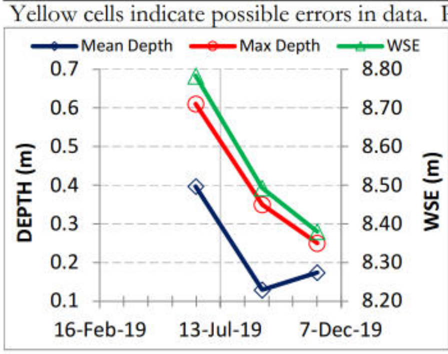


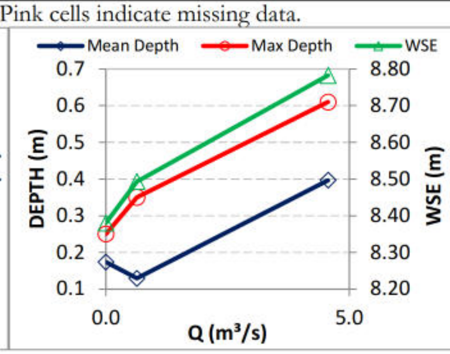
Transect Quality Assurance Report

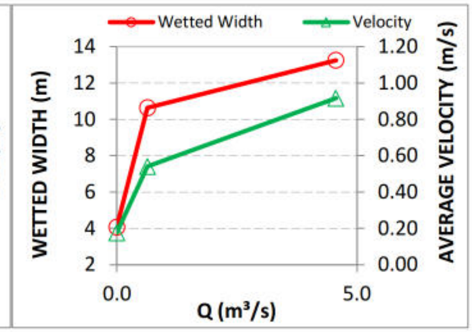
	Stream **Fording River**	**FRD-LWTR12**
Static: Tol: 0.01m	No missing data No errors found	
Dynamic Tol: 0.05m	No missing data Possible Errors: (11/08/2019, Mean Depth)	

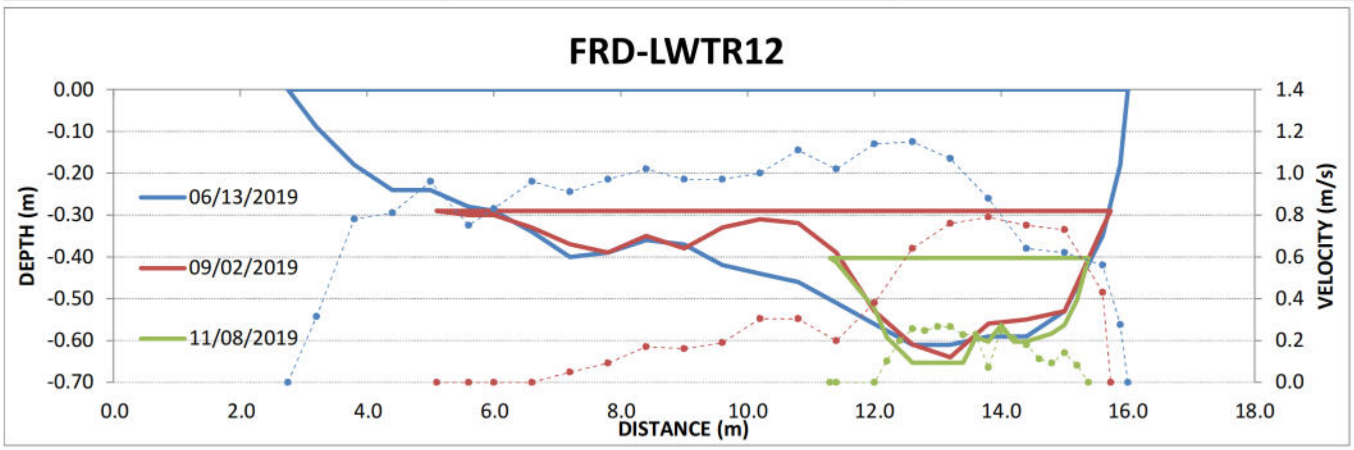
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/13/19	0.405	0.482	0.077	4.560	0.397	0.610	8.783	0.917	13.250	MGL, RLL
09/02/19	0.411	0.480	0.069	0.637	0.129	0.350	8.493	0.541	10.630	MGL, SMS
11/08/19	0.406	0.477	0.071	0.000	0.174	0.250	8.380	0.177	4.080	AMT, JEF

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







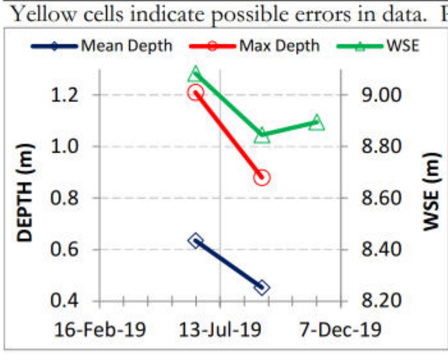


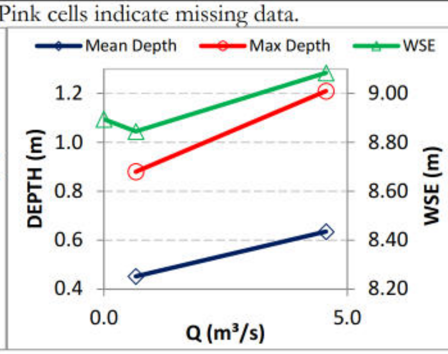
Transect Quality Assurance Report

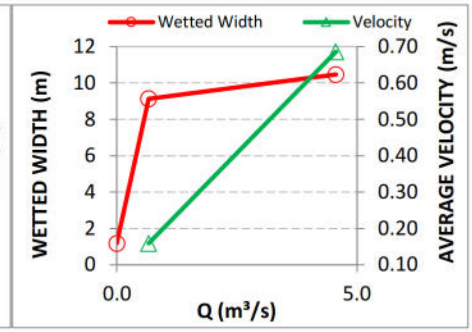
	Stream **Fording River**	**FRD-LWTR13**
Static: Tol: 0.01m	No missing data No errors found	
Dynamic Tol: 0.05m	Missing Information: (11/08/2019, Mean Depth) (11/08/2019, Max Depth) Possible Errors: (06/13/2019, Mean Depth) (06/13/2019, Max Depth) (09/02/2019, Mean Depth) (09/02/2019, Max	

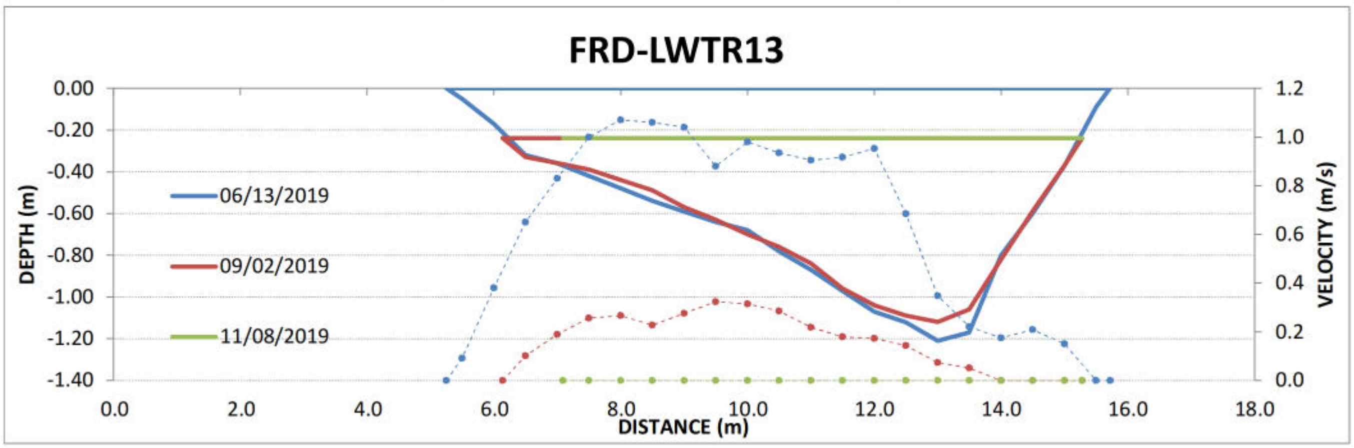
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/13/19	0.451	0.415	0.036	4.560	0.635	1.210	9.084	0.686	10.470	MGL, RLL
09/02/19	0.449	0.417	0.032	0.660	0.452	0.880	8.845	0.160	9.140	MGL, SMS
11/08/19	0.449	0.414	0.035	0.000	0.000	0.000	8.895	0.000	1.190	AMT, JEF

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







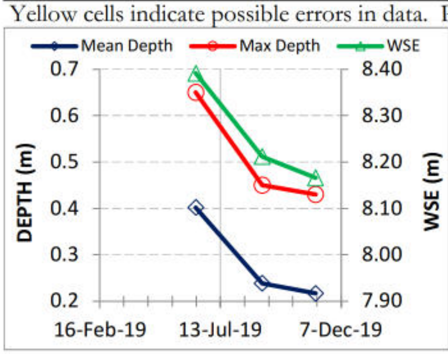


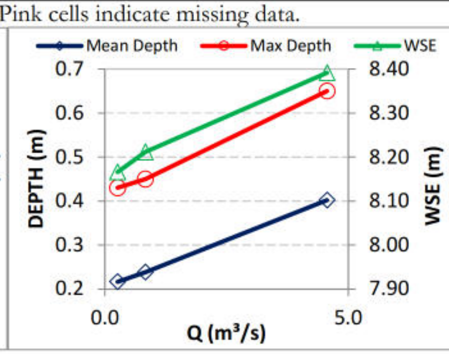
Transect Quality Assurance Report

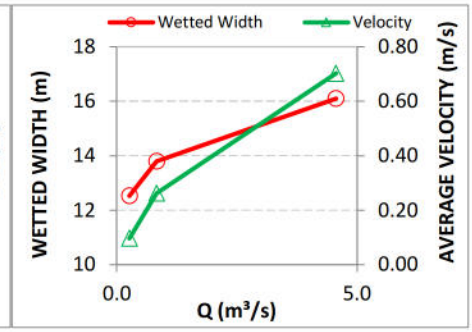
	Stream **Fording River** **FRD-LWTR14**
Static: Tol: 0.01m	No missing data No errors found
Dynamic Tol: 0.05m	No missing data No errors found

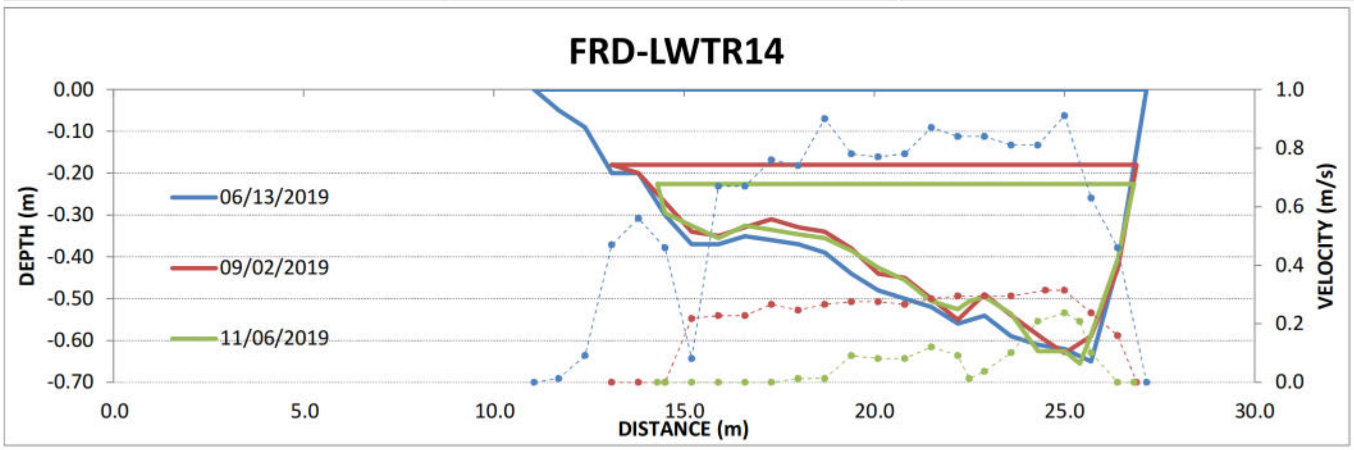
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/13/19	0.958	0.814	0.144	4.560	0.402	0.650	8.391	0.702	16.100	CCF, TRS
09/02/19	0.951	0.802	0.149	0.830	0.238	0.450	8.212	0.262	13.800	MGL, SMS
11/06/19	0.949	0.805	0.144	0.264	0.217	0.430	8.166	0.097	12.530	AMT, JEF

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







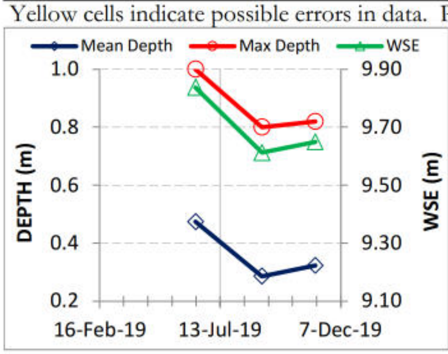


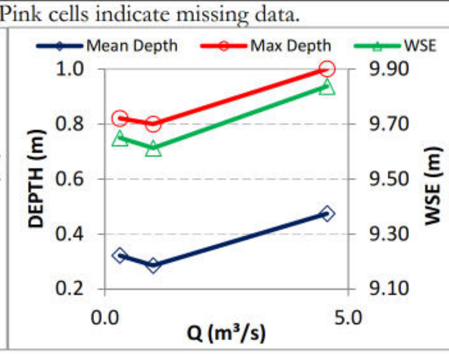
Transect Quality Assurance Report

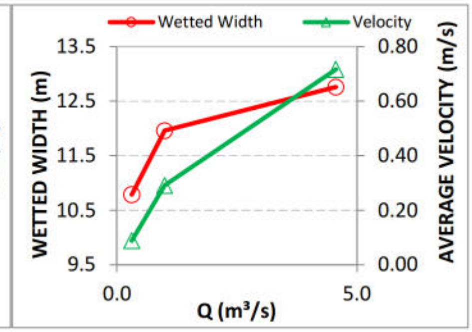
	Stream **Fording River** **FRD-LWTR15**
Static: Tol: 0.01m	No missing data No errors found
Dynamic Tol: 0.05m	No missing data No errors found

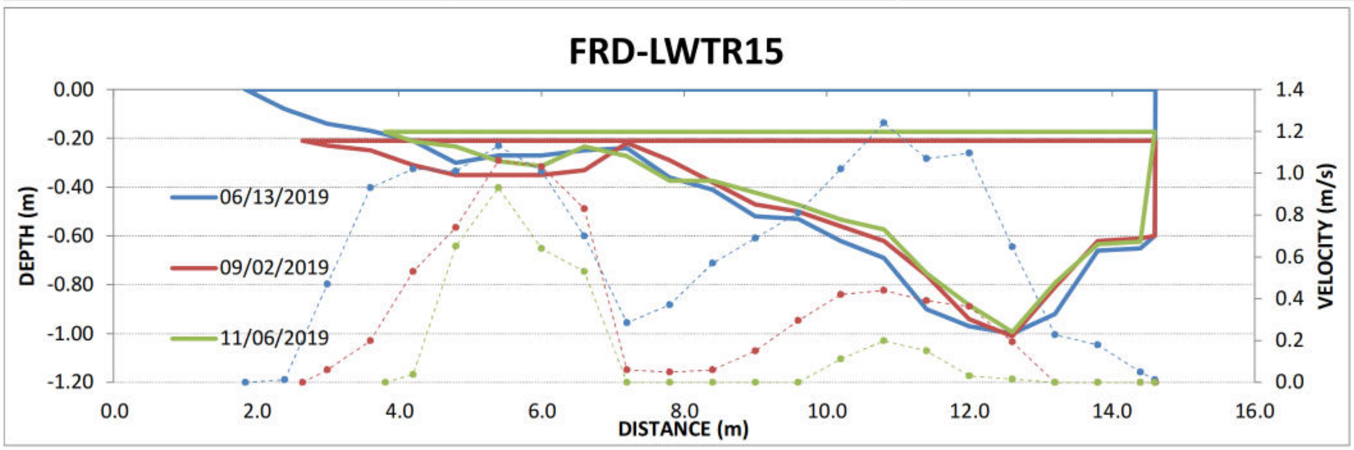
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/13/19	0.313	0.135	0.178	4.560	0.474	1.000	9.837	0.717	12.760	CCF, TRS
09/02/19	0.312	0.134	0.178	0.996	0.286	0.800	9.612	0.291	11.960	AMT, TRS
11/06/19	0.314	0.135	0.179	0.309	0.323	0.820	9.649	0.089	10.790	AMT, JEF

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







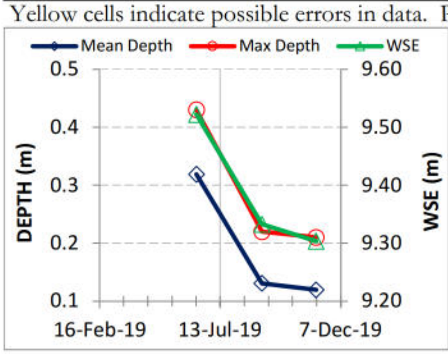


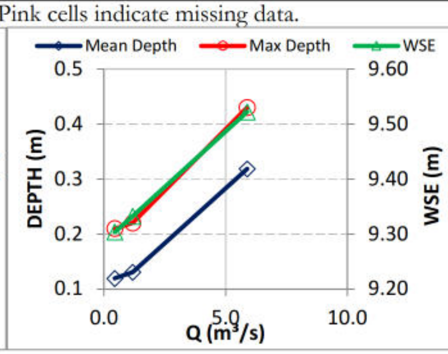
Transect Quality Assurance Report

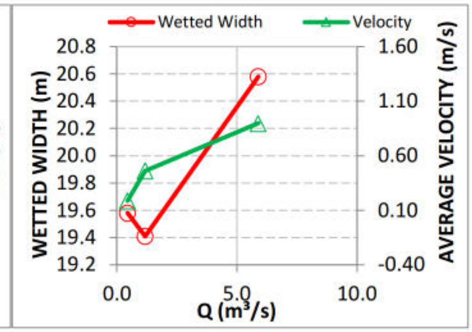
	Stream **Fording River**	**FRD-LWTR16**
Static: Tol: 0.01m	No missing data No errors found	
Dynamic Tol: 0.05m	No missing data No errors found	

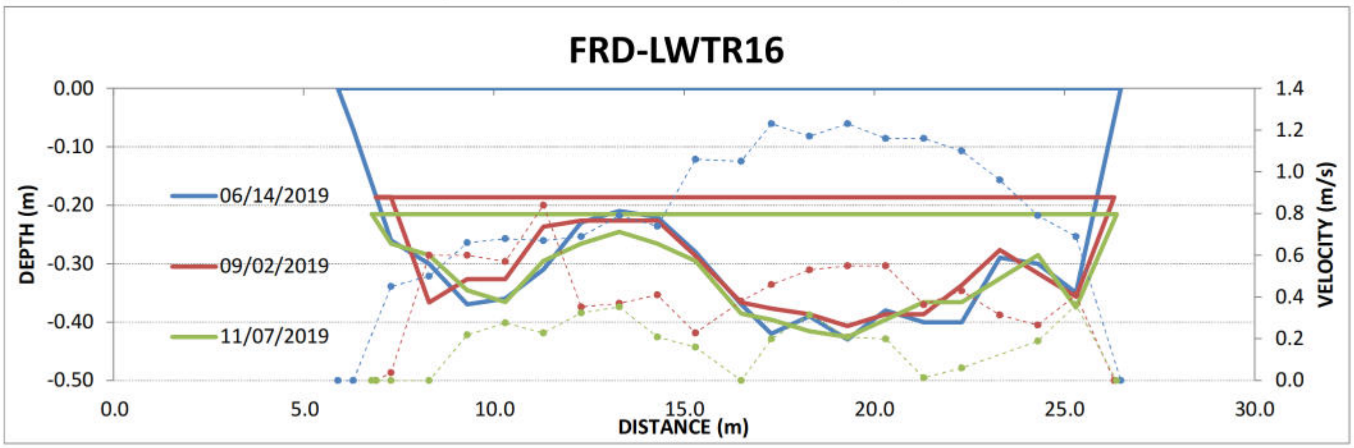
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/14/19	0.507	0.640	0.133	5.882	0.319	0.430	9.522	0.897	20.580	MGL, RLL
09/02/19	0.508	0.643	0.135	1.179	0.131	0.220	9.333	0.462	19.410	MGL, SMS
11/07/19	0.504	0.639	0.135	0.441	0.119	0.210	9.304	0.188	19.580	AMT, JEF

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







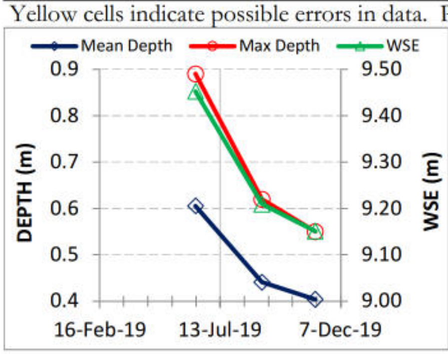


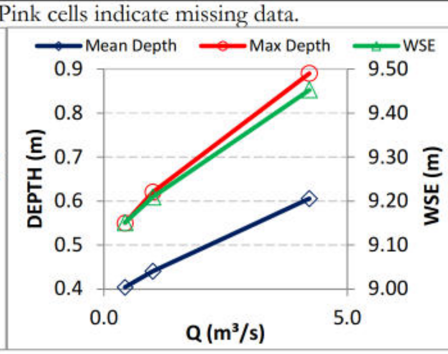
Transect Quality Assurance Report

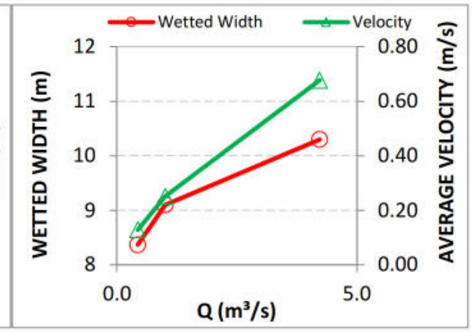
	Stream **Fording River**	**FRD-UPTR17**
Static: Tol: 0.01m	No missing data Possible Errors: (11/06/2019, LB Pin)	
Dynamic Tol: 0.05m	No missing data Possible Errors: (06/13/2019, Mean Depth)	

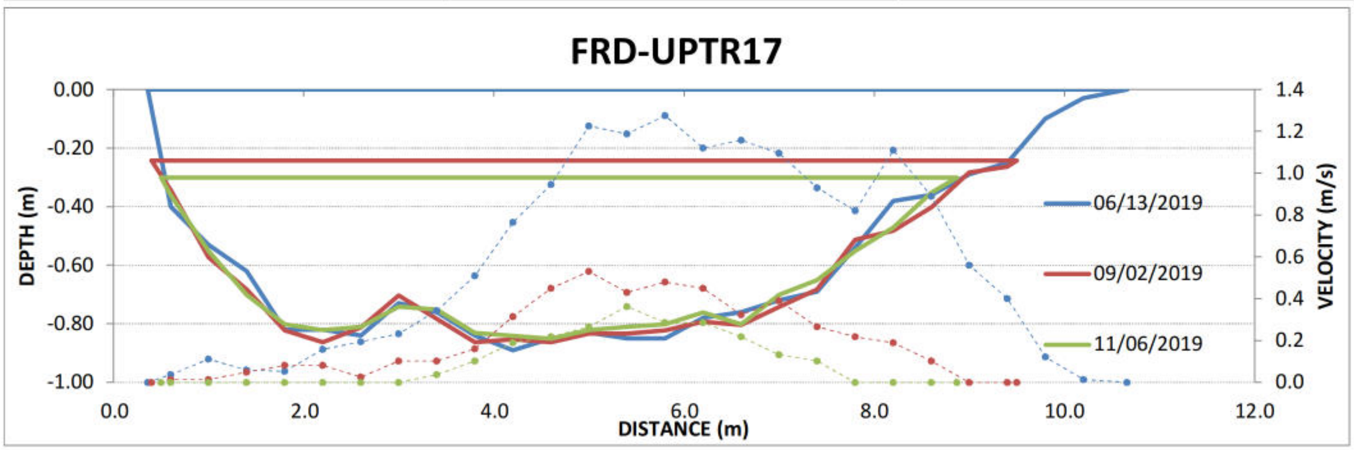
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/13/19	0.220	0.097	0.123	4.218	0.605	0.890	9.452	0.676	10.300	CCF, TRS
09/02/19	0.223	0.098	0.125	1.007	0.441	0.620	9.209	0.251	9.100	AMT, TRS
11/06/19	0.238	0.096	0.142	0.435	0.404	0.550	9.151	0.129	8.370	AMT, JEF

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







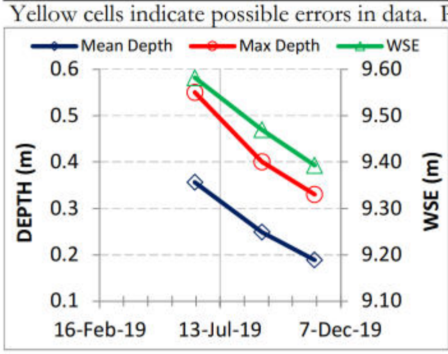


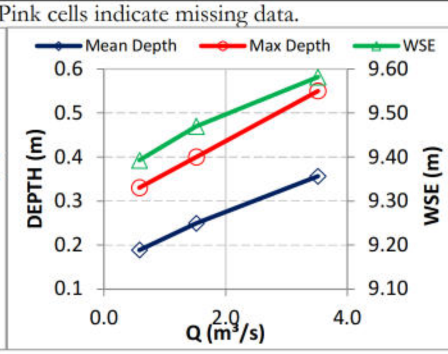
Transect Quality Assurance Report

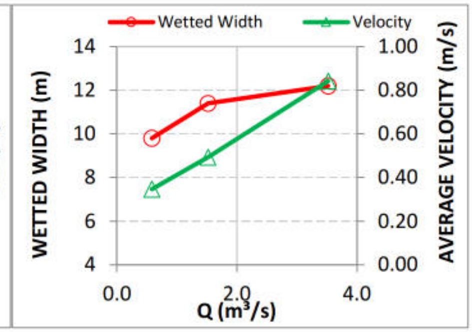
	Stream **Fording River** **FRD-UPTR18**
Static: Tol: 0.01m	No missing data No errors found
Dynamic Tol: 0.05m	No missing data No errors found

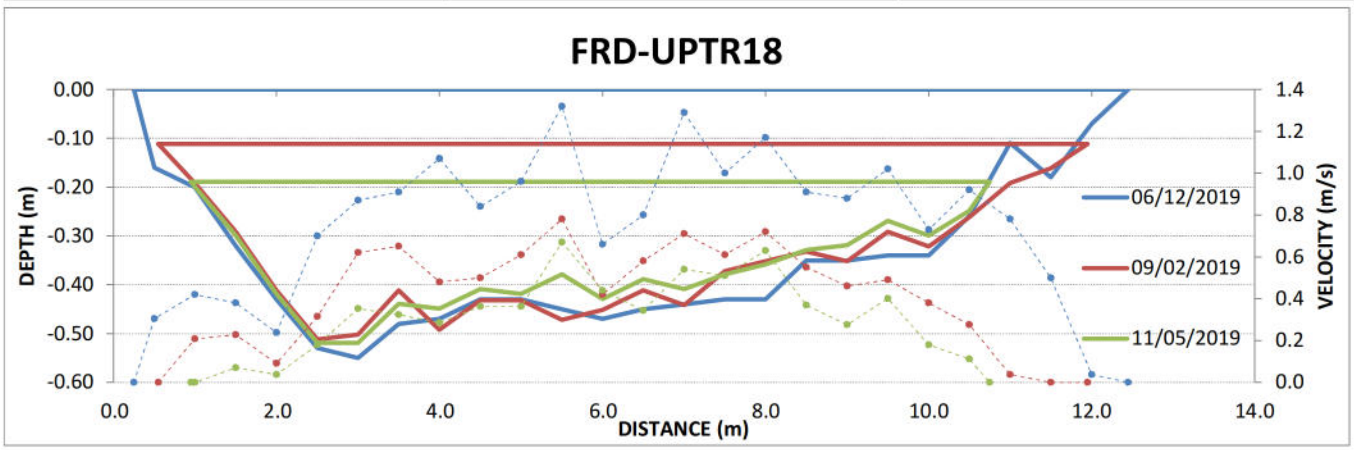
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/12/19	0.134	0.352	0.218	3.517	0.356	0.550	9.582	0.842	12.200	CCF, TRS
09/02/19	0.137	0.352	0.215	1.518	0.249	0.400	9.470	0.493	11.400	AMT, TRS
11/05/19	0.135	0.348	0.213	0.583	0.189	0.330	9.393	0.347	9.800	DJM, MGL

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







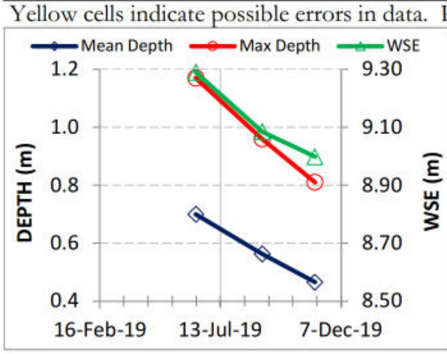


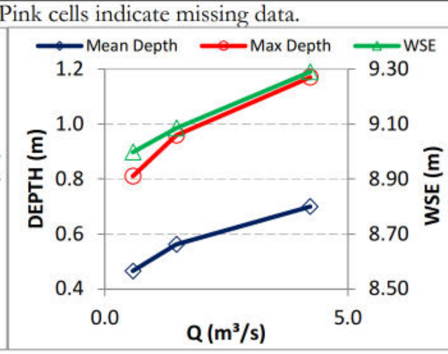
Transect Quality Assurance Report

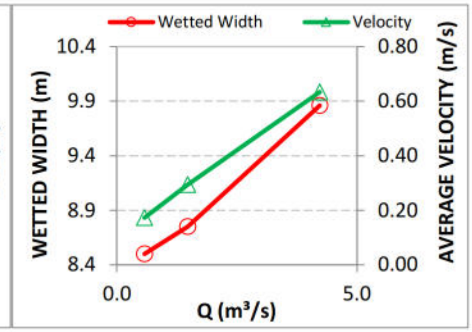
	Stream	**Fording River**	**FRD-UPTR19**
Static: Tol: 0.01m	No missing data No errors found		
Dynamic Tol: 0.05m	No missing data Possible Errors: (06/13/2019, Mean Depth) (11/05/2019, Max Depth)		

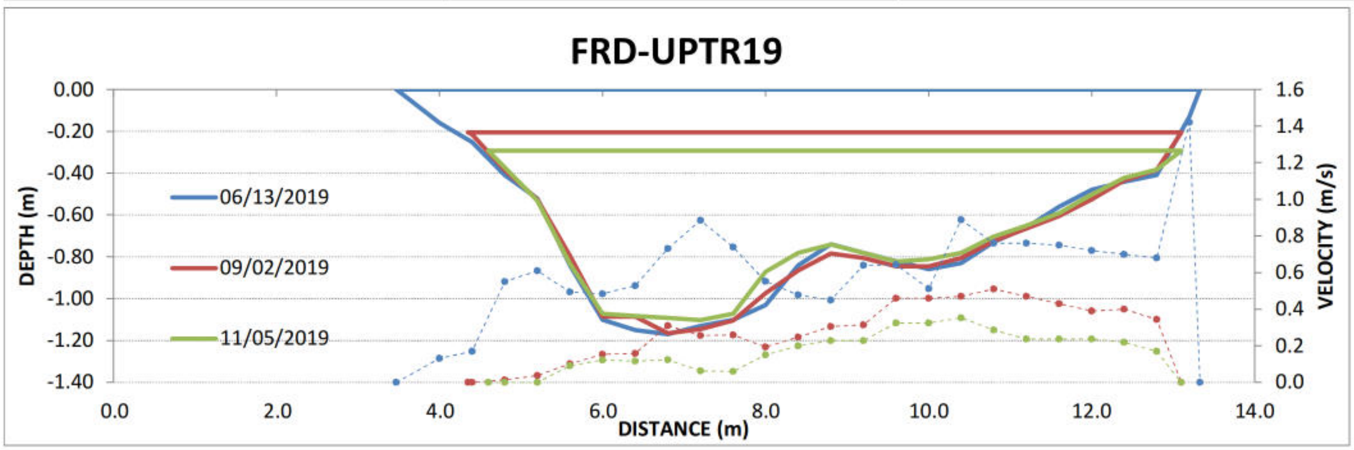
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/13/19	0.573	0.633	0.060	4.224	0.700	1.170	9.290	0.633	9.860	CCF, TRS
09/02/19	0.576	0.635	0.059	1.475	0.562	0.960	9.085	0.294	8.750	AMT, TRS
11/05/19	0.572	0.631	0.059	0.579	0.466	0.810	8.998	0.173	8.500	DJM, MGL

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







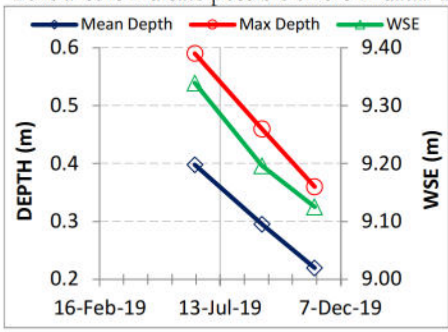


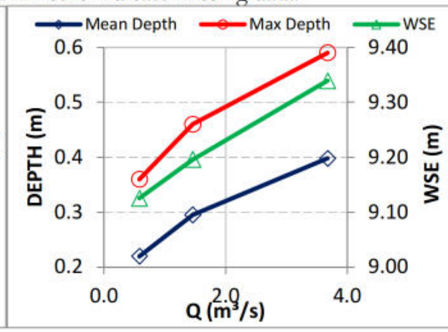
Transect Quality Assurance Report

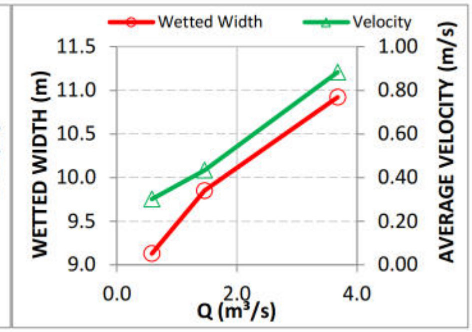
	Stream **Fording River** **FRD-UPTR20**
Static: Tol: 0.01m	No missing data No errors found
Dynamic Tol: 0.05m	No missing data No errors found

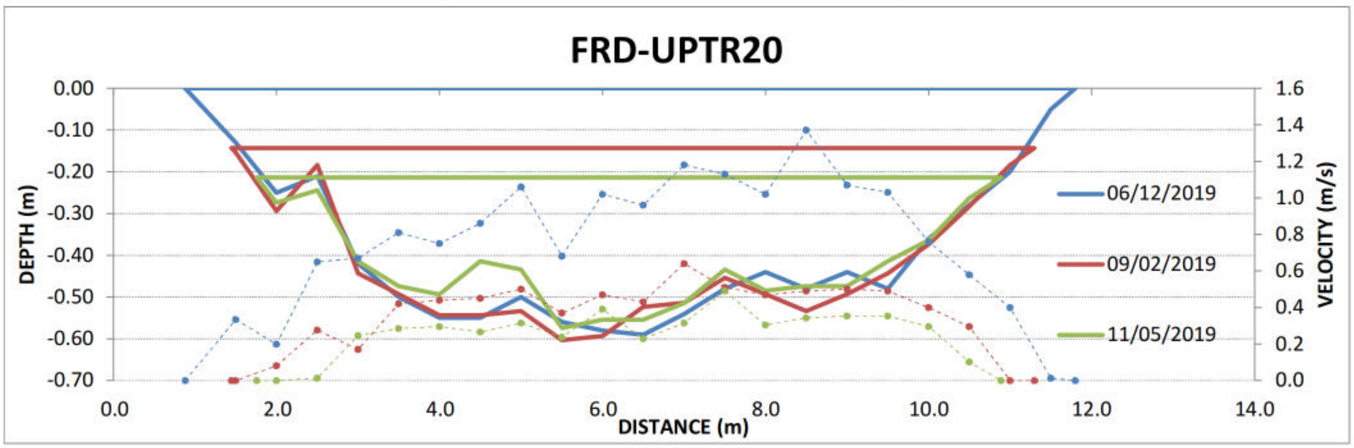
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/12/19	0.374	0.630	0.256	3.676	0.398	0.590	9.339	0.883	10.920	CCF, TRS
09/02/19	0.374	0.628	0.254	1.462	0.295	0.460	9.196	0.434	9.850	AMT, TRS
11/05/19	0.377	0.631	0.254	0.583	0.220	0.360	9.125	0.302	9.130	AMT, JEF

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







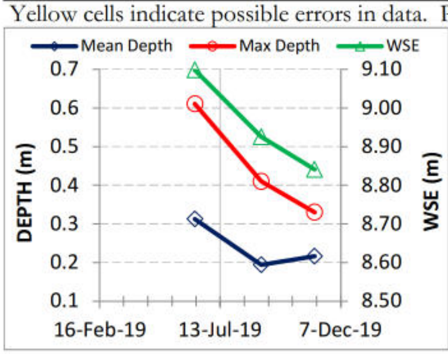


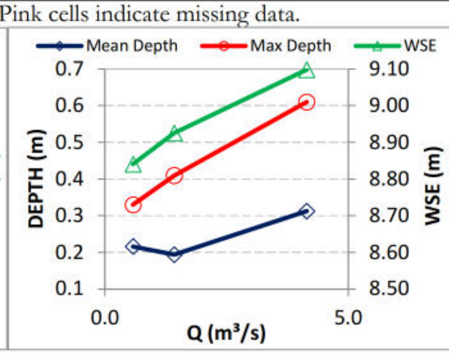
Transect Quality Assurance Report

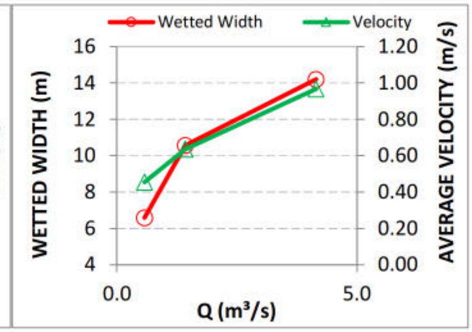
	Stream	**Fording River**	**FRD-UPTR21A**
Static: Tol: 0.01m	No missing data Possible Errors: (09/01/2019, LB Pin)		
Dynamic Tol: 0.05m	No missing data Possible Errors: (06/12/2019, Mean Depth) (09/01/2019, Mean Depth) (11/05/2019, Mean Depth)		

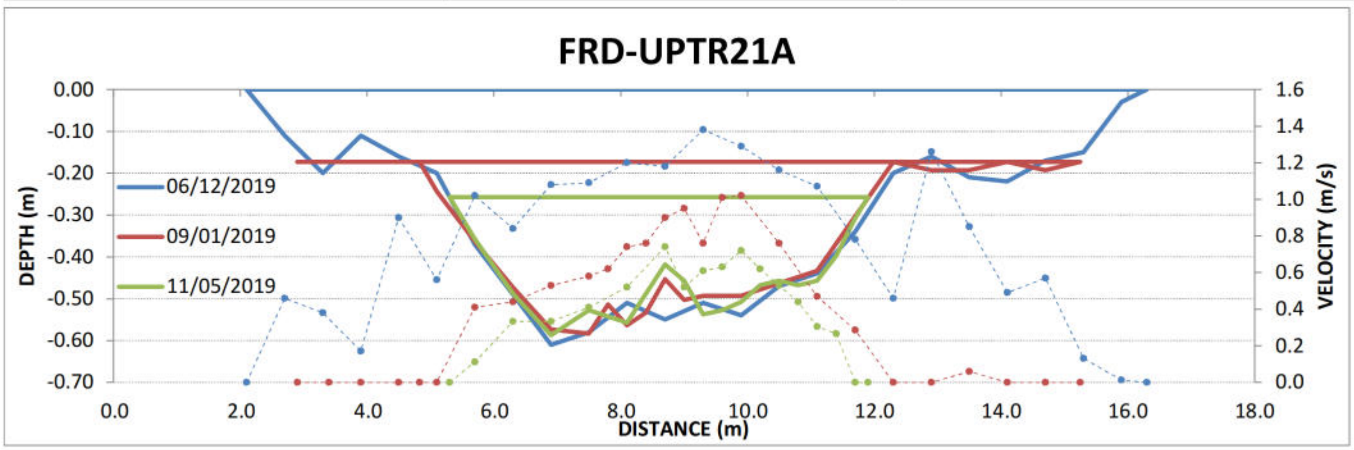
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/12/19	0.402	0.133	0.269	4.145	0.312	0.610	9.098	0.967	14.200	CCF, TRS
09/01/19	0.359	0.135	0.224	1.425	0.194	0.410	8.925	0.637	10.570	MGL, SMS
11/05/19	0.403	0.135	0.268	0.579	0.216	0.330	8.841	0.455	6.600	AMT, JEF

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







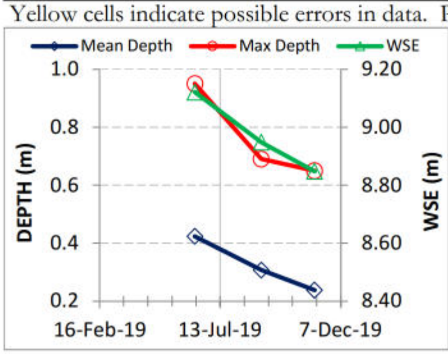


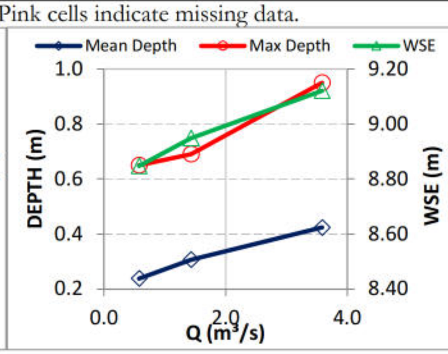
Transect Quality Assurance Report

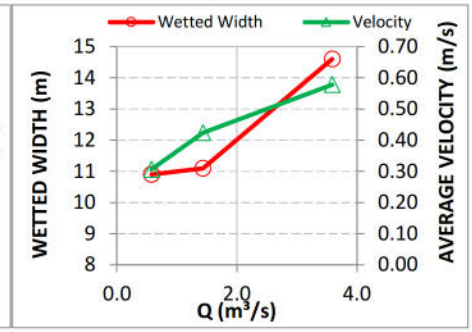
	Stream **Fording River** **FRD-UPTR21B**
Static: Tol: 0.01m	No missing data No errors found
Dynamic Tol: 0.05m	No missing data Possible Errors: (06/12/2019, Mean Depth) (09/01/2019, WSE)

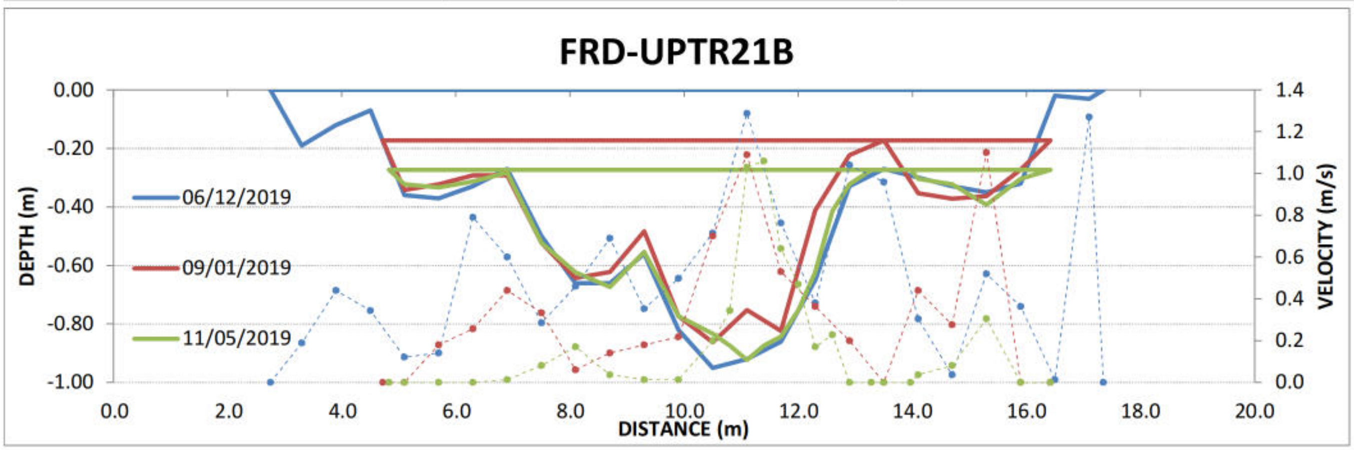
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/12/19	0.110	0.103	0.007	3.586	0.424	0.950	9.121	0.578	14.600	CCF, TRS
09/01/19	0.111	0.101	0.010	1.434	0.307	0.690	8.949	0.424	11.100	MGL, SMS
11/05/19	0.110	0.100	0.010	0.579	0.238	0.650	8.848	0.307	10.900	AMT, JEF

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







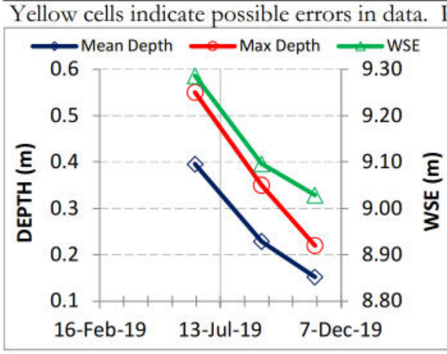


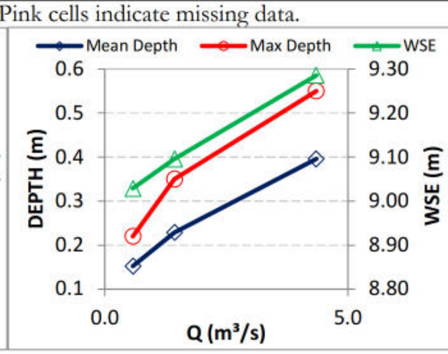
Transect Quality Assurance Report

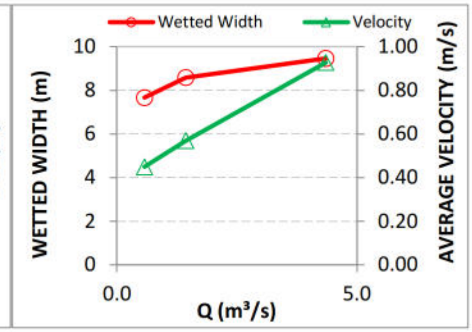
	Stream **Fording River**	**FRD-UPTR22**
Static: Tol: 0.01m	No missing data No errors found	
Dynamic Tol: 0.05m	No missing data Possible Errors: (11/05/2019, Max Depth)	

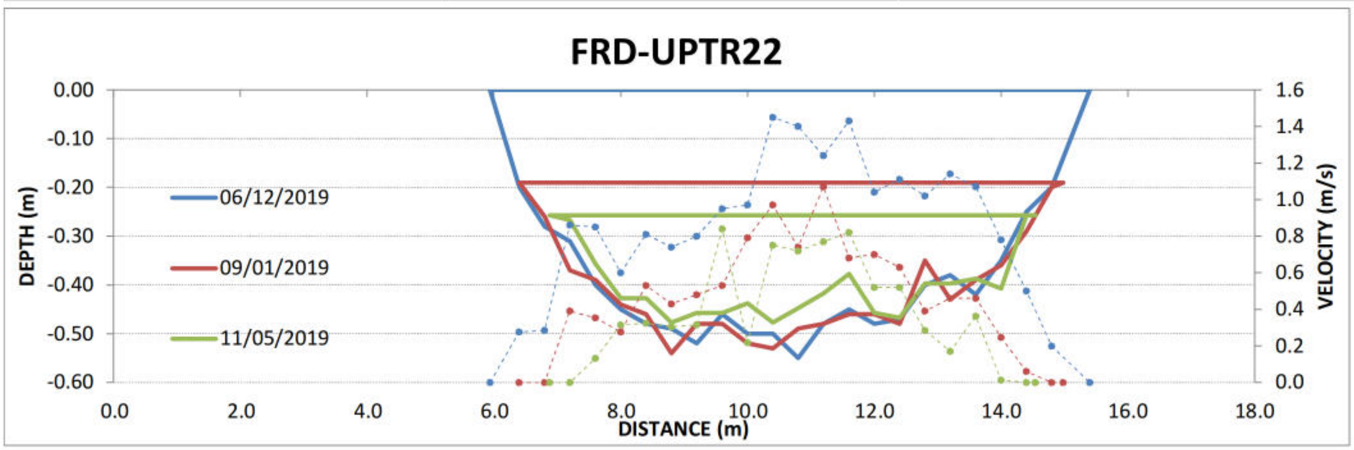
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/12/19	0.646	0.585	0.061	4.347	0.395	0.550	9.286	0.926	9.460	CCF, TRS
09/01/19	0.644	0.588	0.056	1.434	0.229	0.350	9.096	0.568	8.580	AMT, TRS
11/05/19	0.645	0.586	0.059	0.579	0.152	0.220	9.029	0.449	7.660	AMT, JEF

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







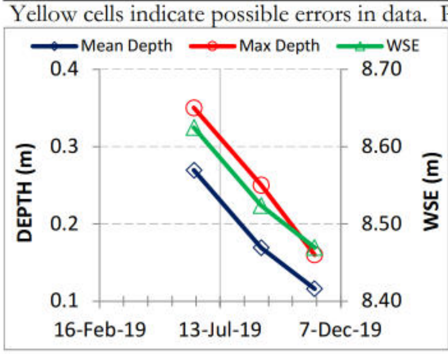


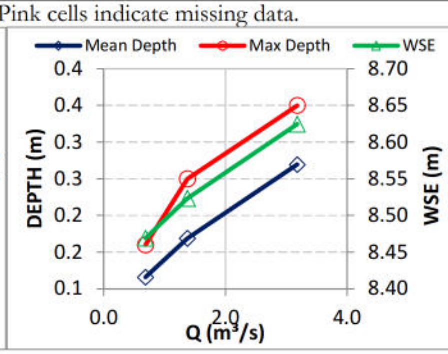
Transect Quality Assurance Report

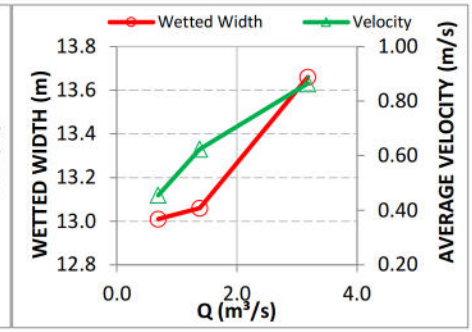
	Stream **Fording River**	**FRD-UPTR23**
Static: Tol: 0.01m	No missing data No errors found	
Dynamic Tol: 0.05m	No missing data No errors found	

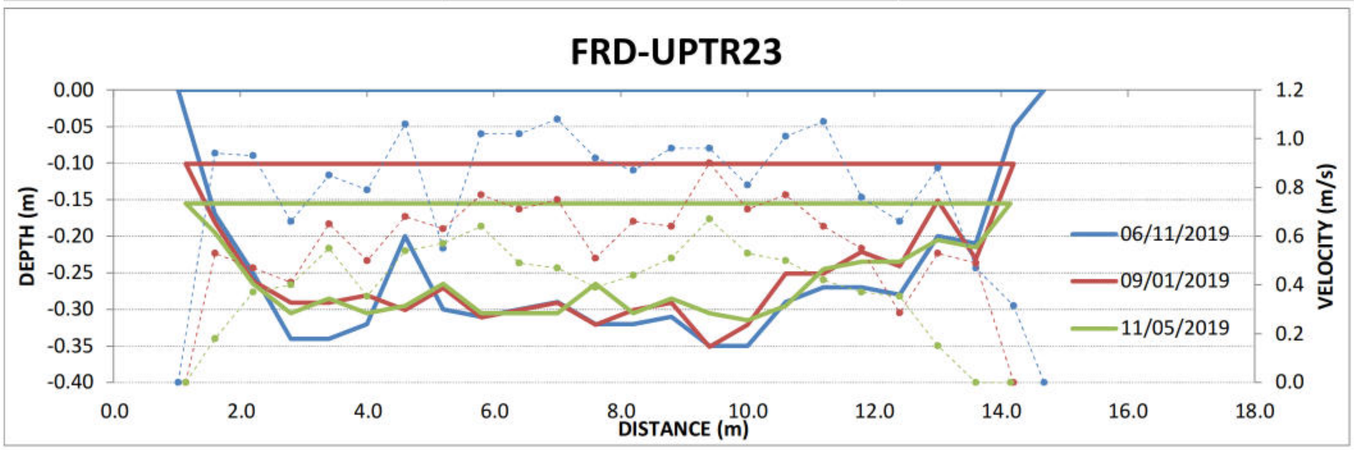
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/11/19	0.768	0.518	0.250	3.181	0.269	0.350	8.625	0.864	13.660	MGL, RLL
09/01/19	0.762	0.520	0.242	1.378	0.169	0.250	8.523	0.625	13.060	MGL, SMS
11/05/19	0.771	0.519	0.252	0.688	0.116	0.160	8.469	0.456	13.010	DJM, MGL

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







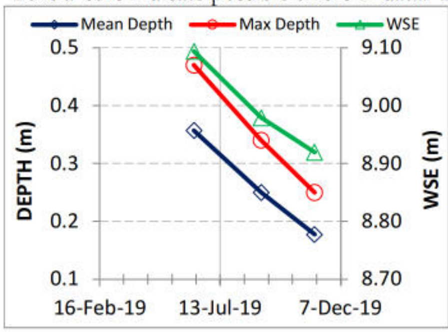


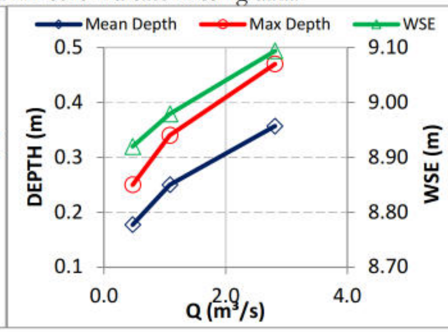
Transect Quality Assurance Report

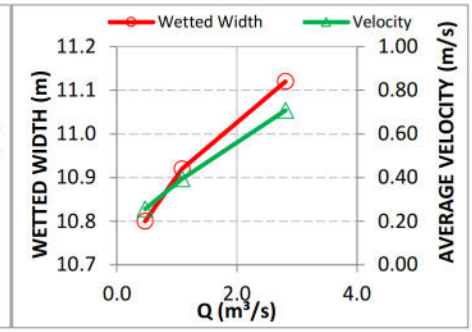
	Stream **Fording River**	**FRD-UPTR24**
Static: Tol: 0.01m	No missing data No errors found	
Dynamic Tol: 0.05m	No missing data No errors found	

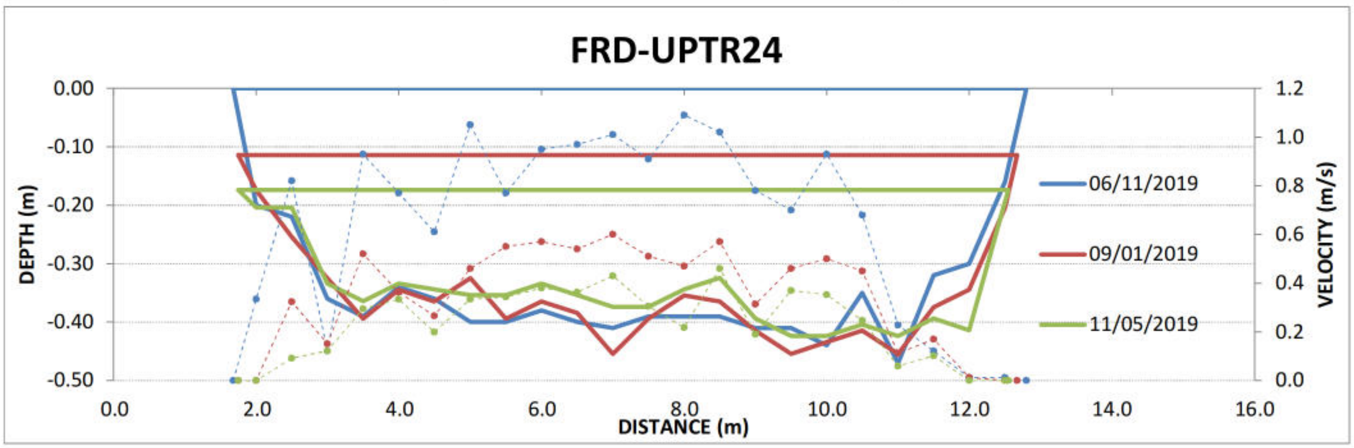
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/11/19	0.008	0.097	0.089	2.810	0.357	0.470	9.094	0.708	11.120	MGL, RLL
09/01/19	0.011	0.095	0.084	1.087	0.250	0.340	8.979	0.393	10.920	AMT, TRS
11/05/19	0.010	0.095	0.085	0.471	0.177	0.250	8.920	0.257	10.800	AMT, JEF

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







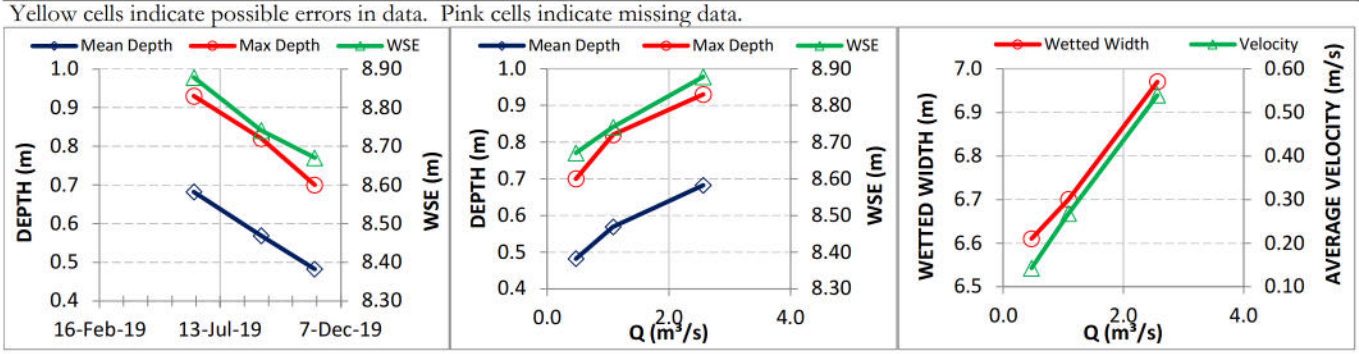


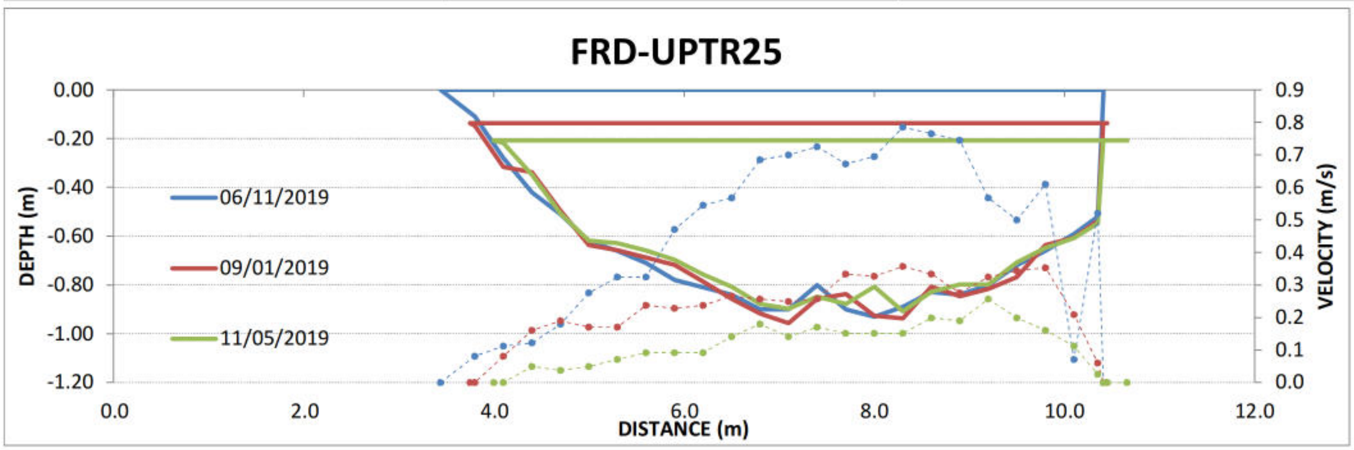
Transect Quality Assurance Report

	Stream **Fording River**	**FRD-UPTR25**
Static: Tol: 0.01m	No missing data Possible Errors: (06/11/2019, RB Pin)	
Dynamic Tol: 0.05m	No missing data No errors found	

Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/11/19	0.004	0.151	0.155	2.565	0.682	0.930	8.878	0.539	6.970	MGL, RLL
09/01/19	0.005	0.136	0.141	1.087	0.569	0.820	8.741	0.267	6.700	AMT, TRS
11/05/19	0.004	0.138	0.142	0.471	0.482	0.700	8.670	0.143	6.610	AMT, JEF

Yellow cells indicate possible errors in data. Pink cells indicate missing data.



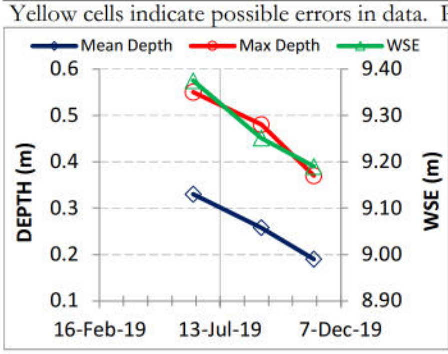


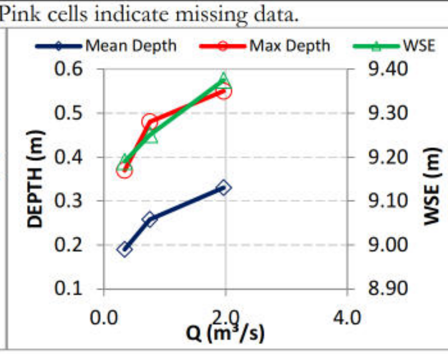
Transect Quality Assurance Report

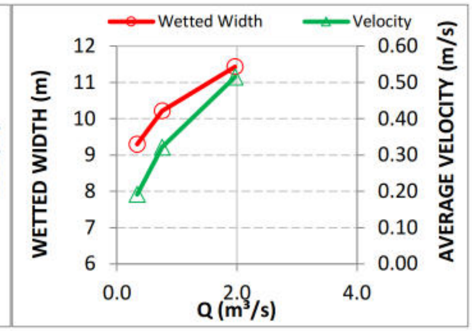
	Stream **Fording River** **FRD-UPTR26**
Static: Tol: 0.01m	No missing data No errors found
Dynamic Tol: 0.05m	No missing data No errors found

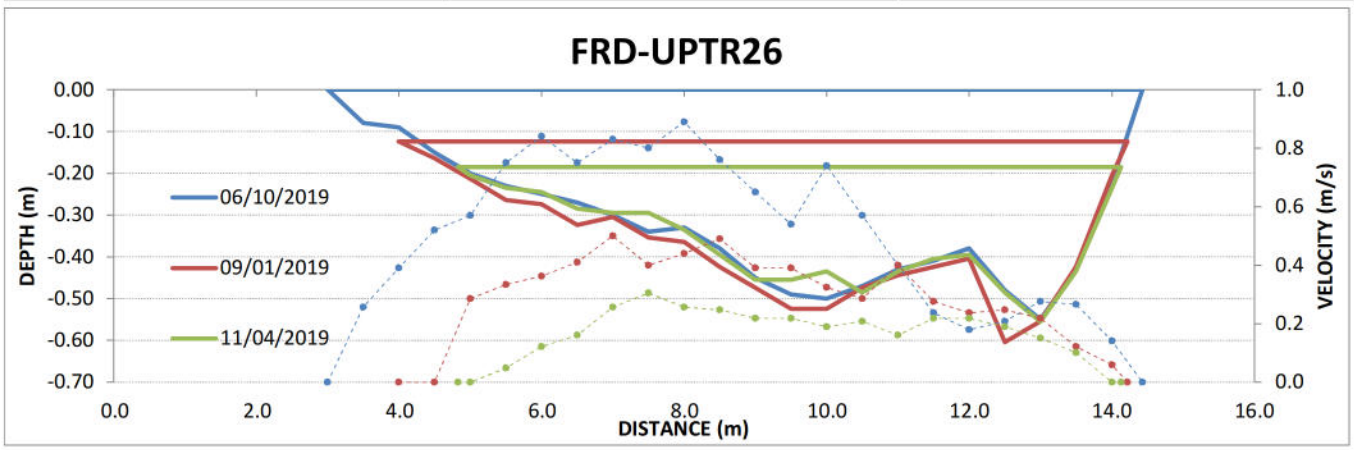
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/10/19	0.202	0.036	0.166	1.966	0.330	0.550	9.375	0.515	11.430	MGL, RLL
09/01/19	0.195	0.033	0.162	0.756	0.258	0.480	9.251	0.321	10.220	AMT, TRS
11/04/19	0.197	0.034	0.163	0.340	0.190	0.370	9.190	0.192	9.300	AMT, JEF

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







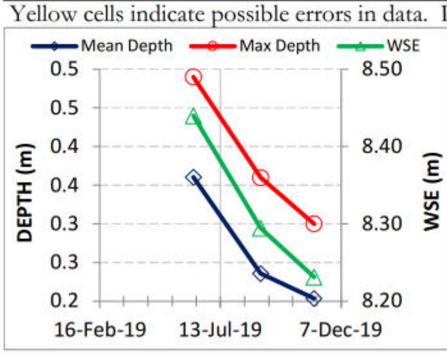


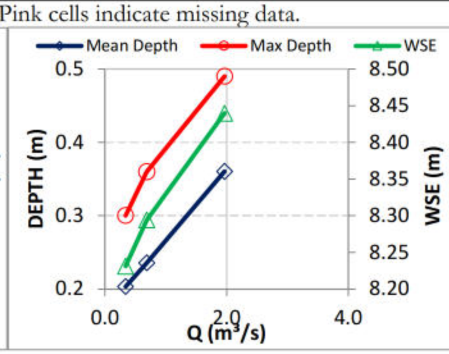
Transect Quality Assurance Report

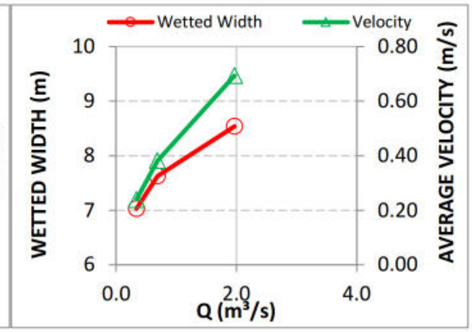
	Stream **Fording River** **FRD-UPTR27A**
Static: Tol: 0.01m	No missing data No errors found
Dynamic Tol: 0.05m	No missing data No errors found

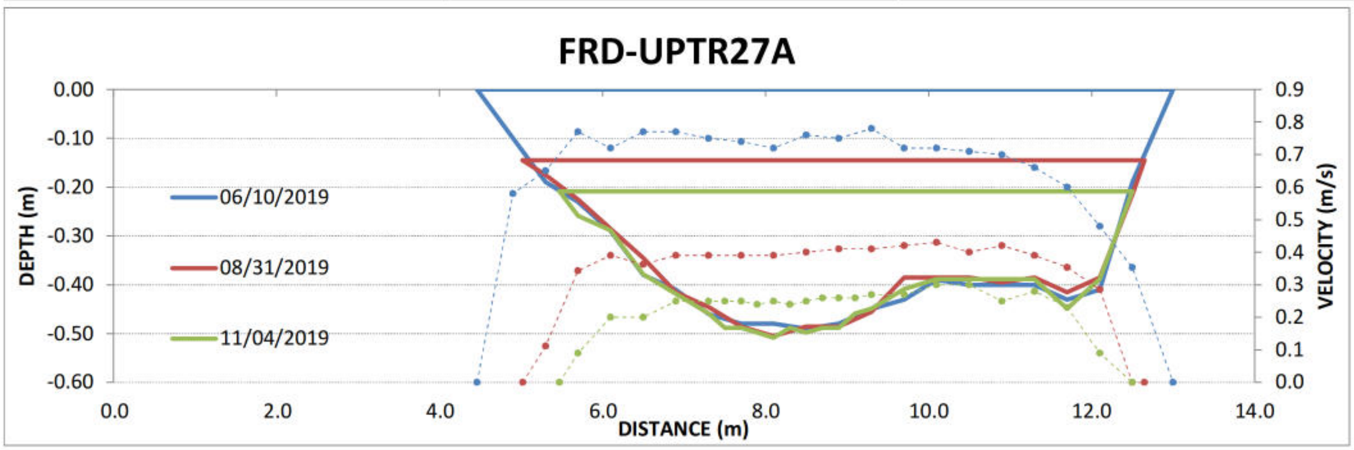
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/10/19	0.604	0.766	0.162	1.966	0.360	0.490	8.440	0.693	8.540	AYR, MGL, R
08/31/19	0.609	0.765	0.156	0.690	0.236	0.360	8.294	0.382	7.630	AMT, MGL
11/04/19	0.605	0.764	0.159	0.340	0.203	0.300	8.231	0.240	7.030	AMT, JEF

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







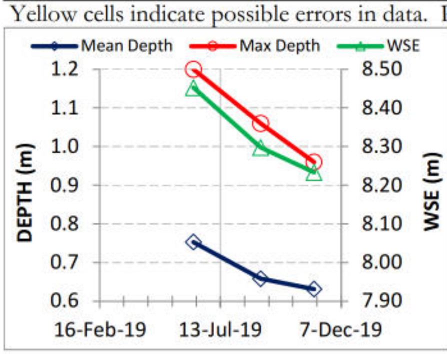


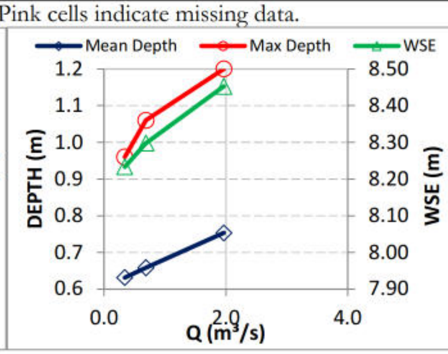
Transect Quality Assurance Report

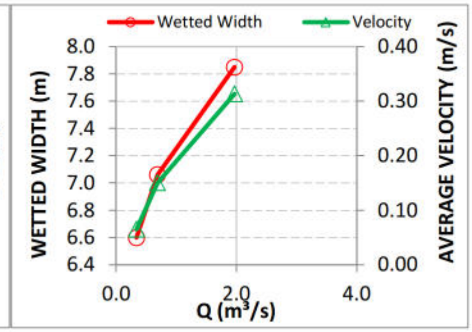
	Stream **Fording River**	**FRD-UPTR27B**
Static: Tol: 0.01m	No missing data No errors found	
Dynamic Tol: 0.05m	No missing data Possible Errors: (06/10/2019, Mean Depth) (08/31/2019, Mean Depth) (11/04/2019, Mean Depth)	

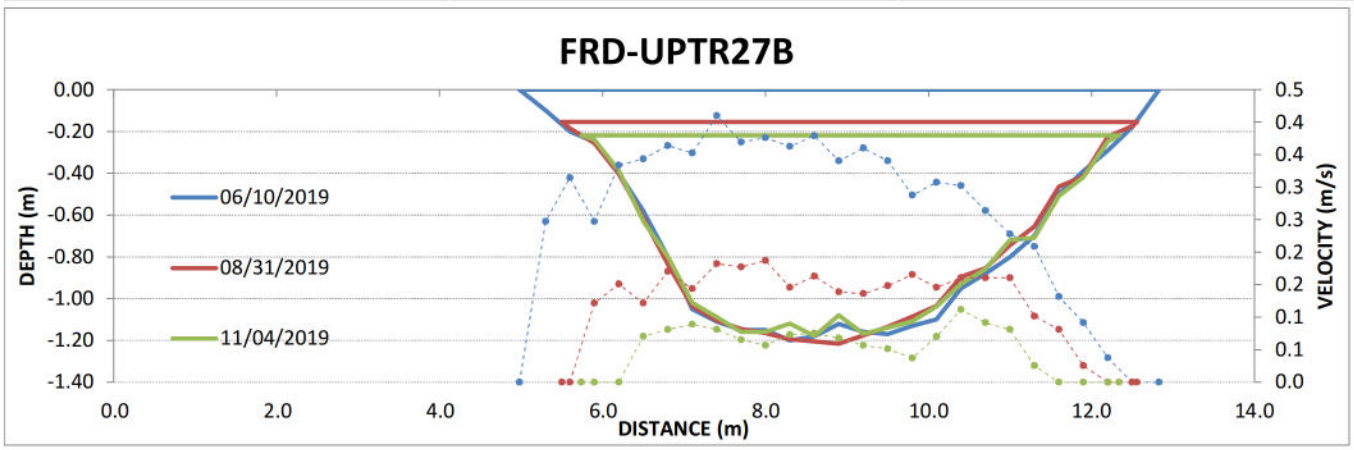
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/10/19	0.593	0.581	0.012	1.966	0.753	1.200	8.452	0.313	7.850	MGL, RLL
08/31/19	0.599	0.584	0.015	0.690	0.658	1.060	8.298	0.151	7.060	AMT, MGL
11/04/19	0.584	0.578	0.006	0.340	0.631	0.960	8.233	0.066	6.600	AMT, JEF

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







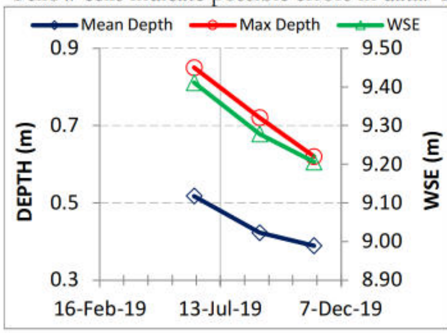


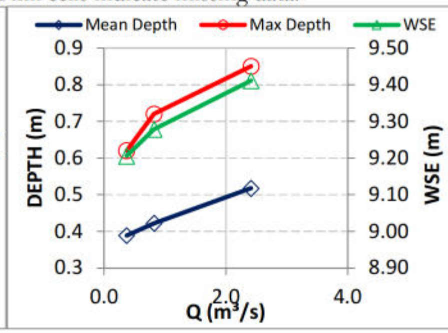
Transect Quality Assurance Report

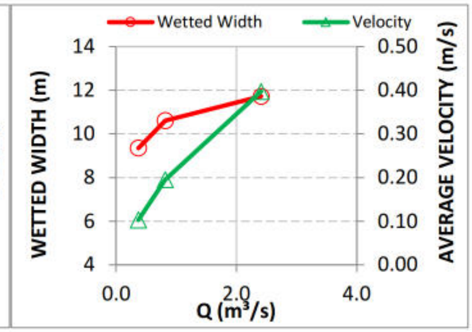
	Stream **Fording River** **FRD-UPTR28**
Static: Tol: 0.01m	No missing data No errors found
Dynamic Tol: 0.05m	No missing data Possible Errors: (11/04/2019, Mean Depth)

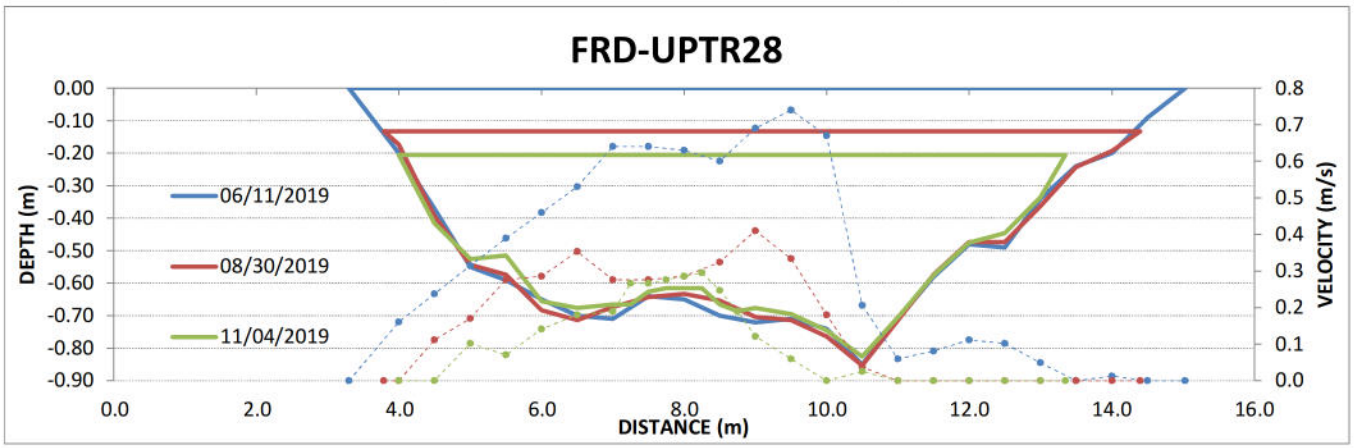
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/11/19	0.240	0.049	0.191	2.410	0.517	0.850	9.411	0.397	11.730	MGL, RLL
08/30/19	0.229	0.045	0.184	0.820	0.422	0.720	9.278	0.195	10.610	AMT, MGL
11/04/19	0.232	0.051	0.181	0.372	0.389	0.620	9.206	0.103	9.350	DJM, MGL

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







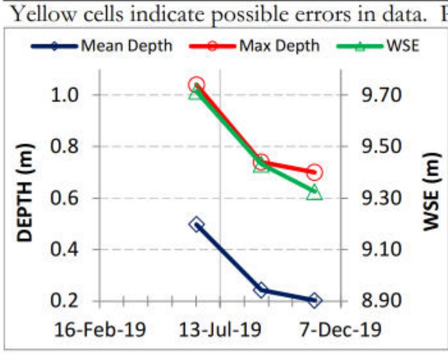


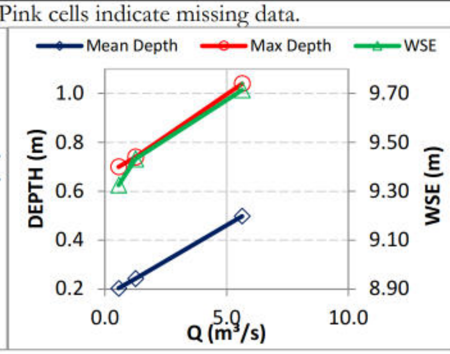
Transect Quality Assurance Report

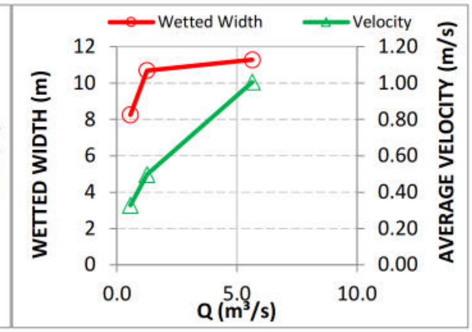
	Stream **Fording River** **FRD-UPTR29A**
Static: Tol: 0.01m	No missing data No errors found
Dynamic Tol: 0.05m	No missing data Possible Errors: (11/05/2019, WSE)

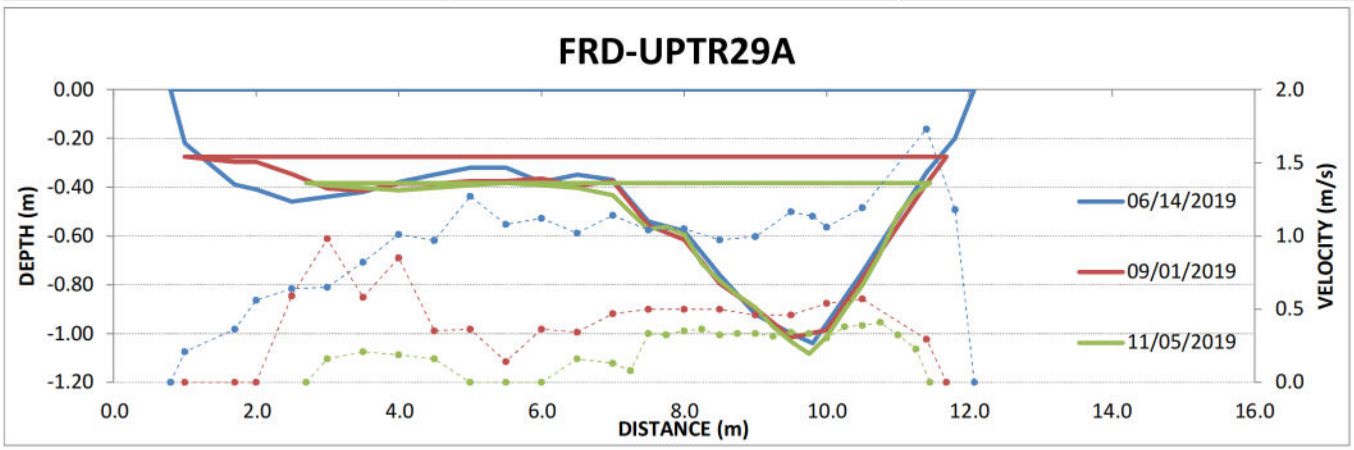
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/14/19	0.491	0.297	0.194	5.639	0.498	1.040	9.714	1.005	11.270	MGL, RLL
09/01/19	0.492	0.299	0.193	1.256	0.243	0.740	9.432	0.497	10.680	MGL, SMS
11/05/19	0.481	0.297	0.184	0.567	0.203	0.700	9.325	0.327	8.250	DJM, MGL

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







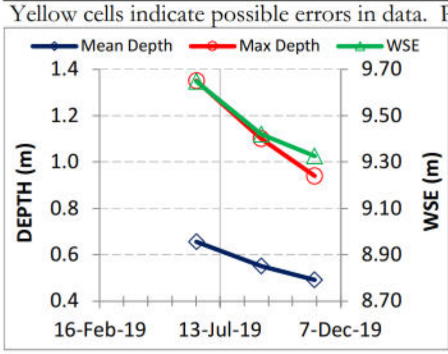


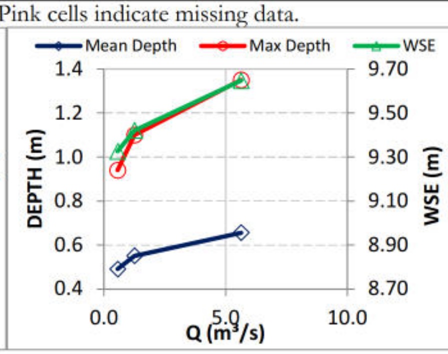
Transect Quality Assurance Report

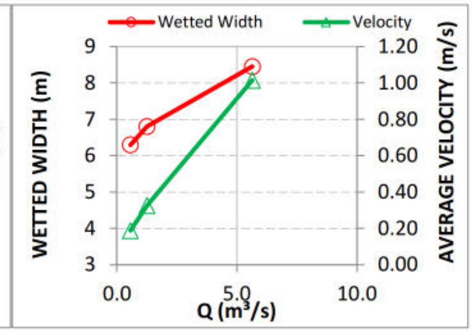
	Stream **Fording River**	**FRD-UPTR29B**
Static: Tol: 0.01m	No missing data No errors found	
Dynamic Tol: 0.05m	No missing data Possible Errors: (06/14/2019, Mean Depth) (11/05/2019, Max Depth)	

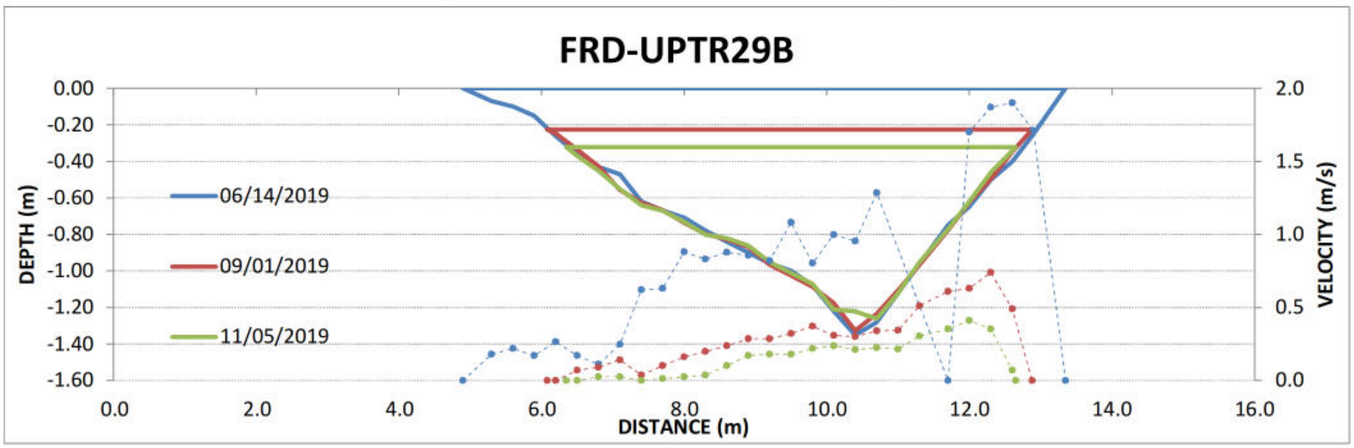
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/14/19	0.647	0.277	0.370	5.639	0.656	1.350	9.647	1.015	8.450	MGL, RLL
09/01/19	0.650	0.279	0.371	1.256	0.552	1.100	9.421	0.326	6.800	MGL, SMS
11/05/19	0.646	0.279	0.367	0.567	0.492	0.940	9.326	0.189	6.300	DJM, MGL

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







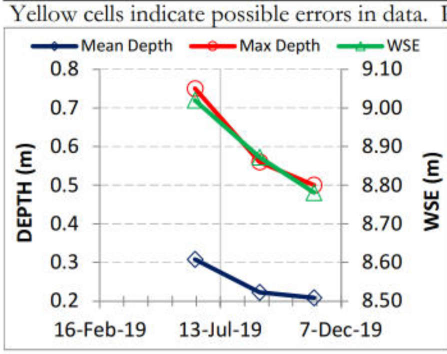


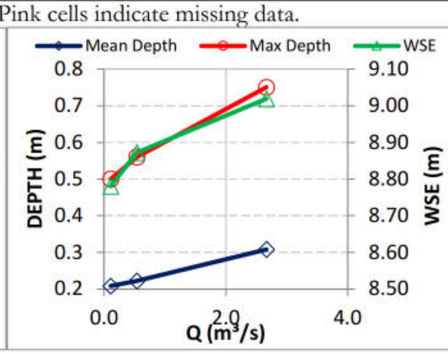
Transect Quality Assurance Report

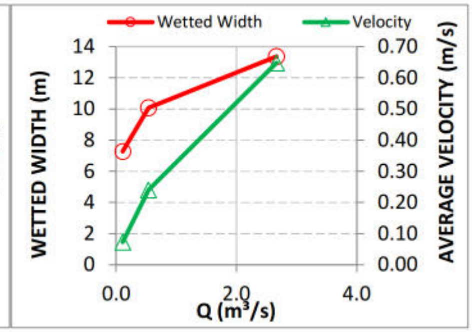
	Stream **Fording River** **FRD-UPTR30A**
Static: Tol: 0.01m	No missing data No errors found
Dynamic Tol: 0.05m	No missing data Possible Errors: (06/12/2019, Mean Depth) (08/30/2019, Mean Depth) (11/04/2019, Mean Depth)

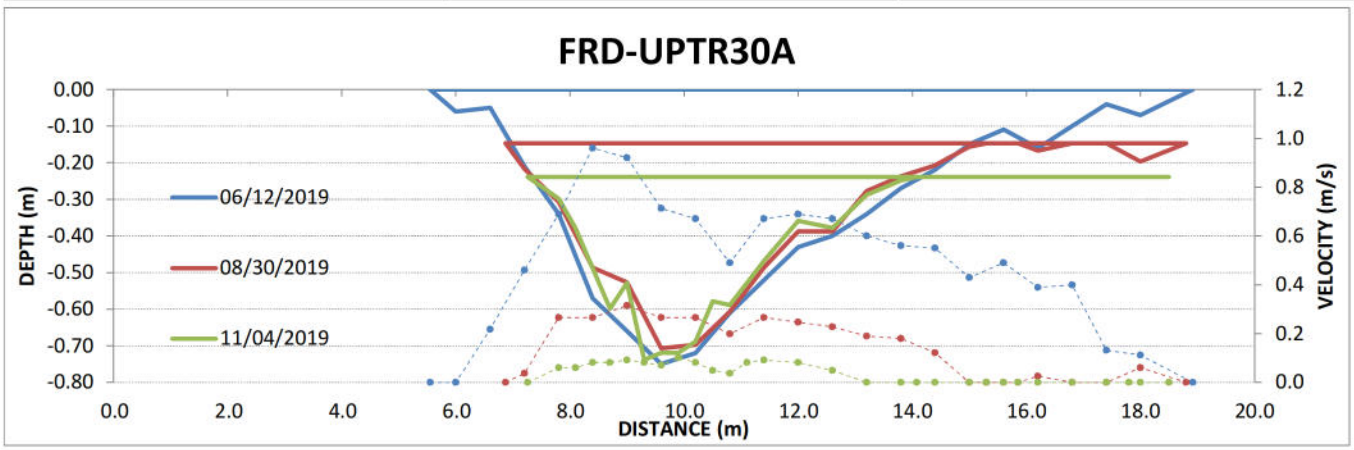
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/12/19	0.236	0.309	0.073	2.666	0.308	0.750	9.019	0.647	13.370	MGL, RLL
08/30/19	0.236	0.309	0.073	0.540	0.223	0.560	8.872	0.241	10.080	AMT, MGL
11/04/19	0.233	0.300	0.067	0.111	0.208	0.500	8.781	0.073	7.270	DJM, MGL

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







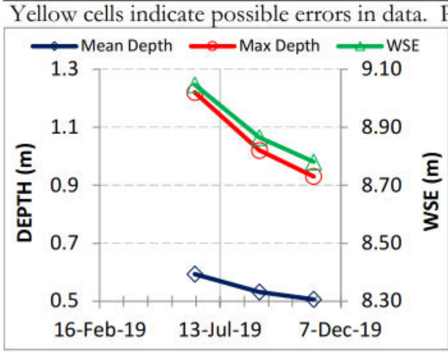


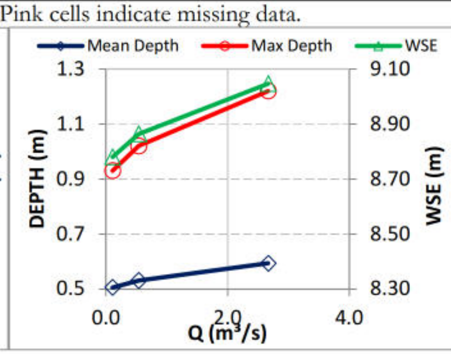
Transect Quality Assurance Report

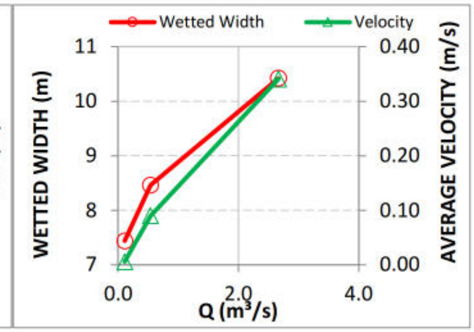
	Stream **Fording River**	**FRD-UPTR30B**
Static: Tol: 0.01m	No missing data No errors found	
Dynamic Tol: 0.05m	No missing data Possible Errors: (06/12/2019, Mean Depth) (08/30/2019, Mean Depth) (11/04/2019, Mean Depth)	

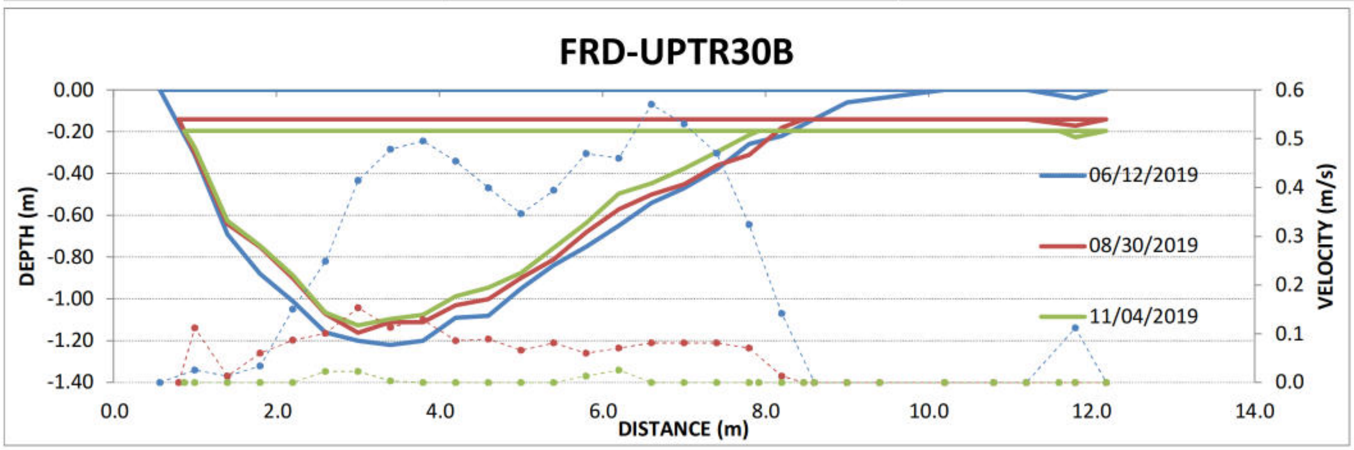
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/12/19	0.360	0.264	0.096	2.666	0.593	1.220	9.047	0.340	10.420	MGL, RLL
08/30/19	0.361	0.263	0.098	0.540	0.531	1.020	8.864	0.090	8.460	AMT, MGL
11/04/19	0.362	0.262	0.100	0.111	0.506	0.930	8.780	0.006	7.440	DJM, MGL

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







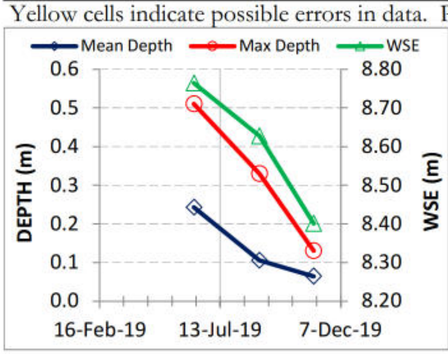


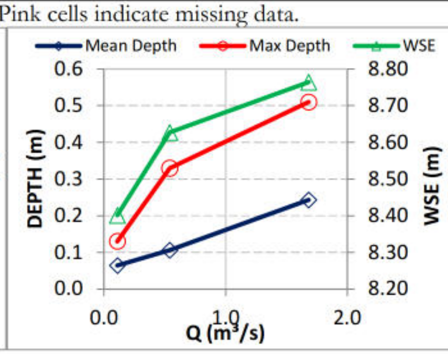
Transect Quality Assurance Report

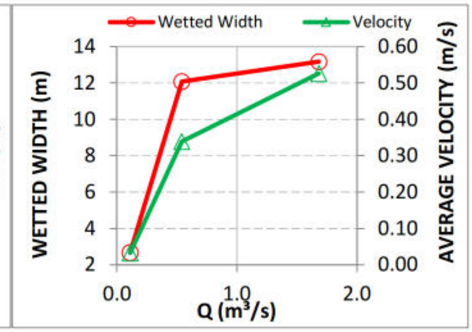
	Stream **Fording River**	**FRD-UPTR31**
Static: Tol: 0.01m	No missing data No errors found	
Dynamic Tol: 0.05m	No missing data Possible Errors: (11/04/2019, Mean Depth)	

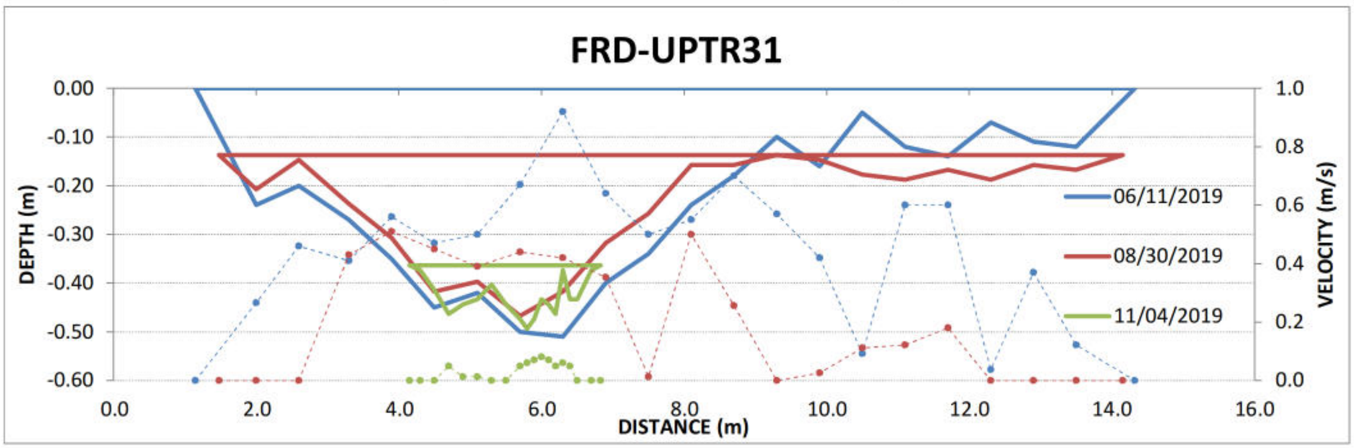
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/11/19	0.206	0.258	0.052	1.682	0.243	0.510	8.764	0.526	13.170	MGL, RLL
08/30/19	0.209	0.257	0.048	0.540	0.106	0.330	8.627	0.339	12.070	AMT, MGL
11/04/19	0.208	0.258	0.050	0.111	0.064	0.130	8.401	0.033	2.680	AMT, JEF

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







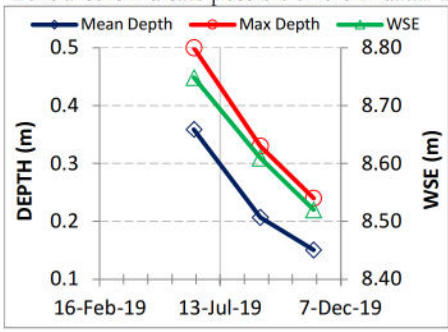


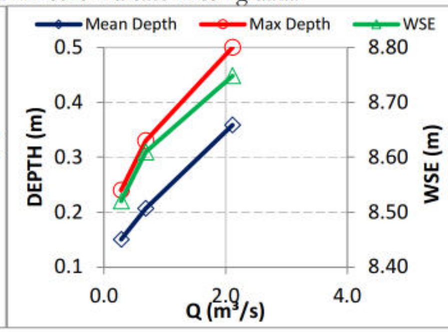
Transect Quality Assurance Report

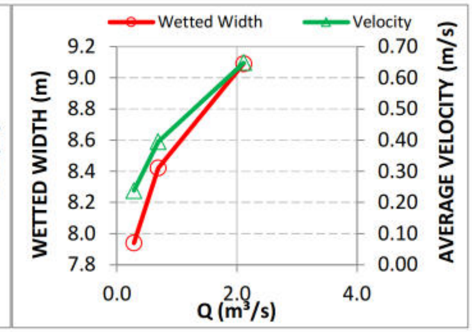
	Stream **Fording River** **FRD-UPTR32**
Static: Tol: 0.01m	No missing data No errors found
Dynamic Tol: 0.05m	No missing data No errors found

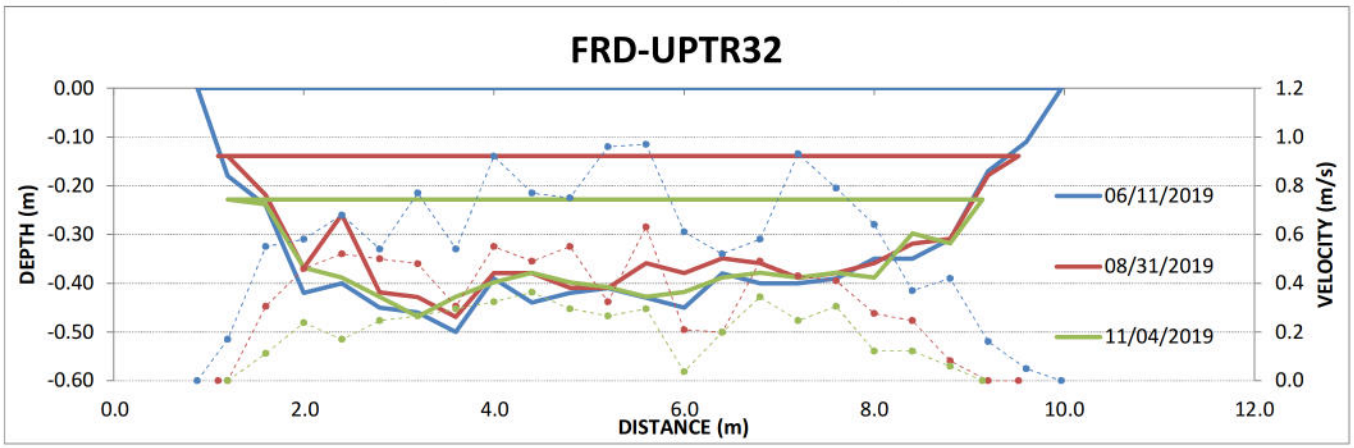
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/11/19	0.143	0.021	0.122	2.112	0.359	0.500	8.748	0.648	9.090	AYR, TRS
08/31/19	0.138	0.019	0.119	0.688	0.207	0.330	8.609	0.395	8.420	AMT, MGL
11/04/19	0.140	0.019	0.121	0.285	0.150	0.240	8.520	0.238	7.940	AMT, JEF

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







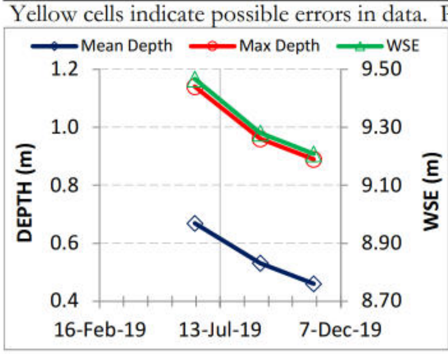


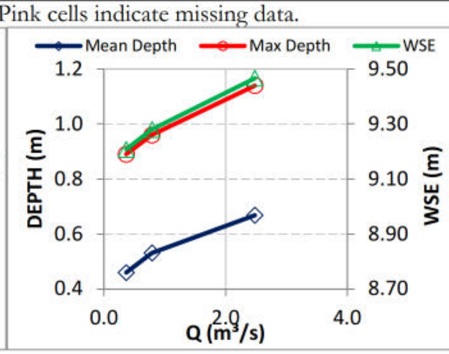
Transect Quality Assurance Report

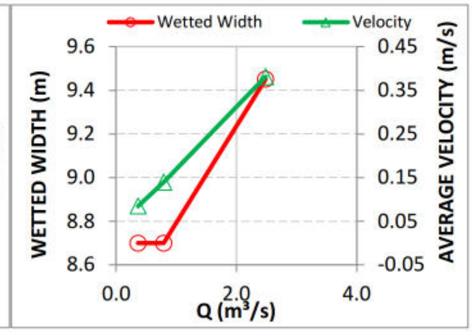
	Stream **Henretta Creek** **FRD-UPTR33**
Static: Tol: 0.01m	No missing data Possible Errors: (11/04/2019, RB Pin)
Dynamic Tol: 0.05m	No missing data No errors found

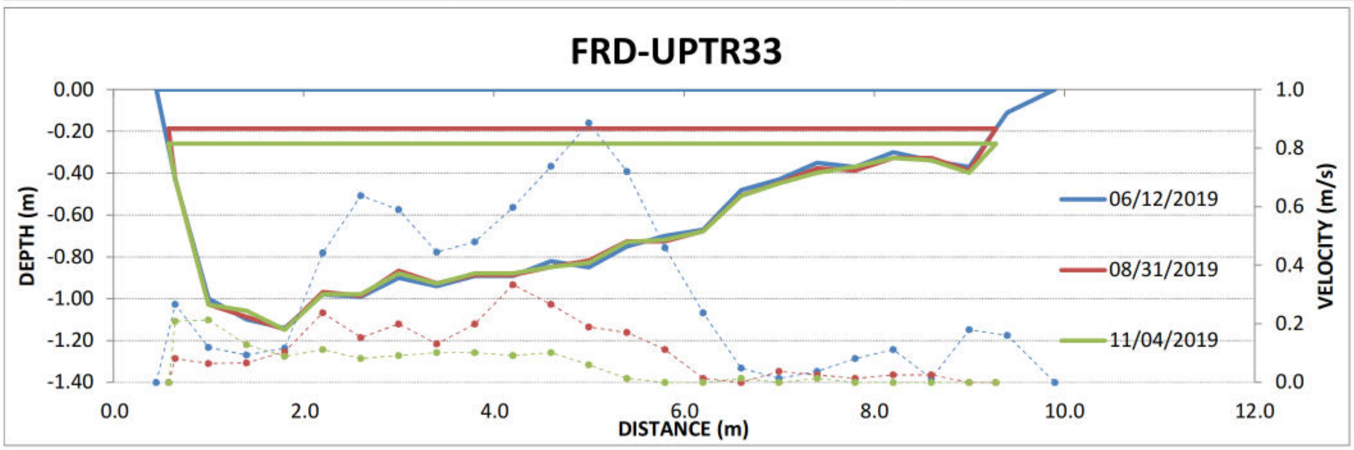
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/12/19	0.154	0.096	0.058	2.481	0.668	1.140	9.466	0.381	9.450	MGL, RLL
08/31/19	0.154	0.093	0.061	0.791	0.531	0.960	9.280	0.140	8.700	AMT, MGL
11/04/19	0.152	0.388	0.236	0.366	0.460	0.890	9.208	0.085	8.700	DJM, MGL

Yellow cells indicate possible errors in data. Pink cells indicate missing data.







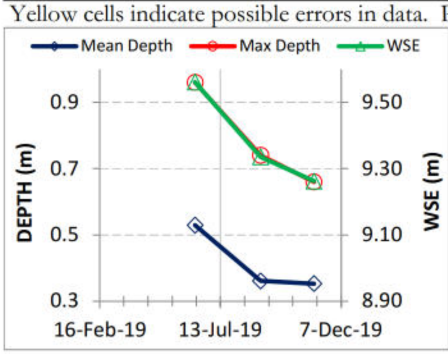


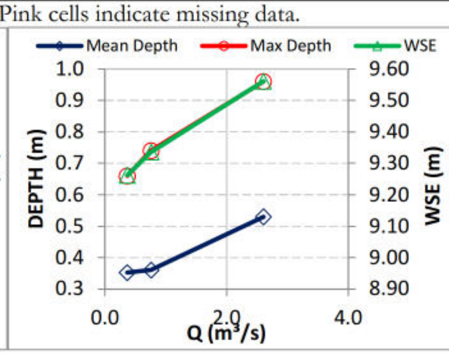
Transect Quality Assurance Report

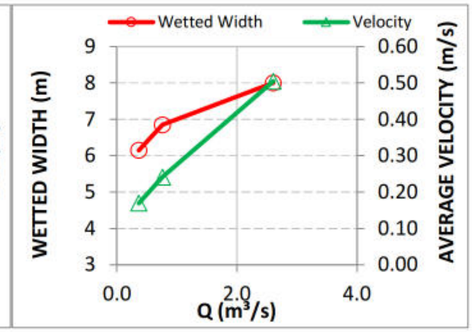
	Stream **Henretta Creek**	**FRD-UPTR34**
Static: Tol: 0.01m	No missing data No errors found	
Dynamic Tol: 0.05m	No missing data Possible Errors: (06/12/2019, Mean Depth) (08/31/2019, Mean Depth) (11/04/2019, Mean Depth)	

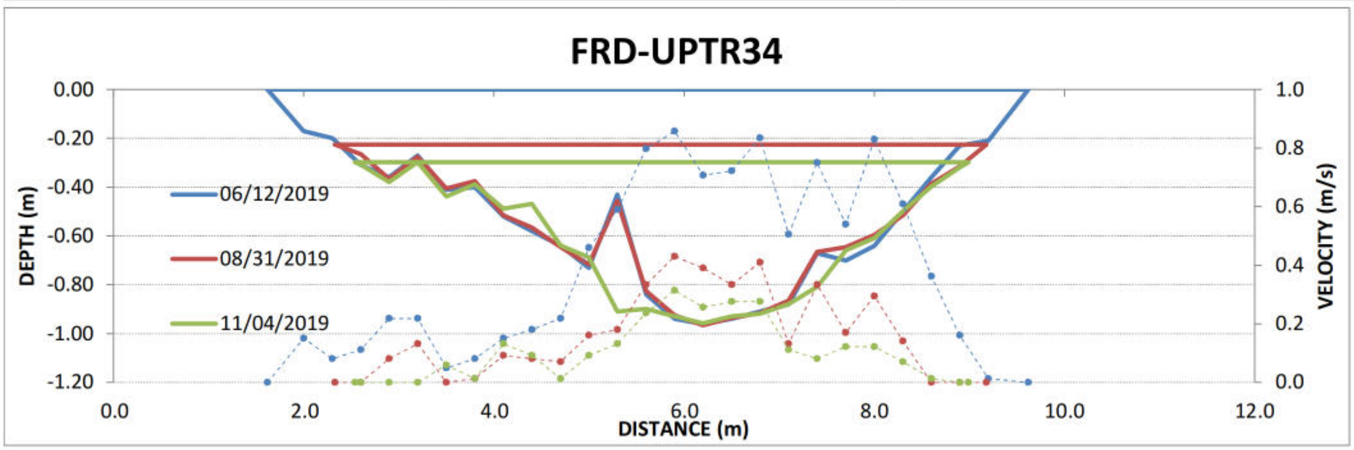
Date	BM - LB Pin (m)	BM - RB Pin (m)	LB Pin - RB Pin (m)	Q (m^3/s)	Mean Depth (m)	Max. Depth (m)	WSE (m)	Mean Velocity (m/s)	Wetted Width (m)	Crew
06/12/19	0.291	0.401	0.110	2.606	0.529	0.960	9.561	0.505	8.000	MGL, RLL
08/31/19	0.290	0.401	0.111	0.759	0.361	0.740	9.336	0.241	6.850	AMT, MGL
11/04/19	0.299	0.404	0.105	0.366	0.353	0.660	9.263	0.170	6.150	AMT, JEF

Yellow cells indicate possible errors in data. Pink cells indicate missing data.









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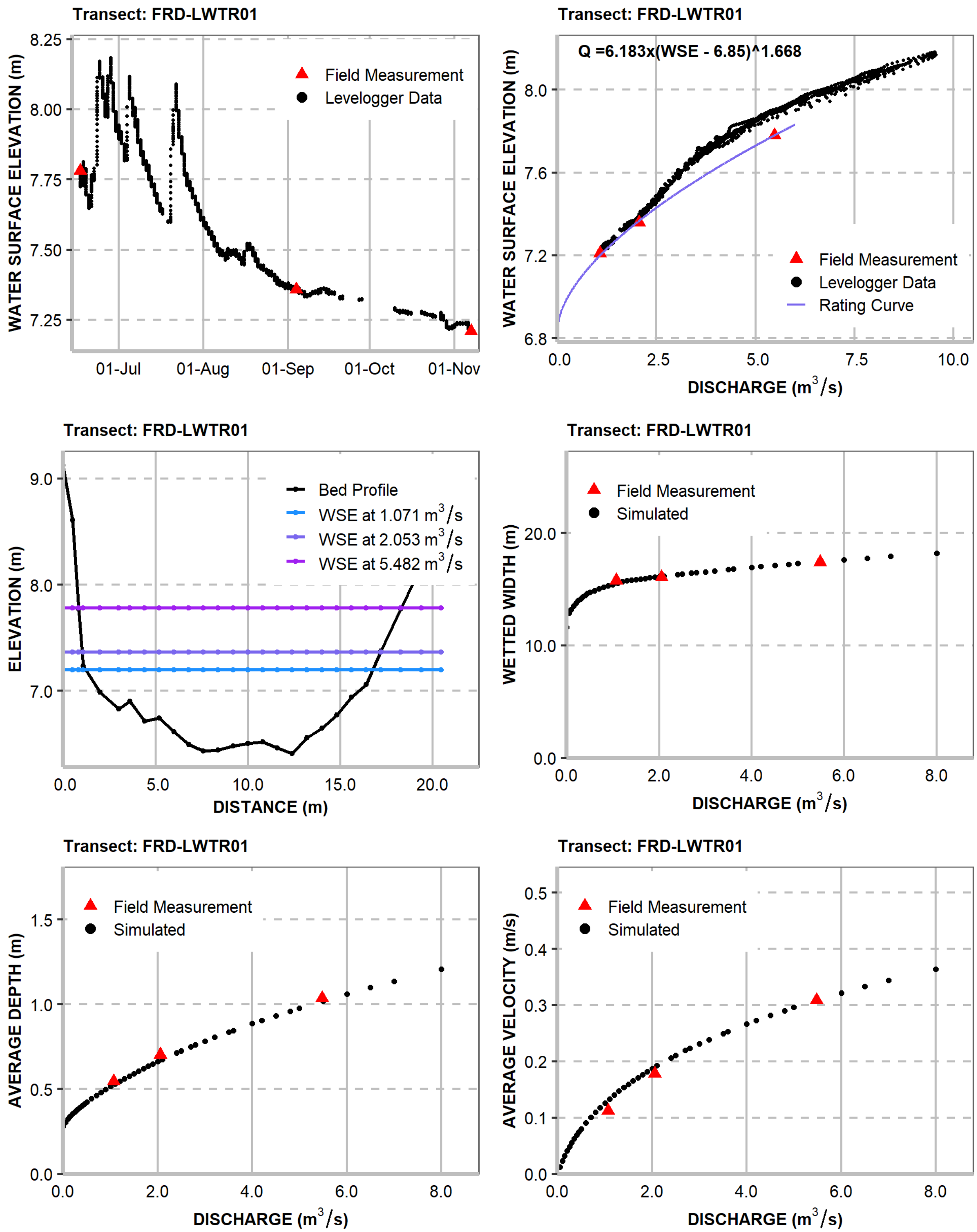

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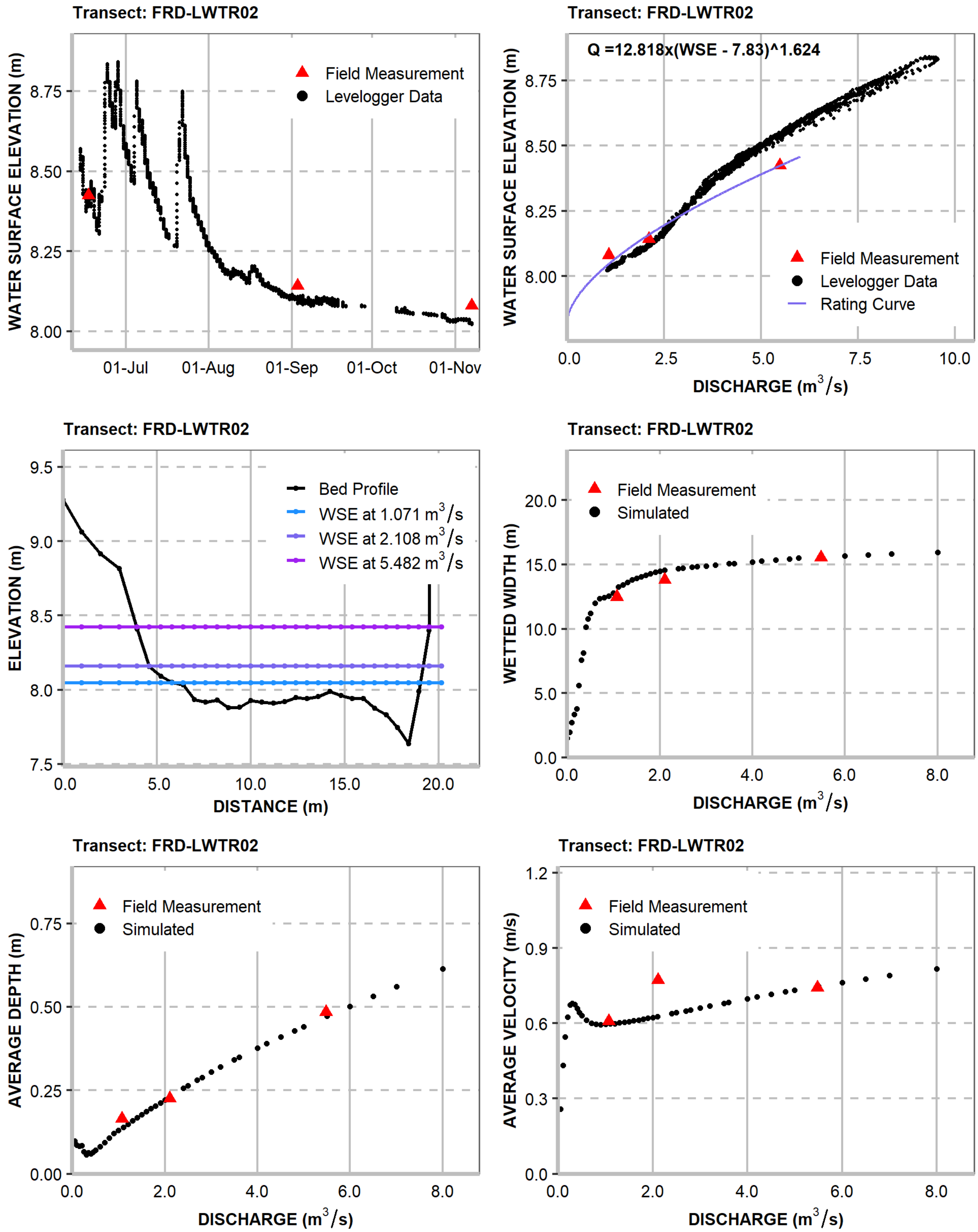

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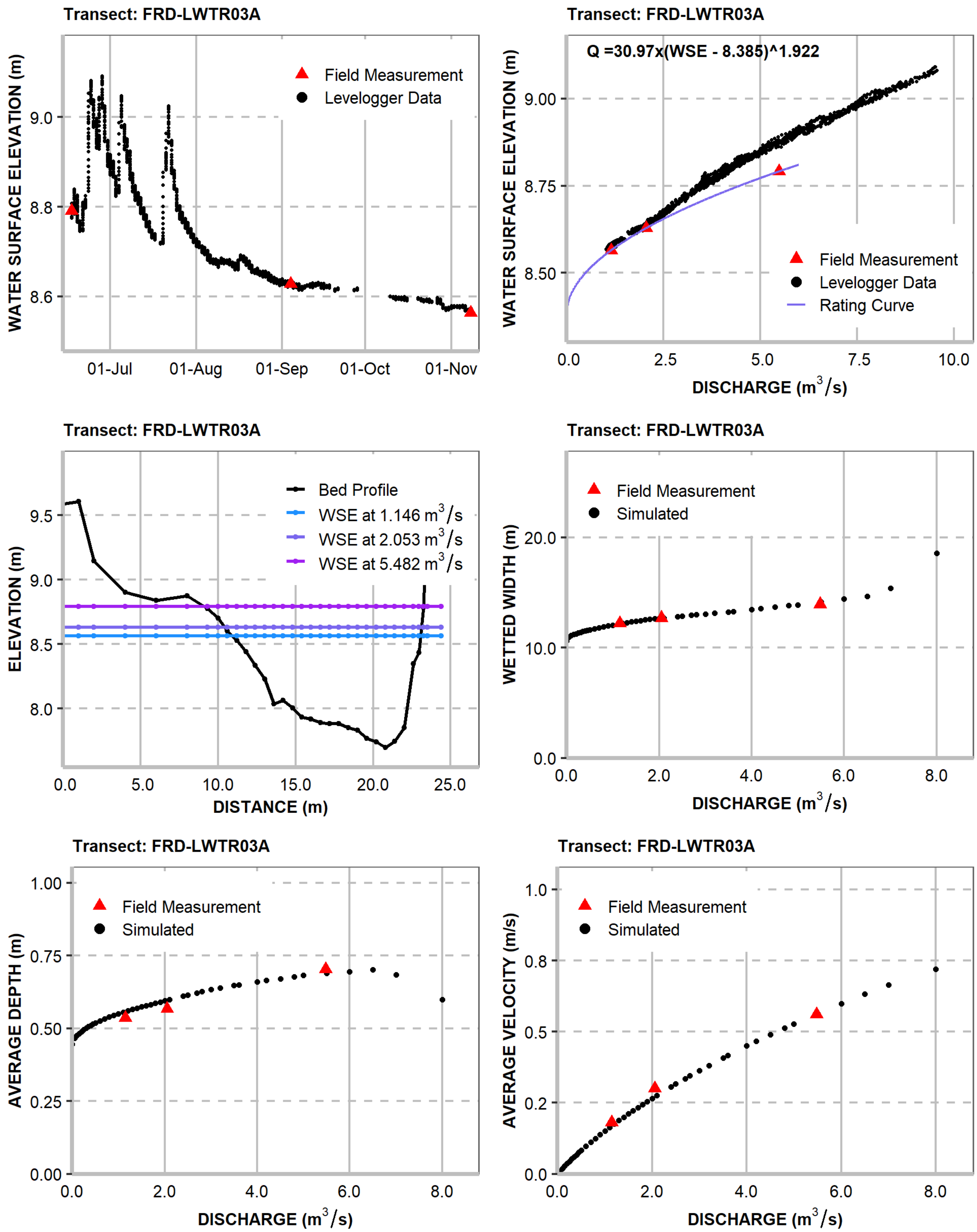

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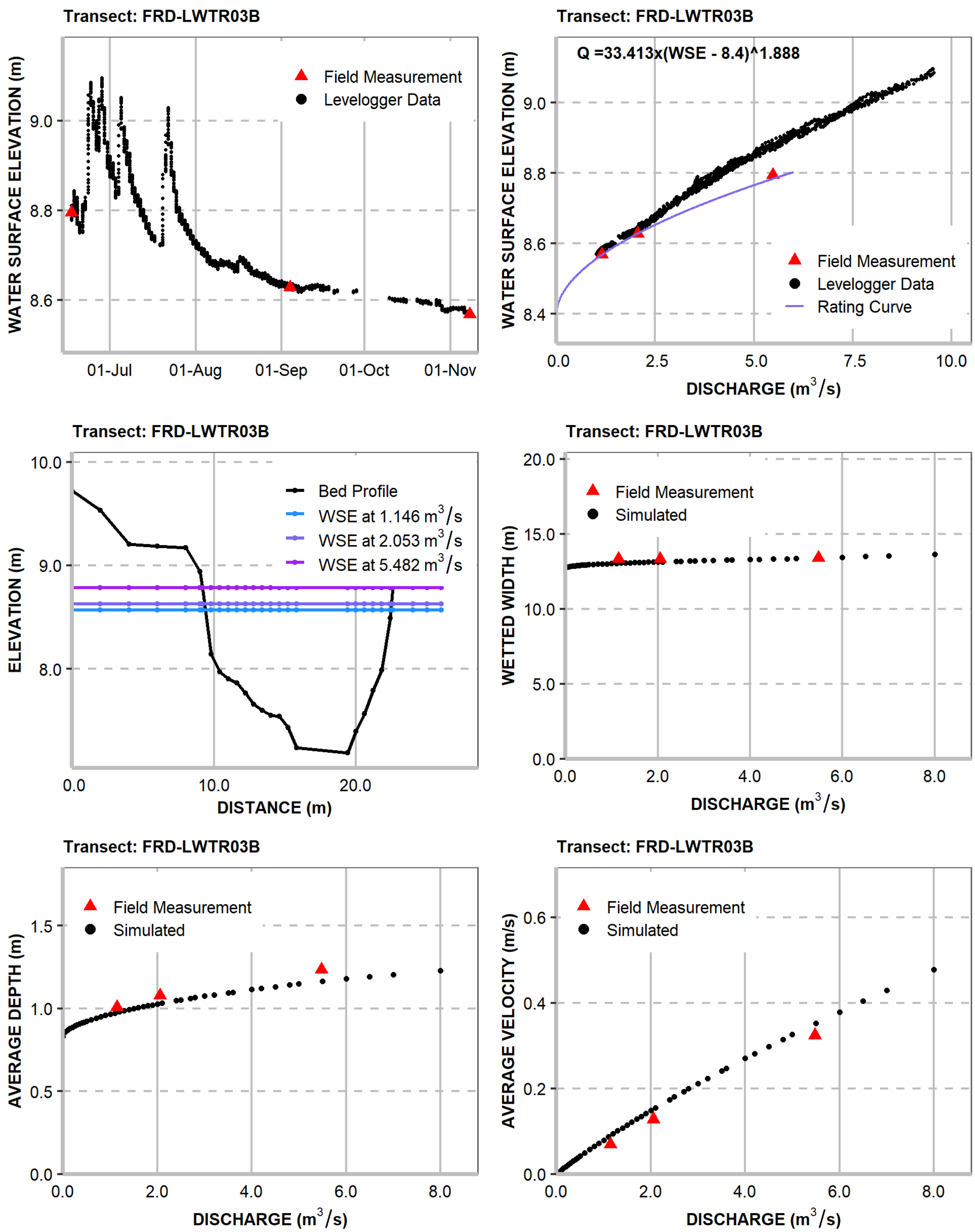
Figure 4. River: Fording River, Transect: FRD-LWTR03B.



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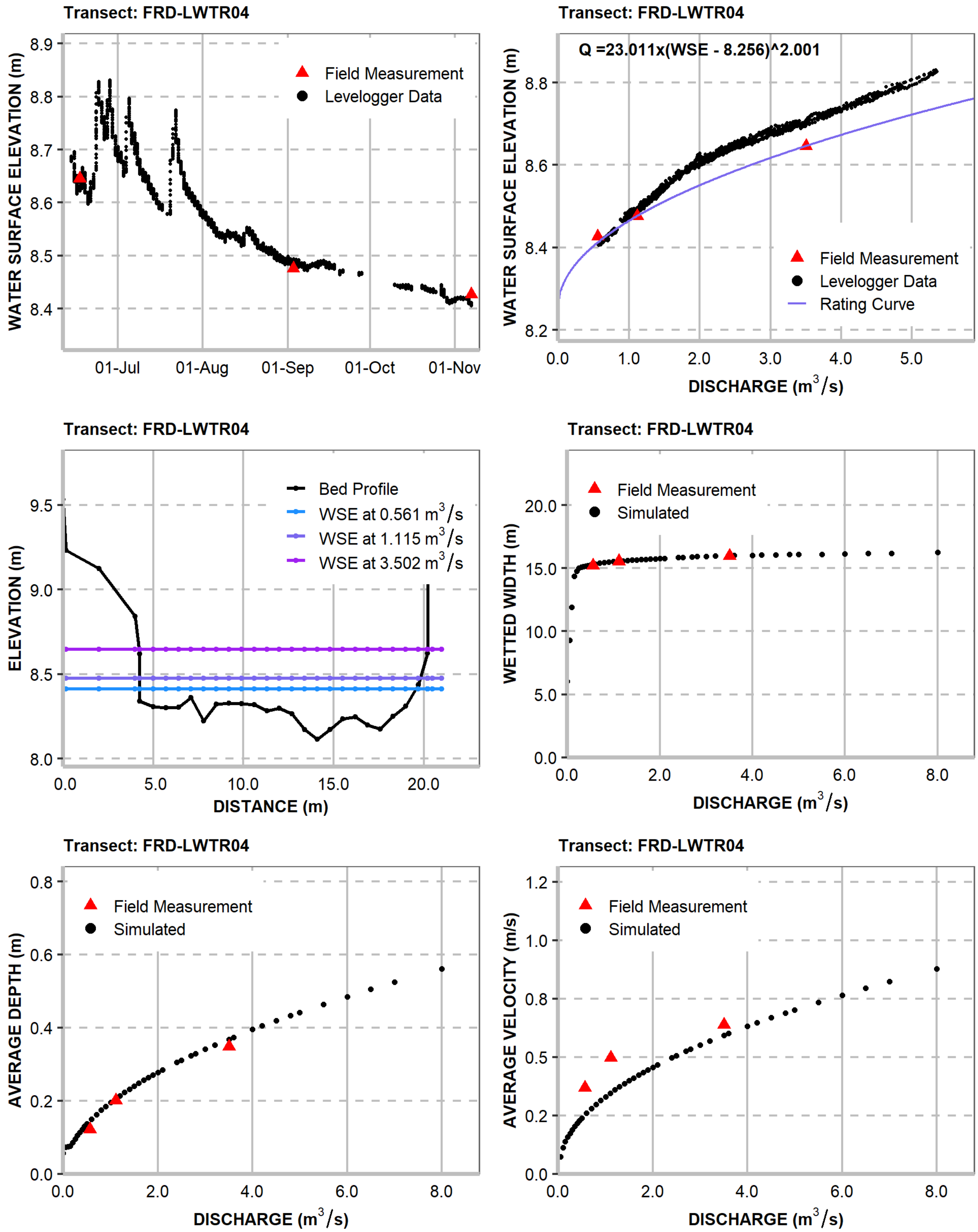

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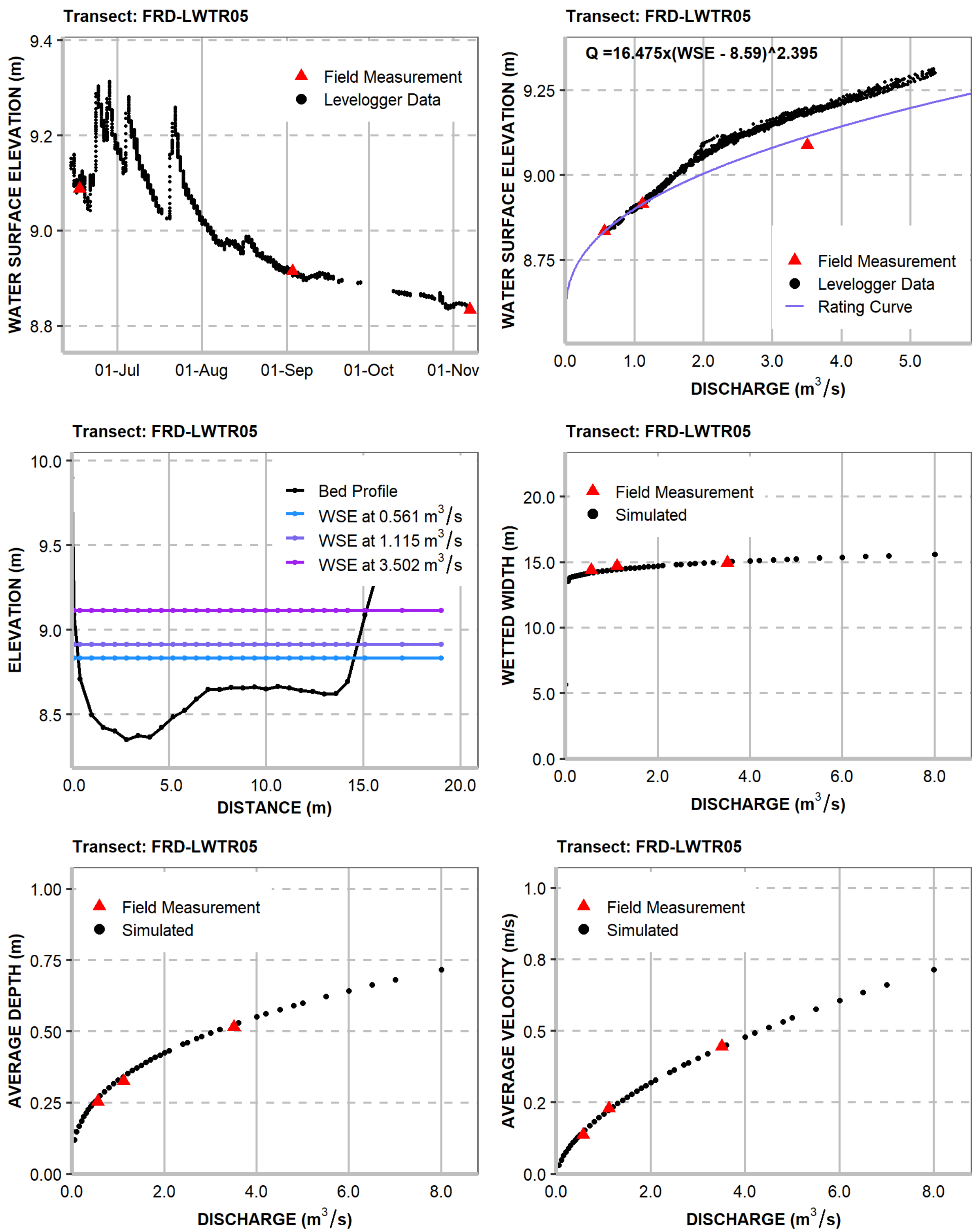

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Figure 7. River: Fording River, Transect: FRD-LWTR06.

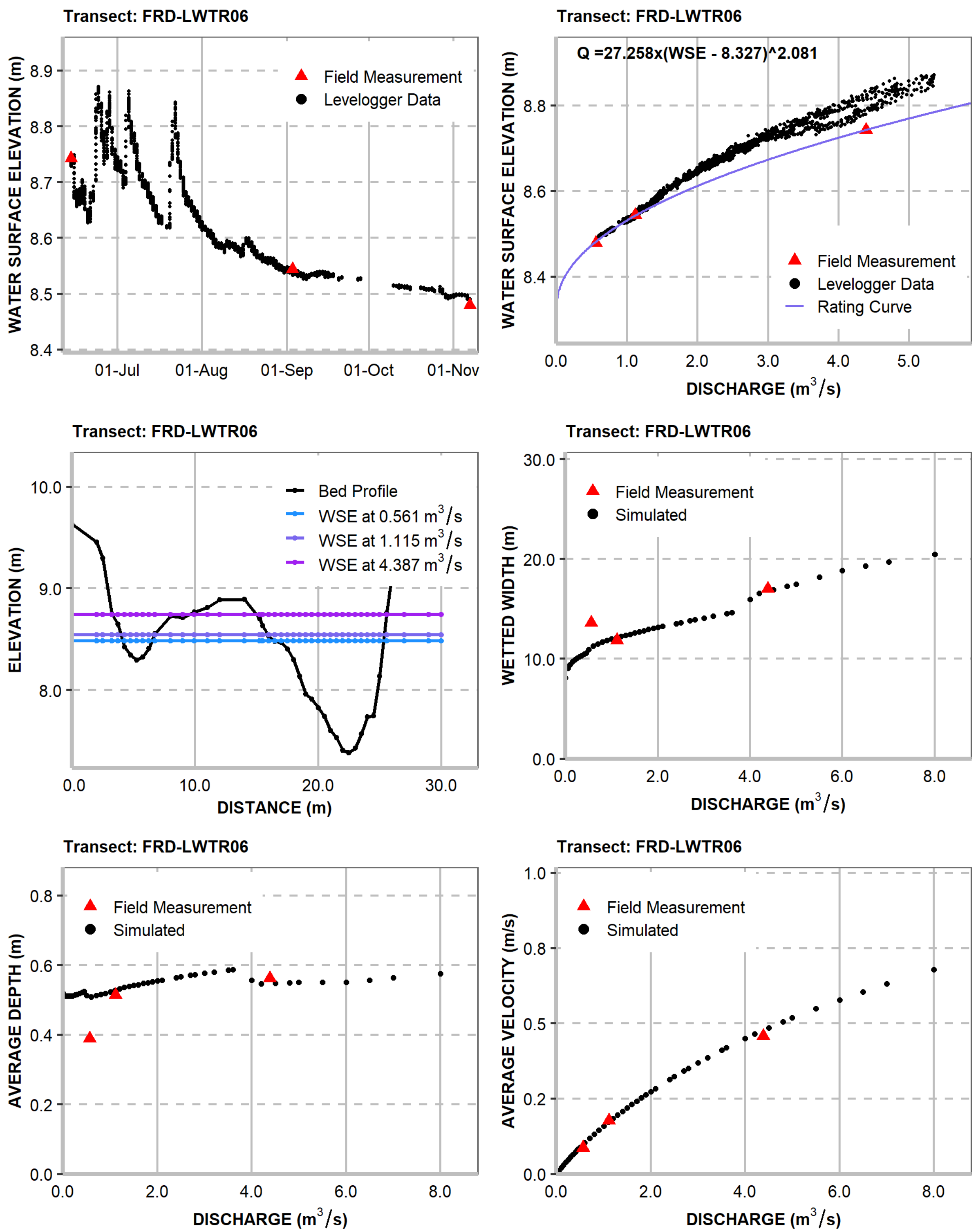
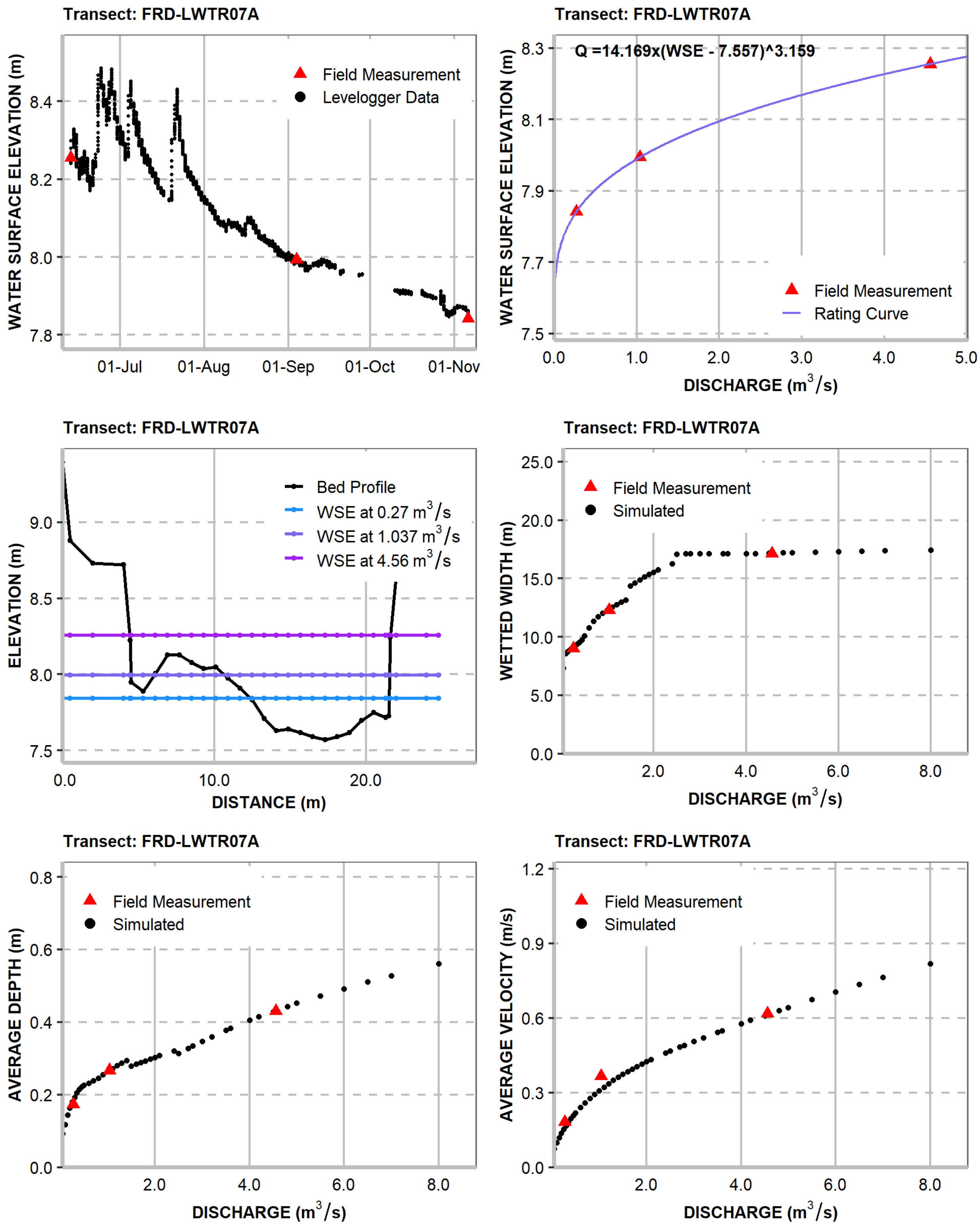


Figure 8. River: Fording River, Transect: FRD-LWTR07A.



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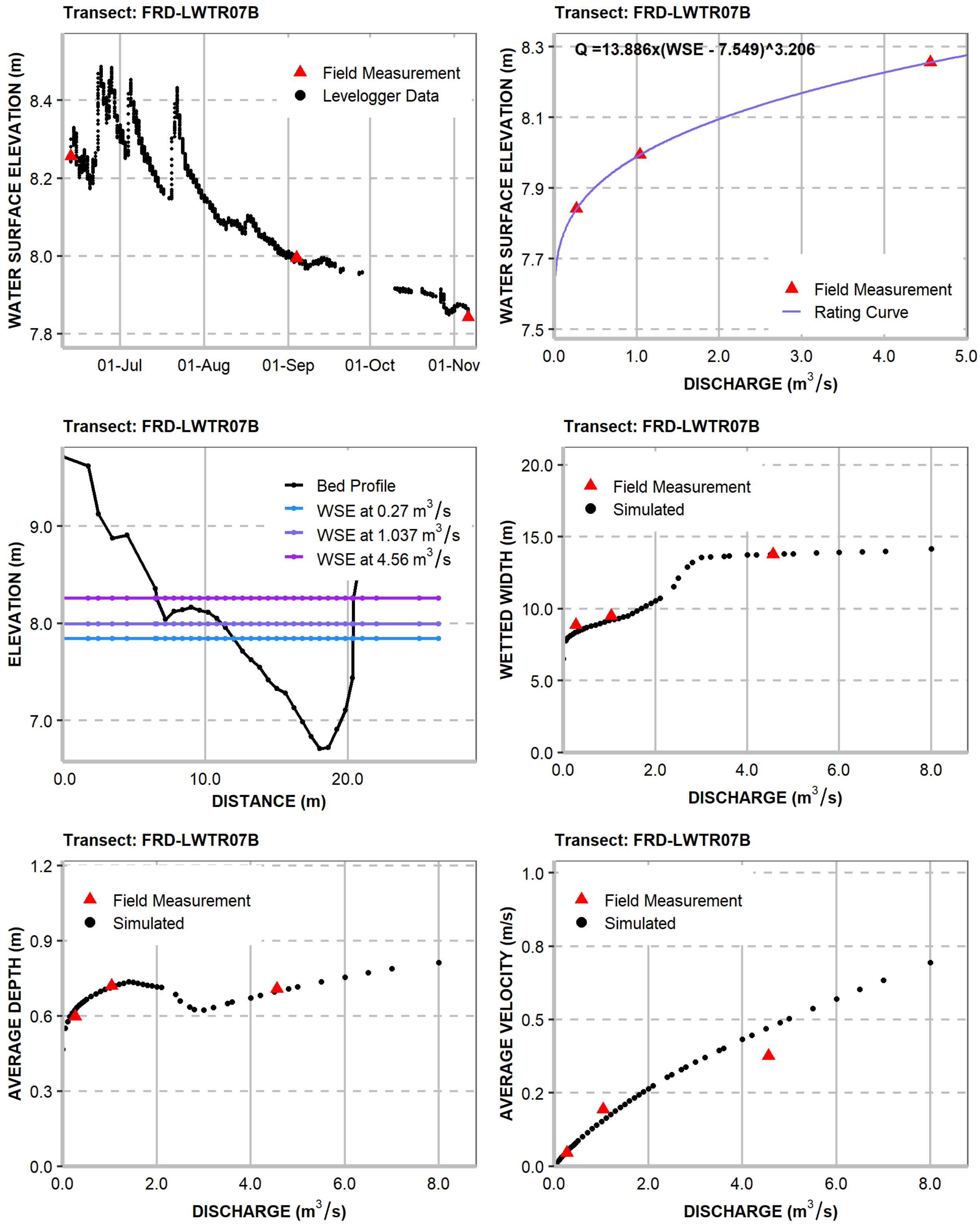

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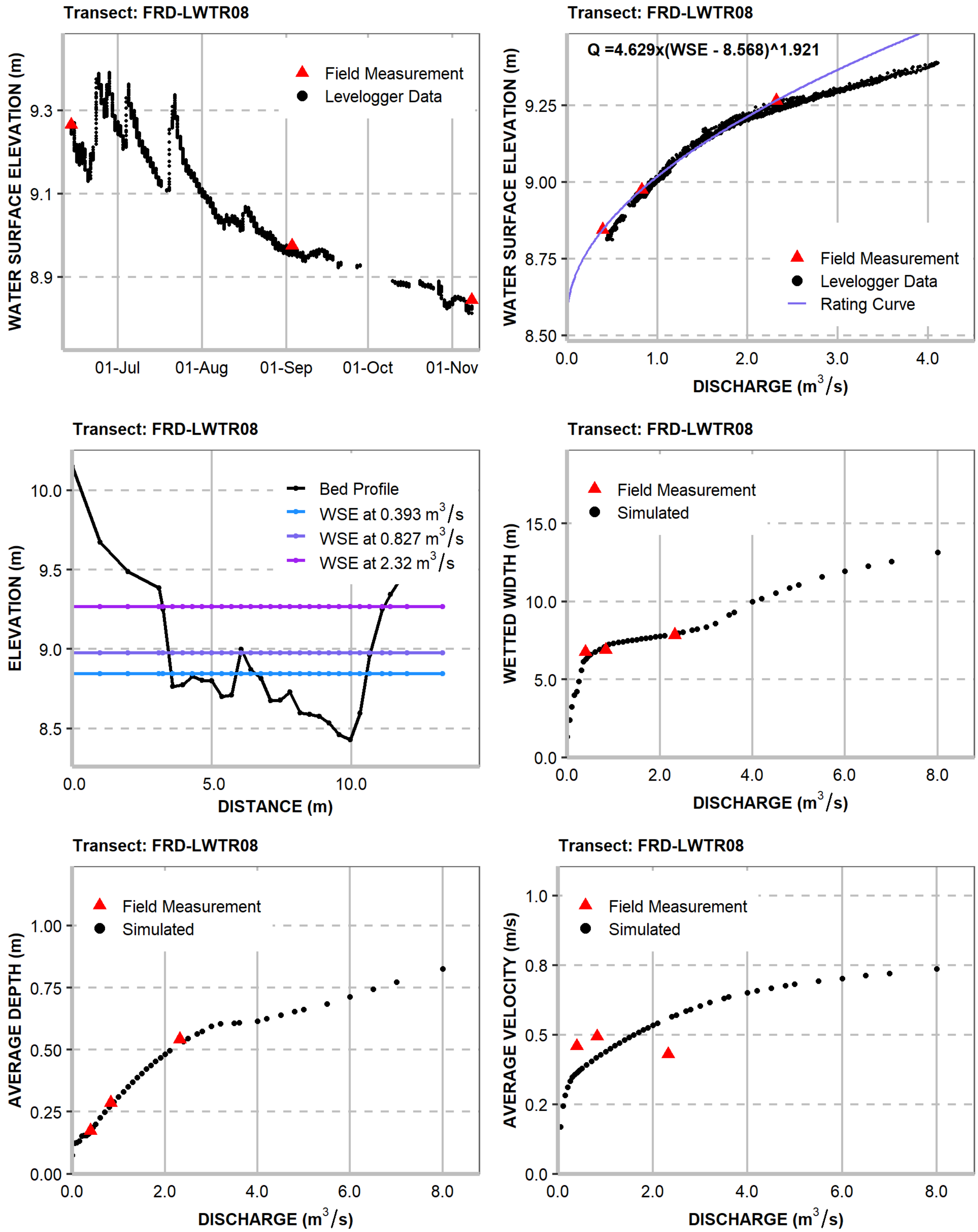

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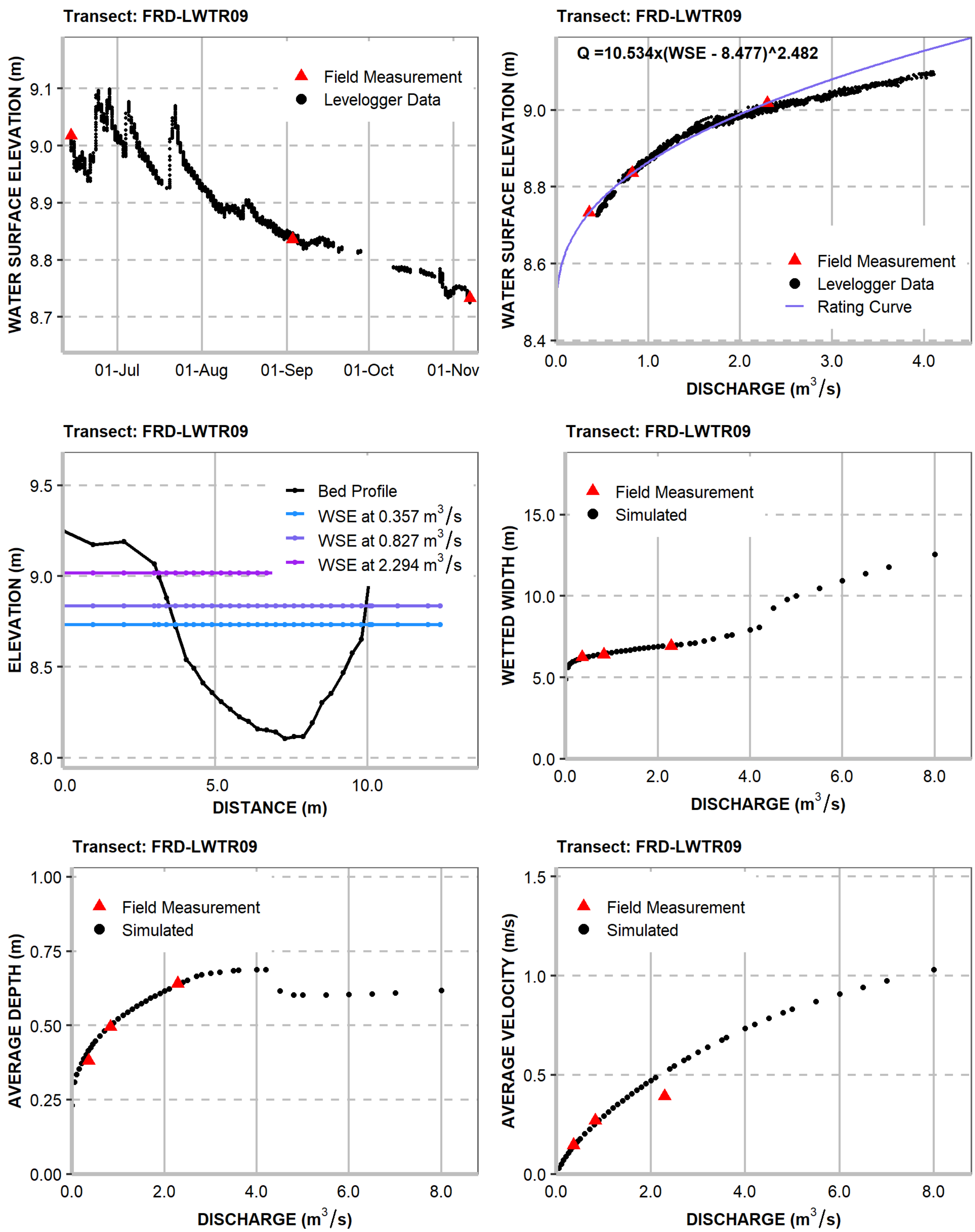

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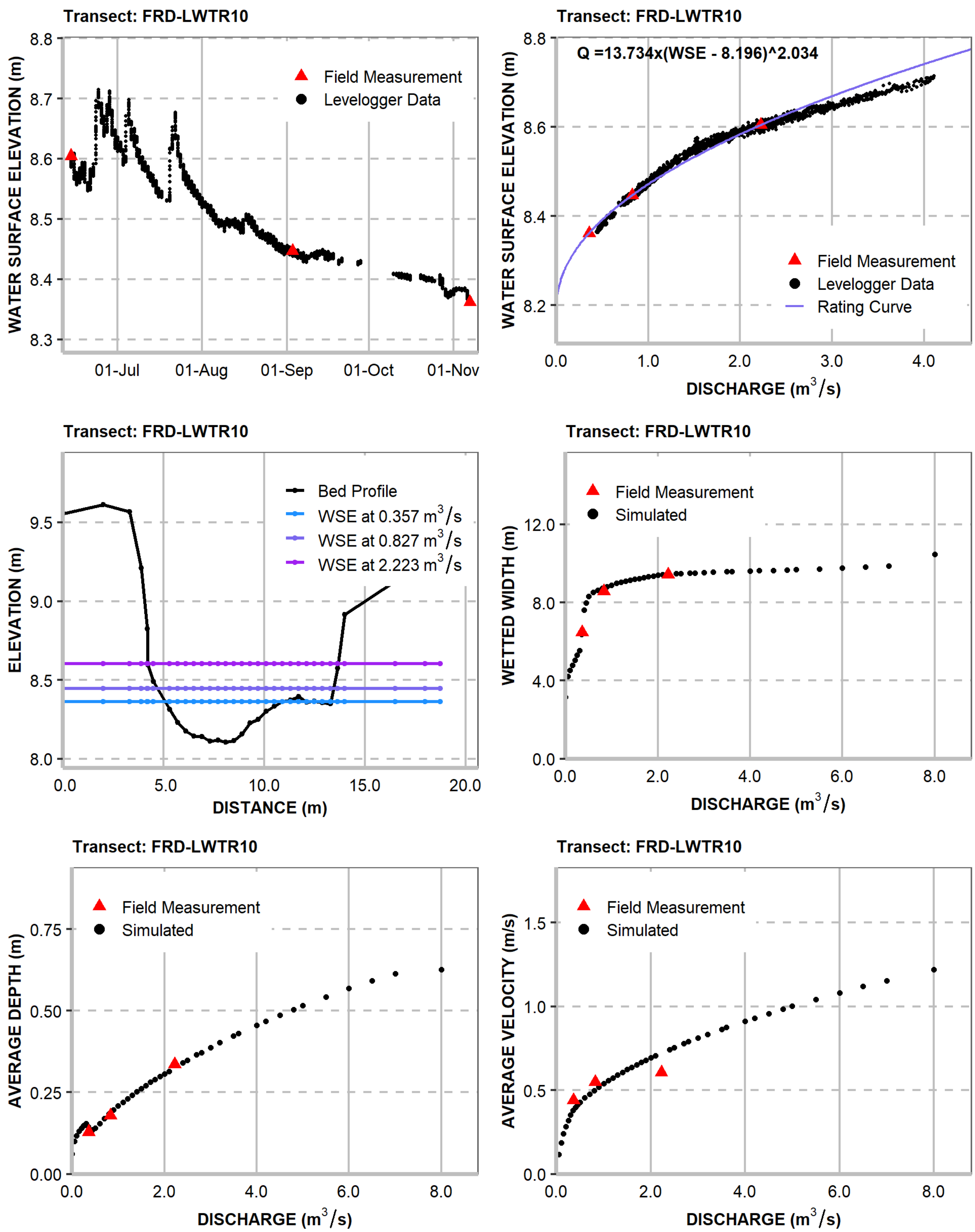

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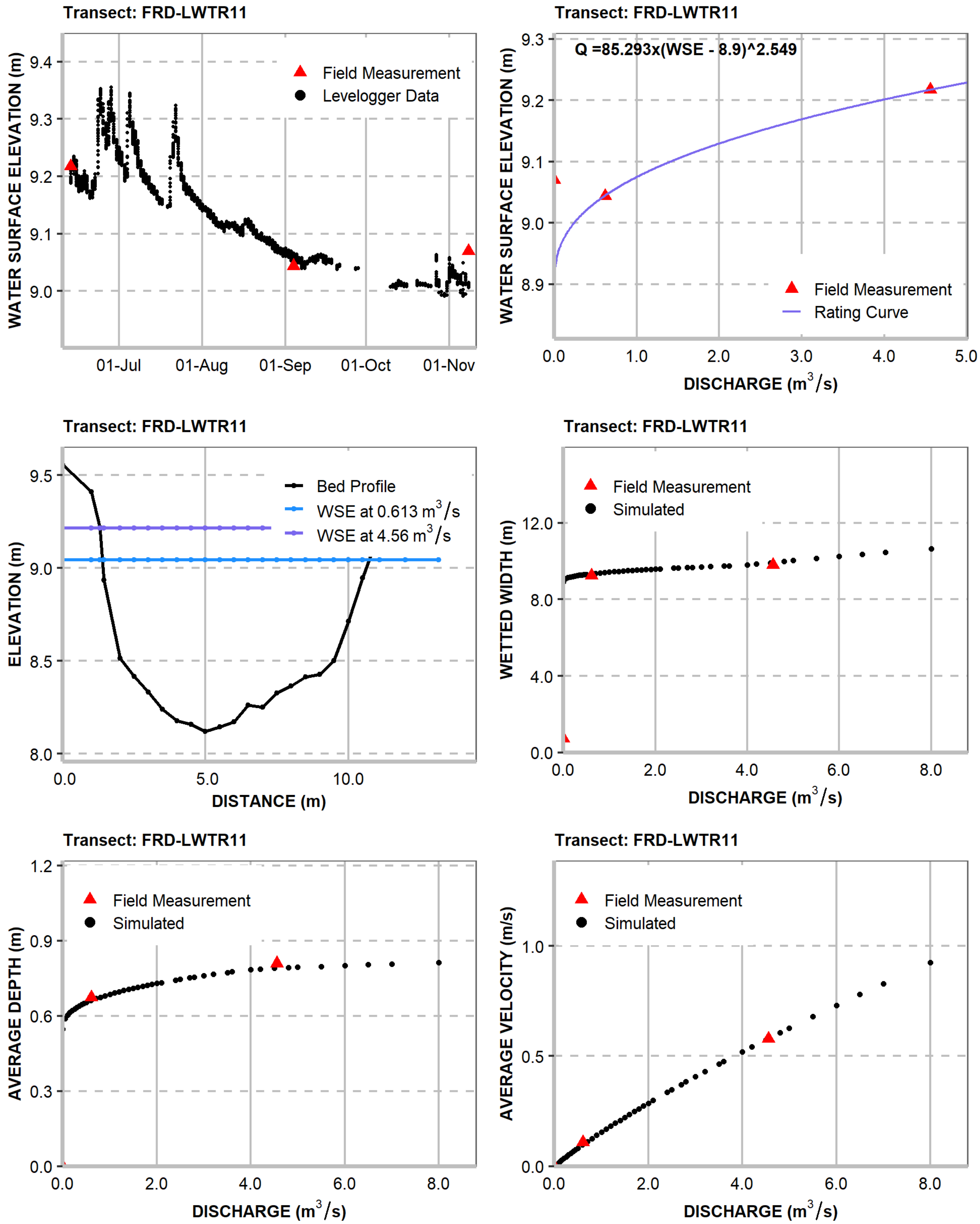
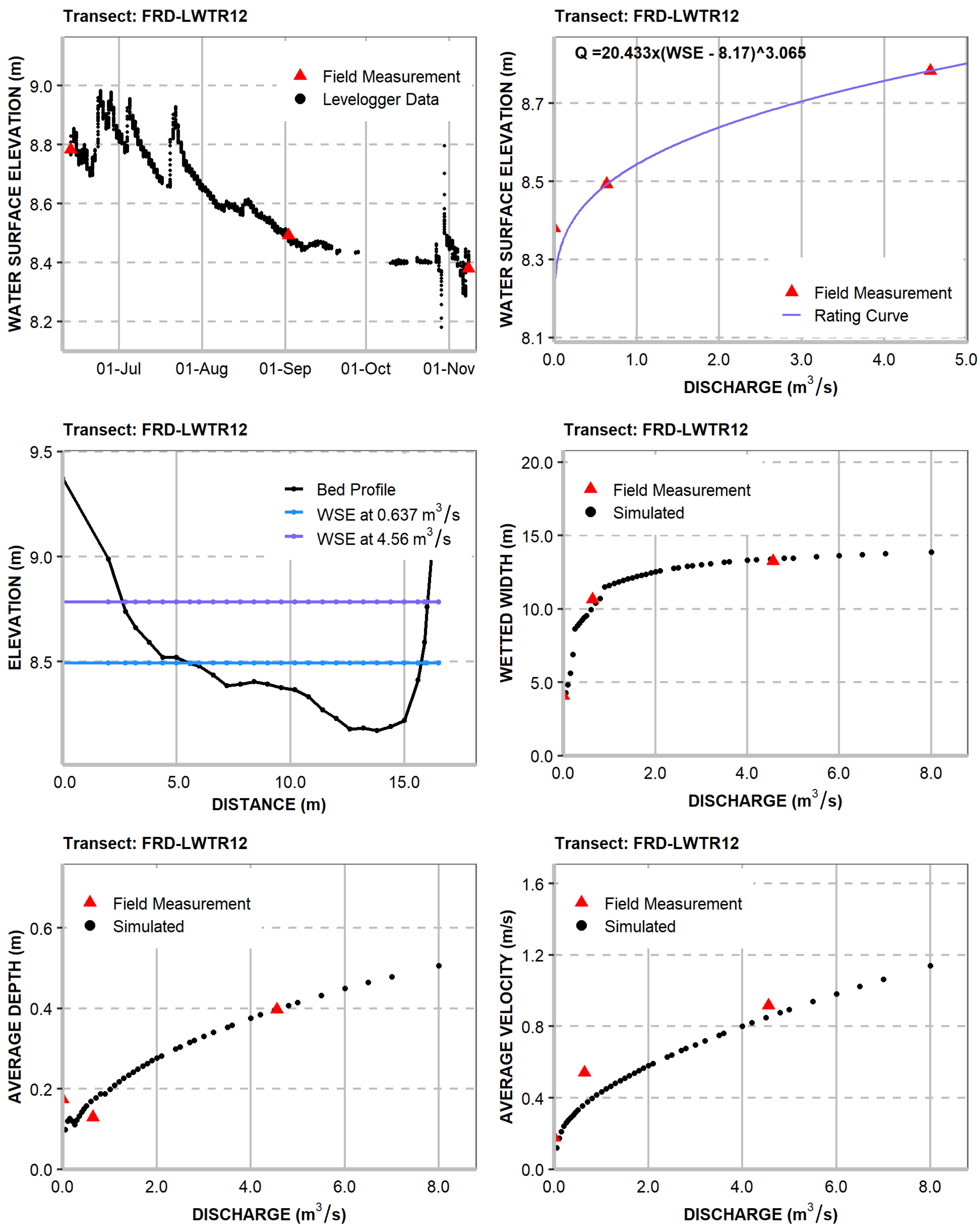


Figure 14. River: Fording River, Transect: FRD-LWTR12.



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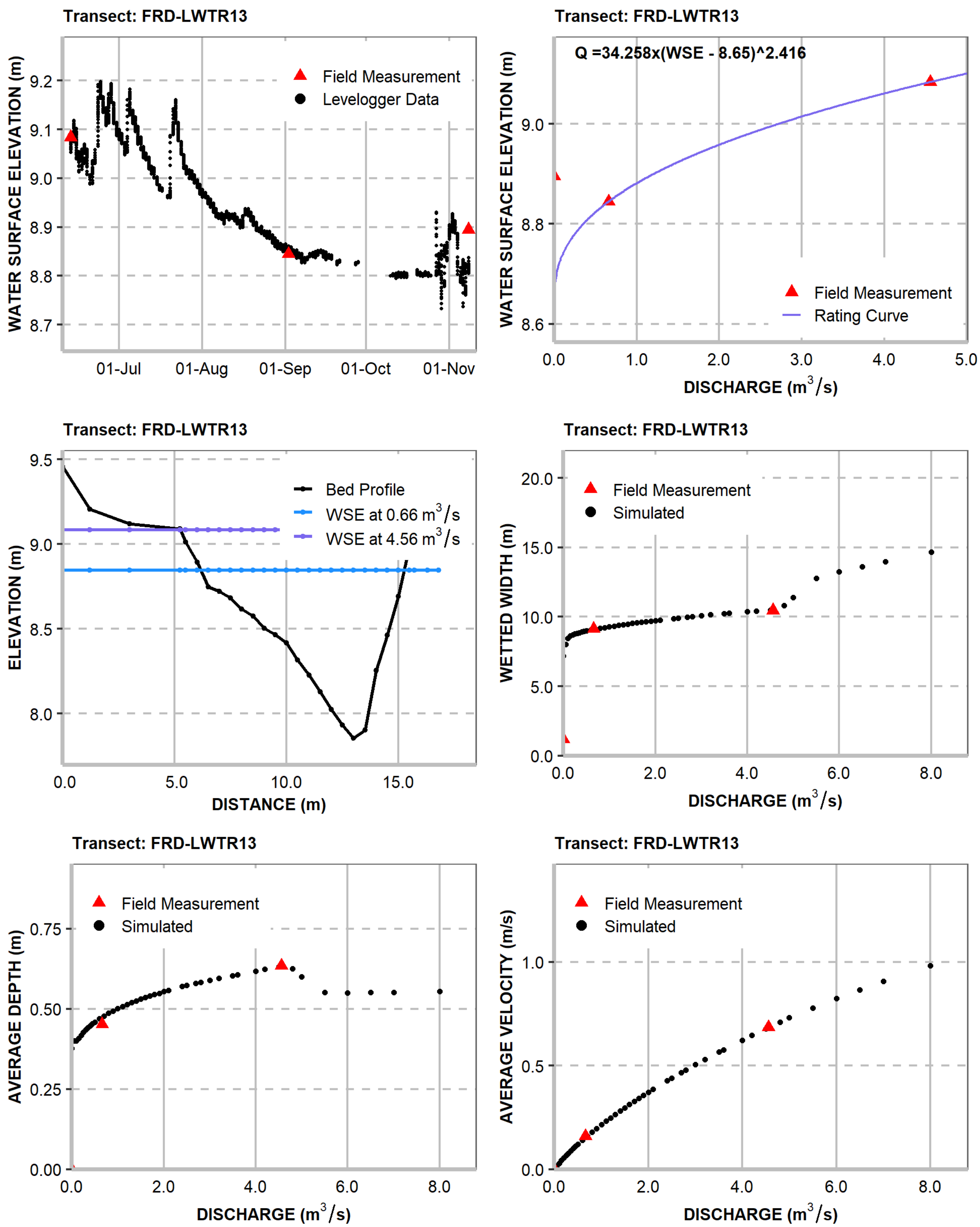

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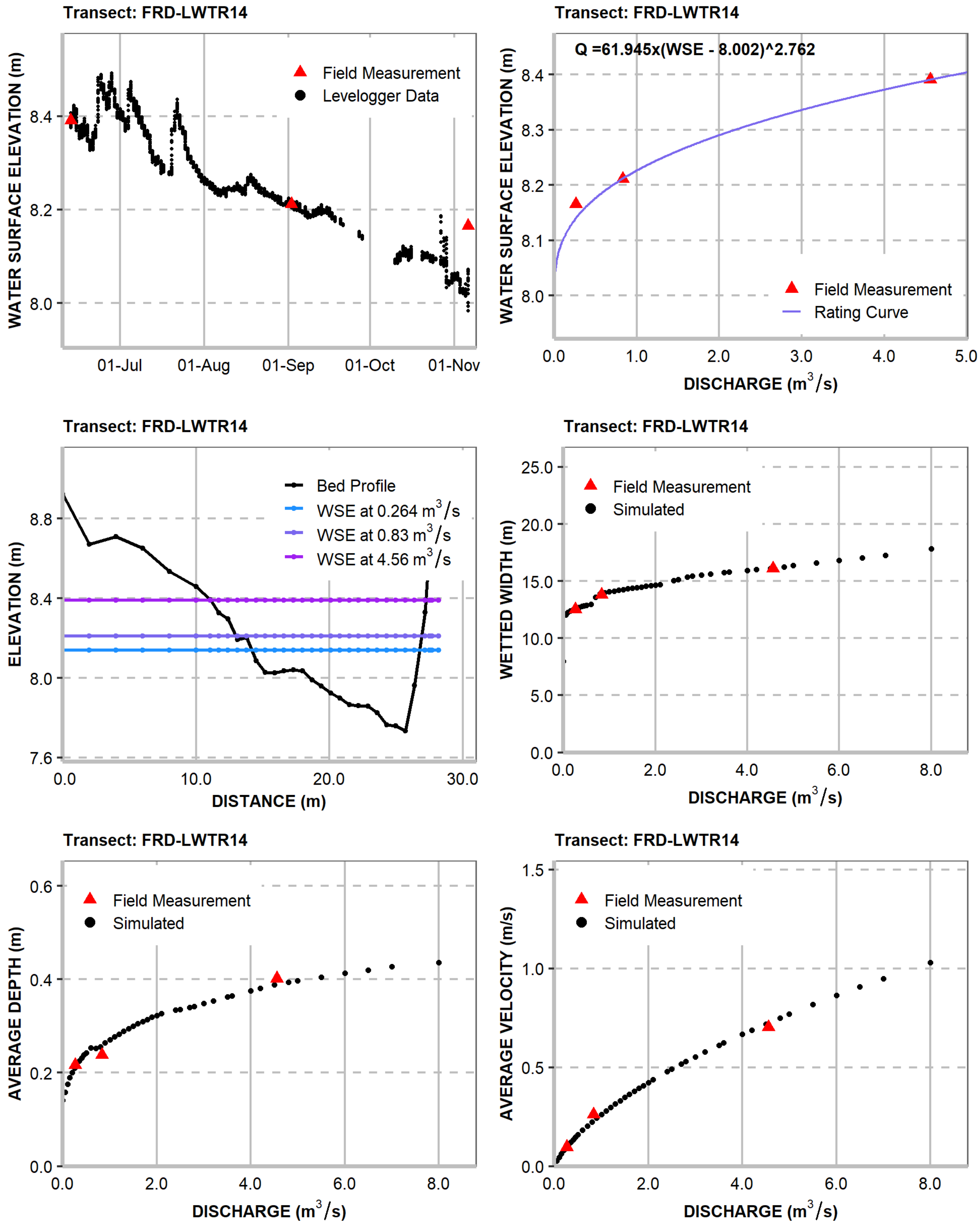

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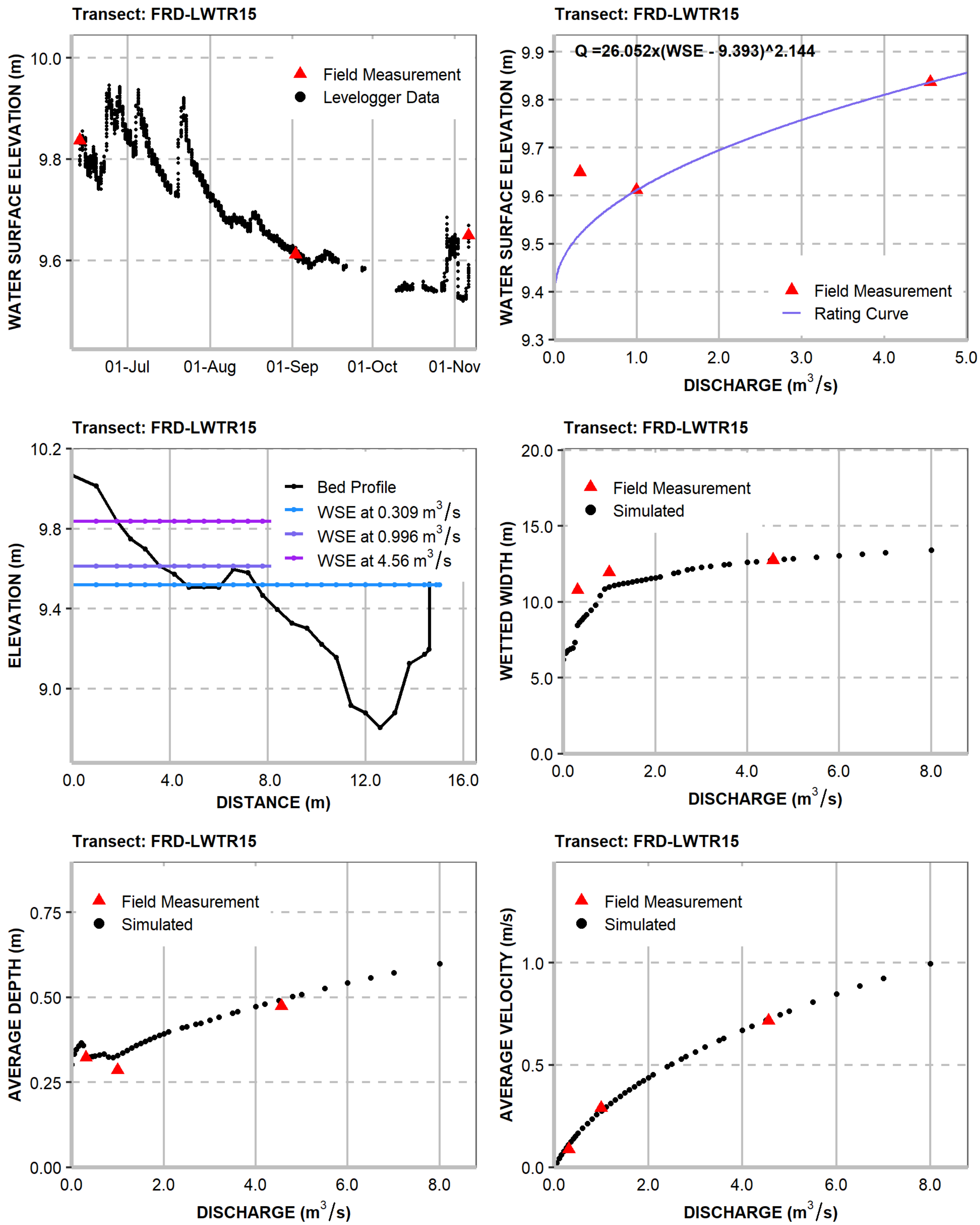

Figure 18. River: Fording River, Transect: FRD-LWTR16.

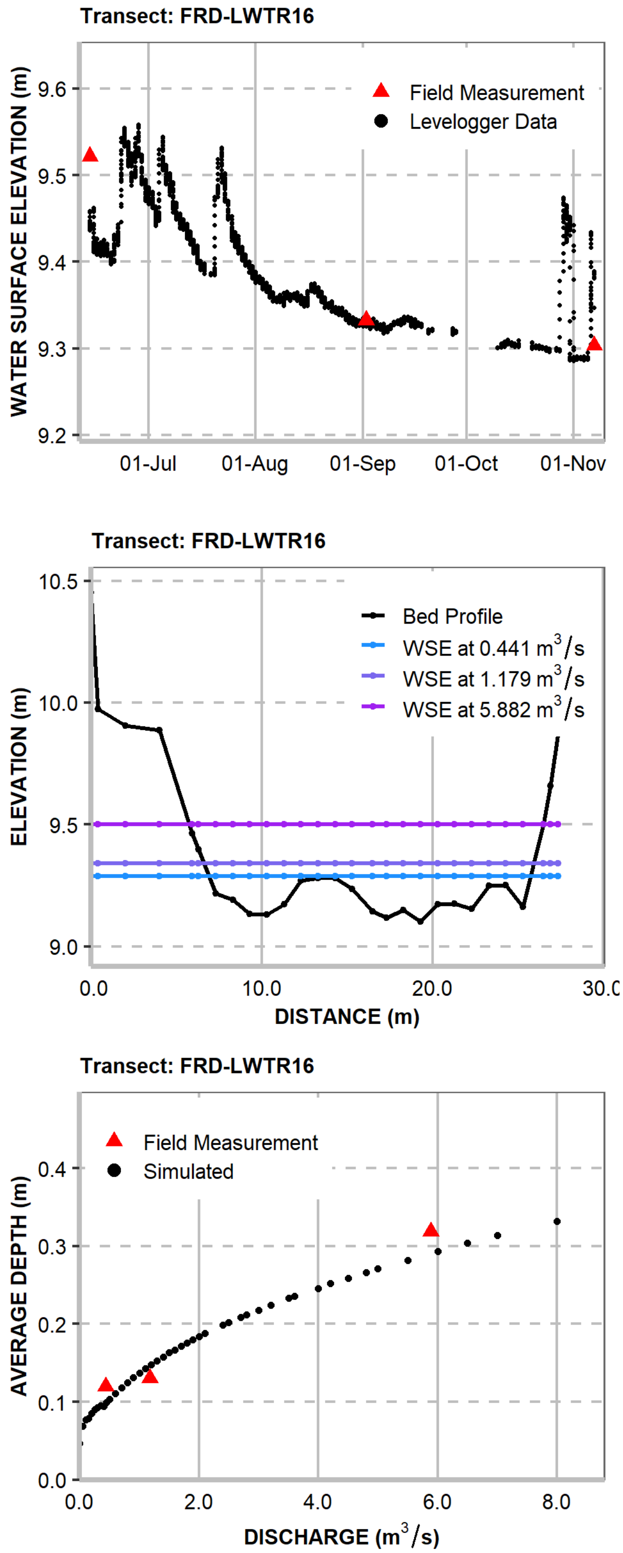

Figure 19. River: Fording River, Transect: FRD-UPTR17.

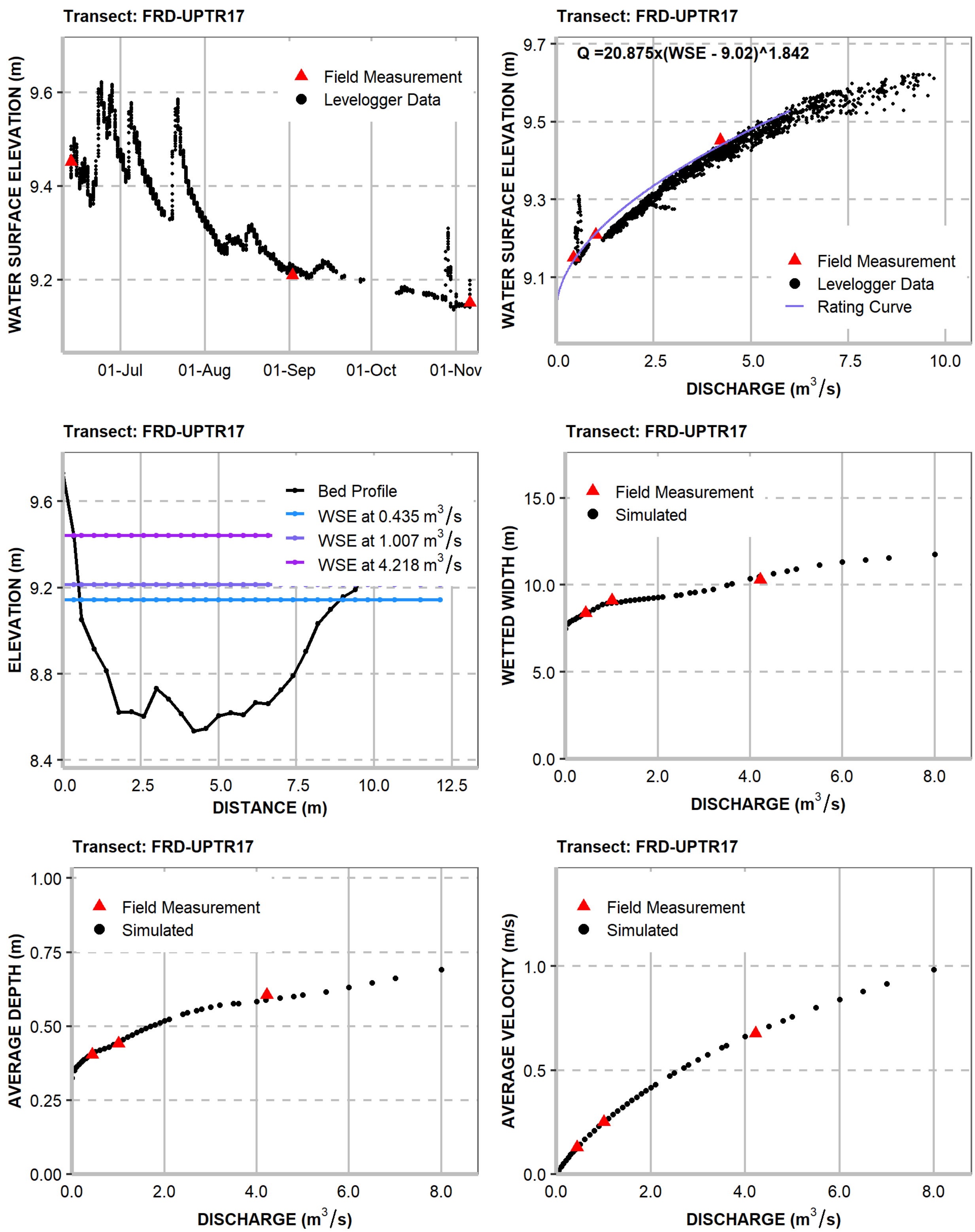

Figure 20. River: Fording River, Transect: FRD-UPTR18.

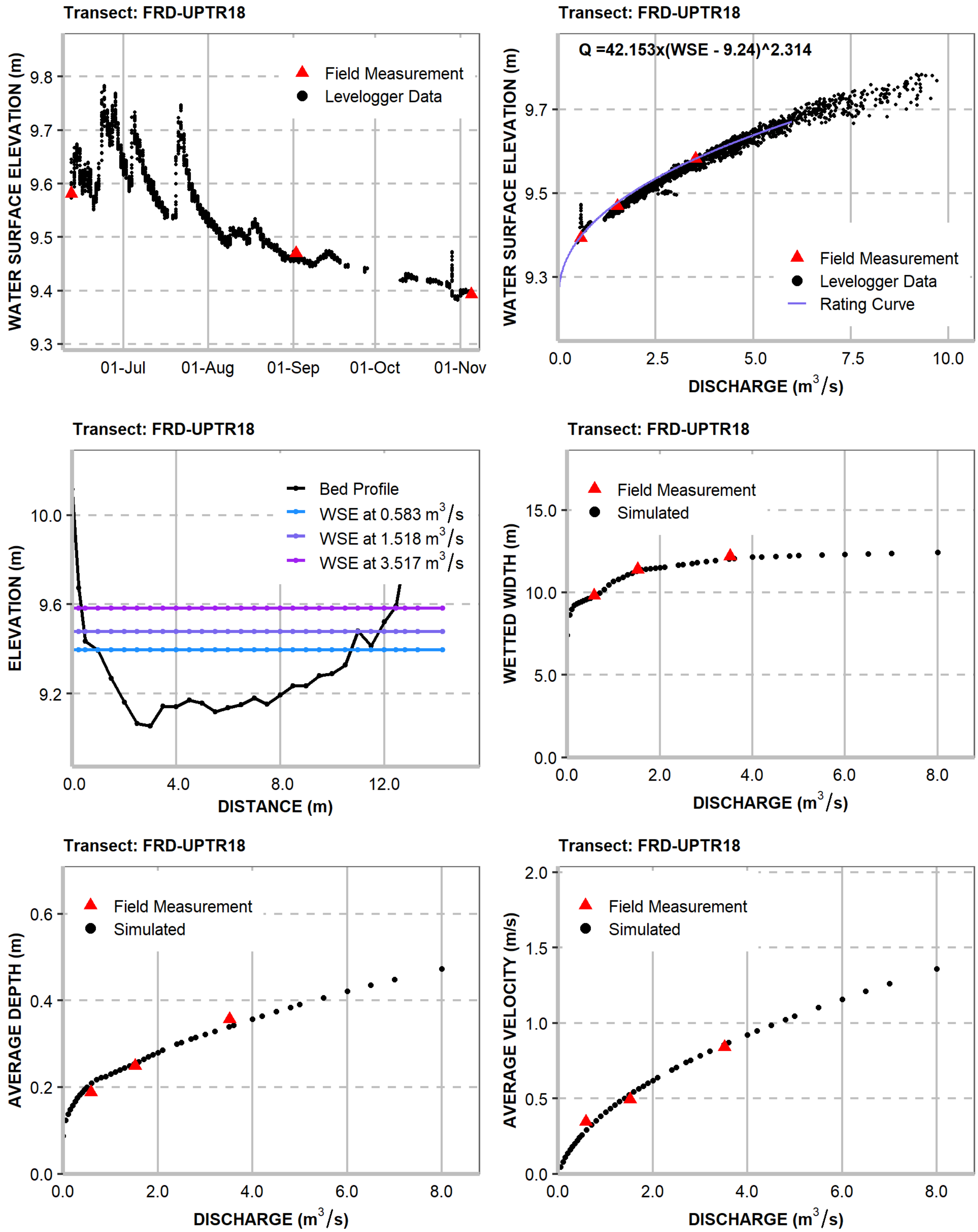

Figure 21. River: Fording River, Transect: FRD-UPTR19.

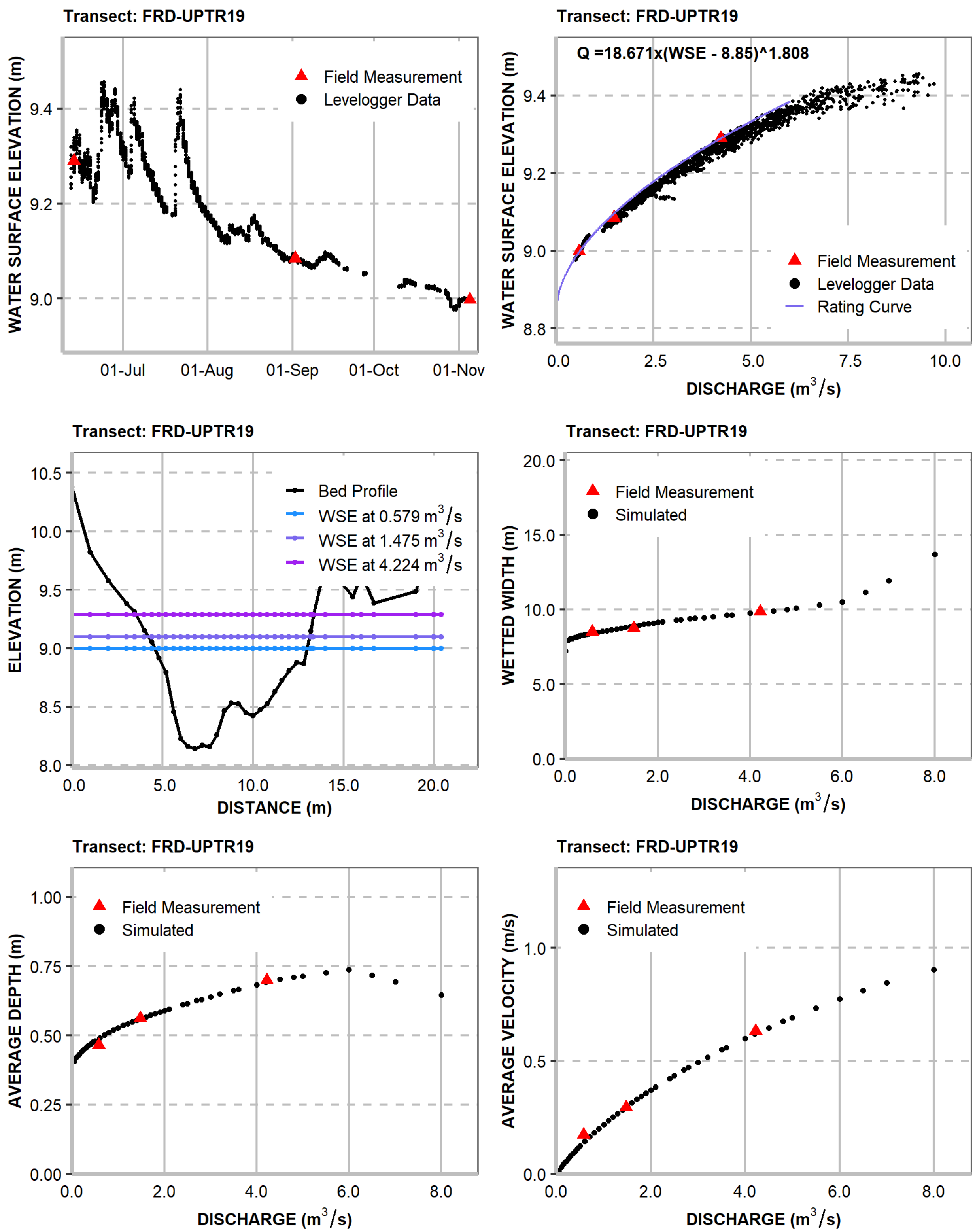

Figure 22. River: Fording River, Transect: FRD-UPTR20.

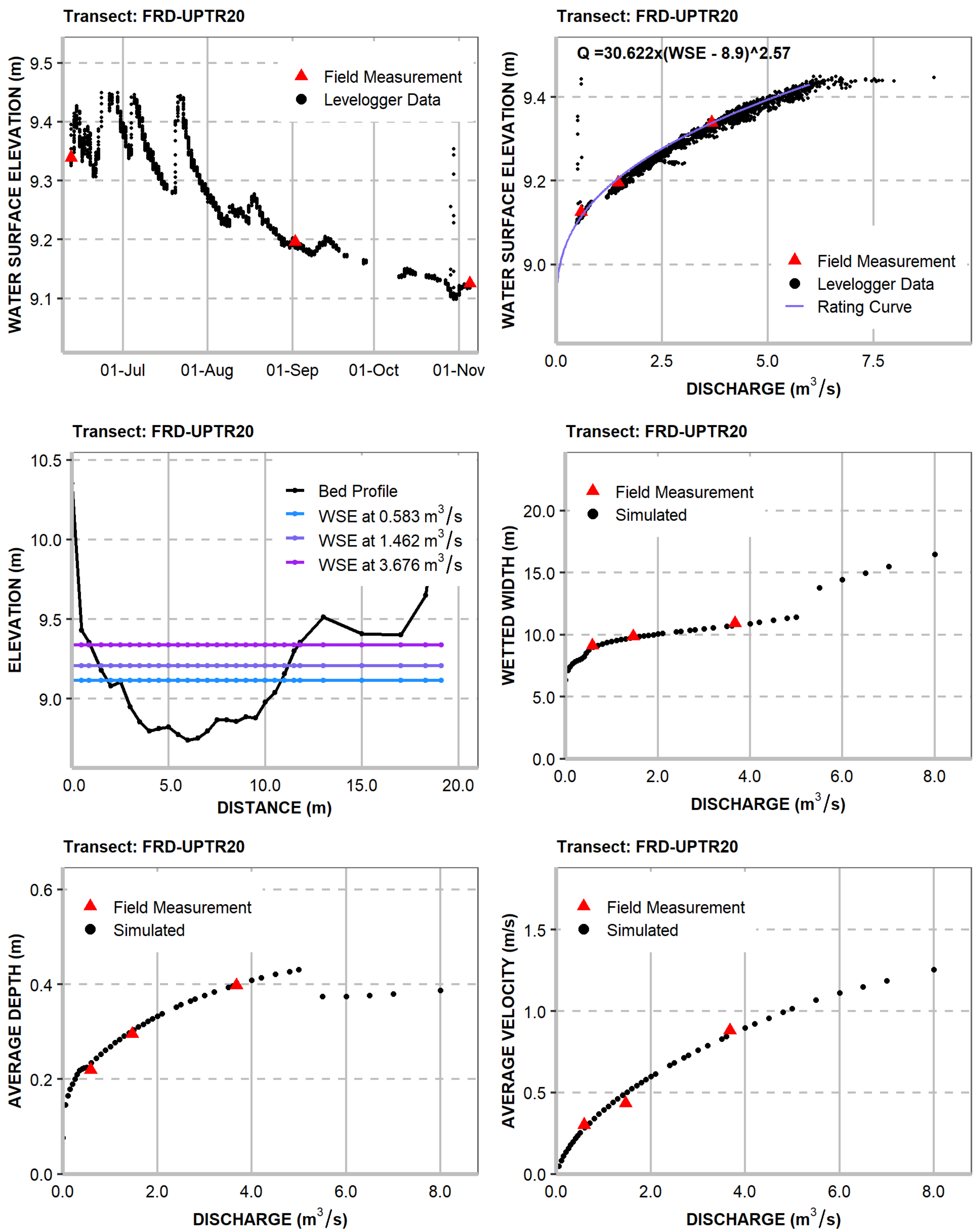

Figure 23. River: Fording River, Transect: FRD-UPTR21A.

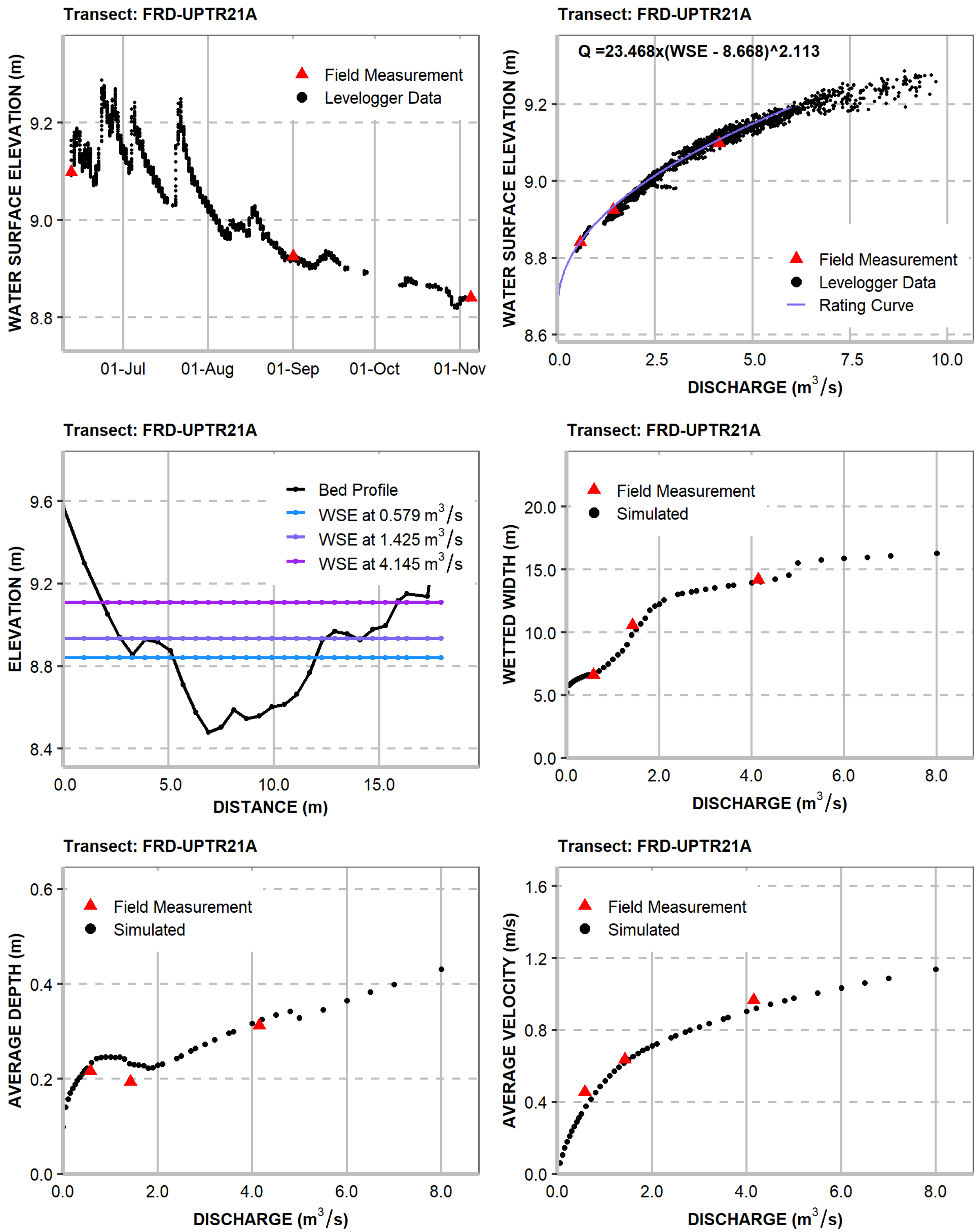

Figure 24. River: Fording River, Transect: FRD-UPTR21B.

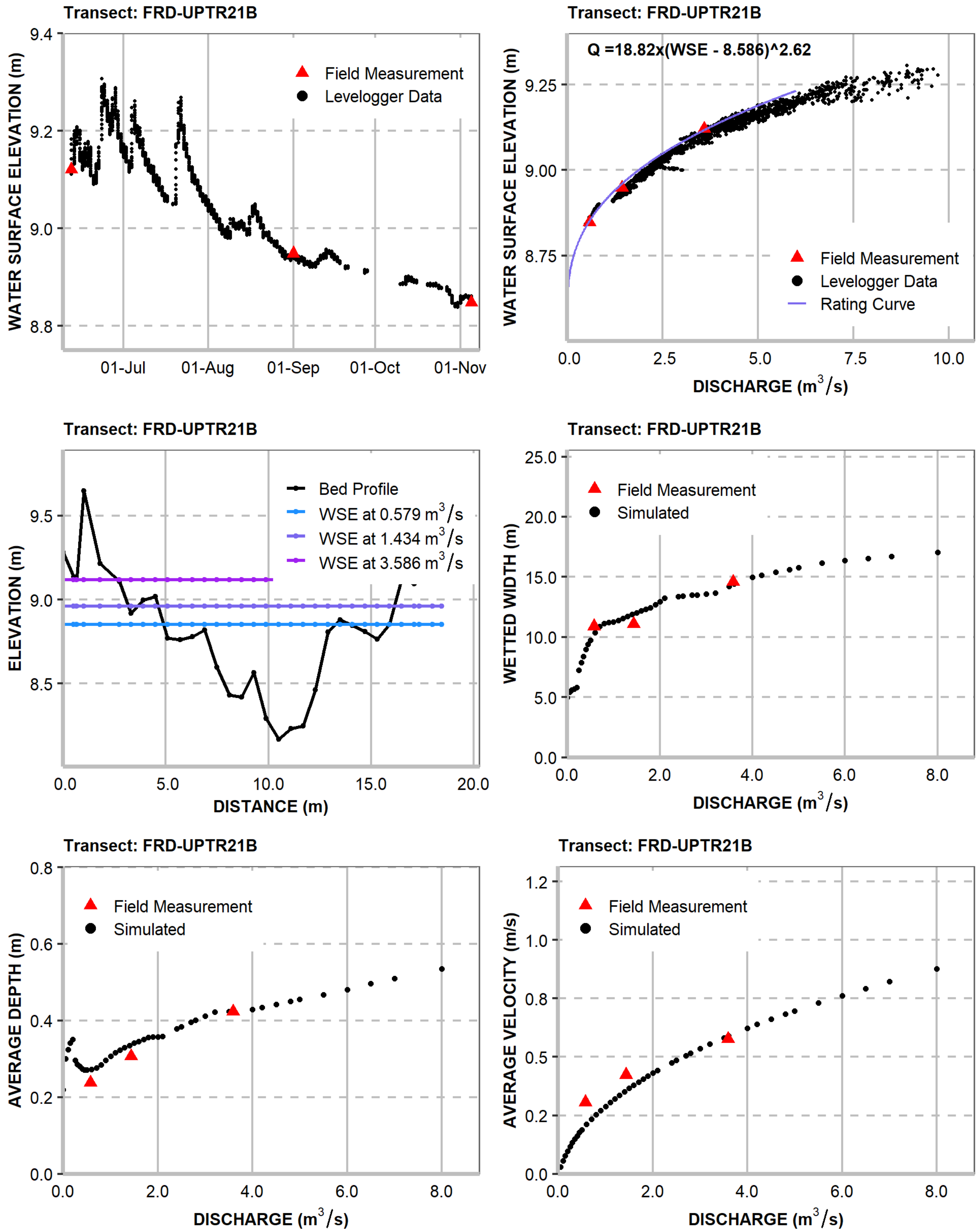

Figure 25. River: Fording River, Transect: FRD-UPTR22.

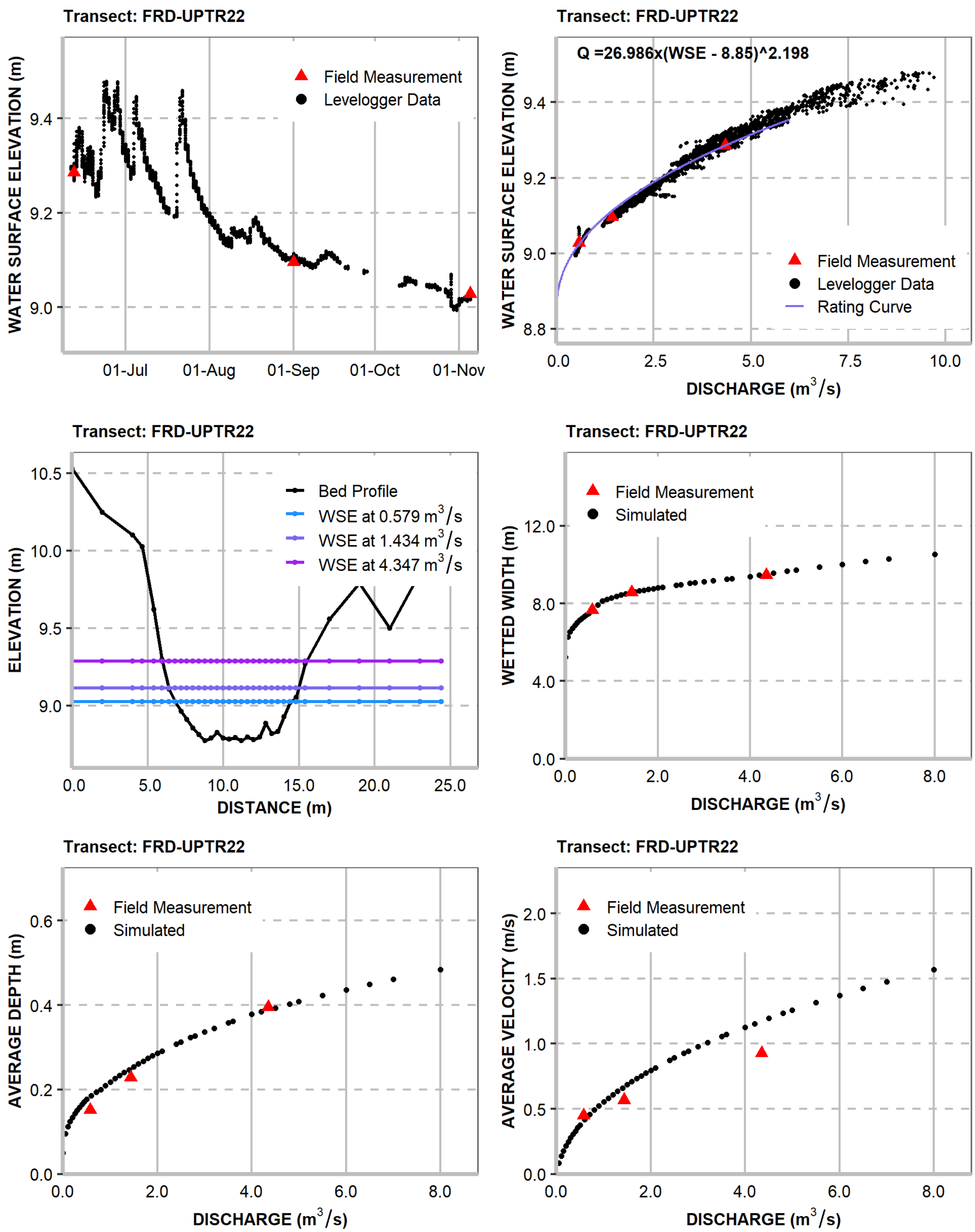

Figure 26. River: Fording River, Transect: FRD-UPTR23.

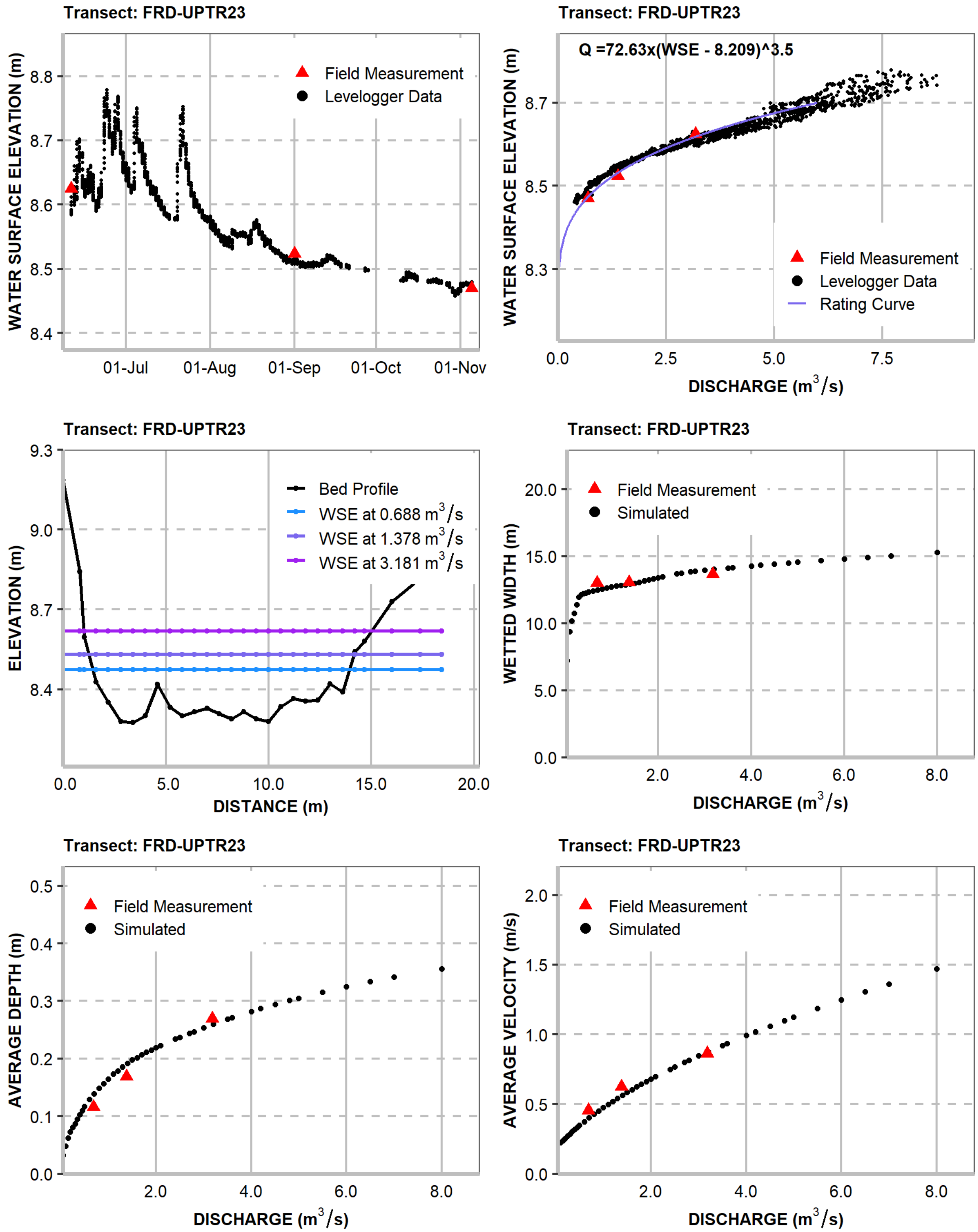

Figure 27. River: Fording River, Transect: FRD-UPTR24.

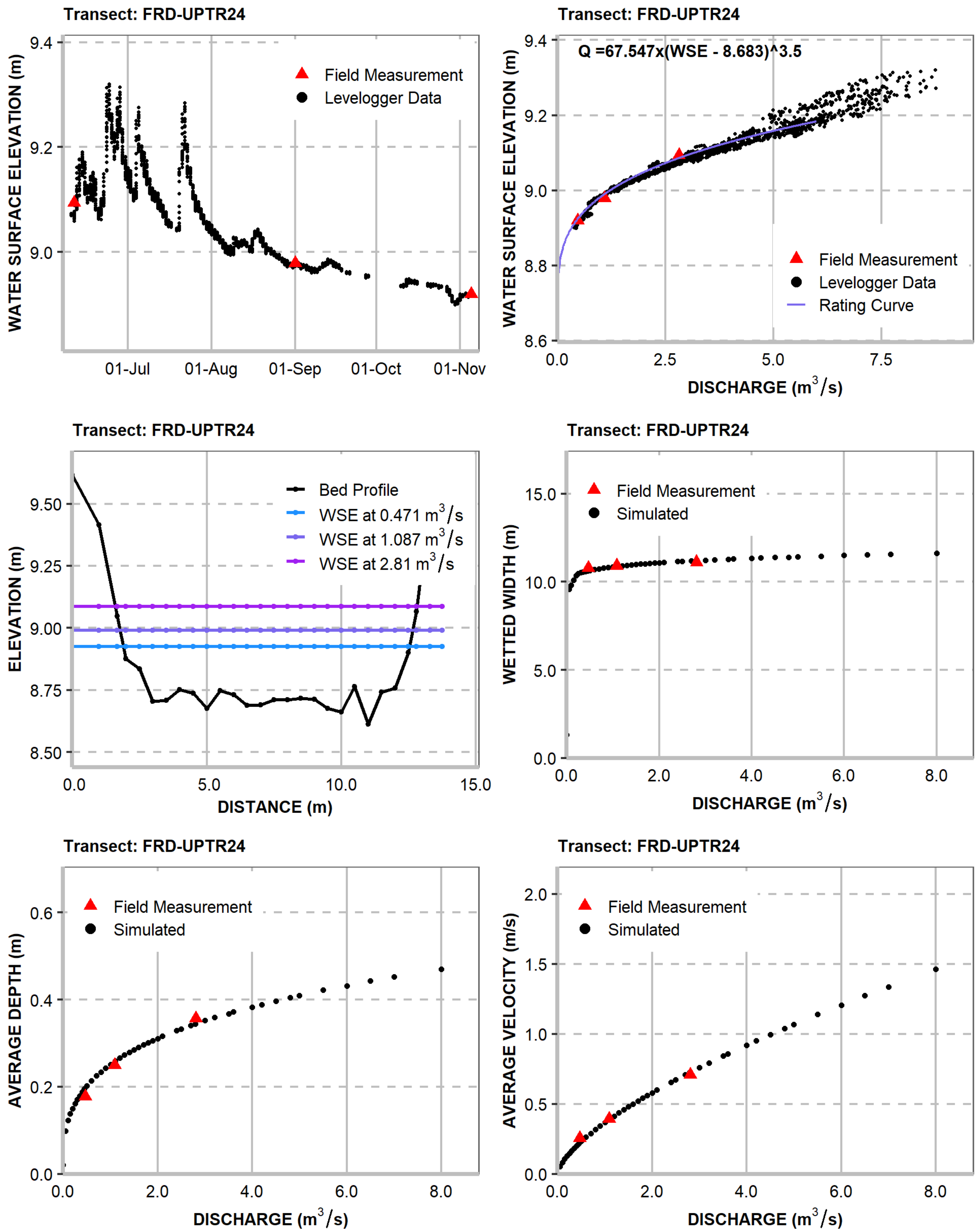

Figure 28. River: Fording River, Transect: FRD-UPTR25.

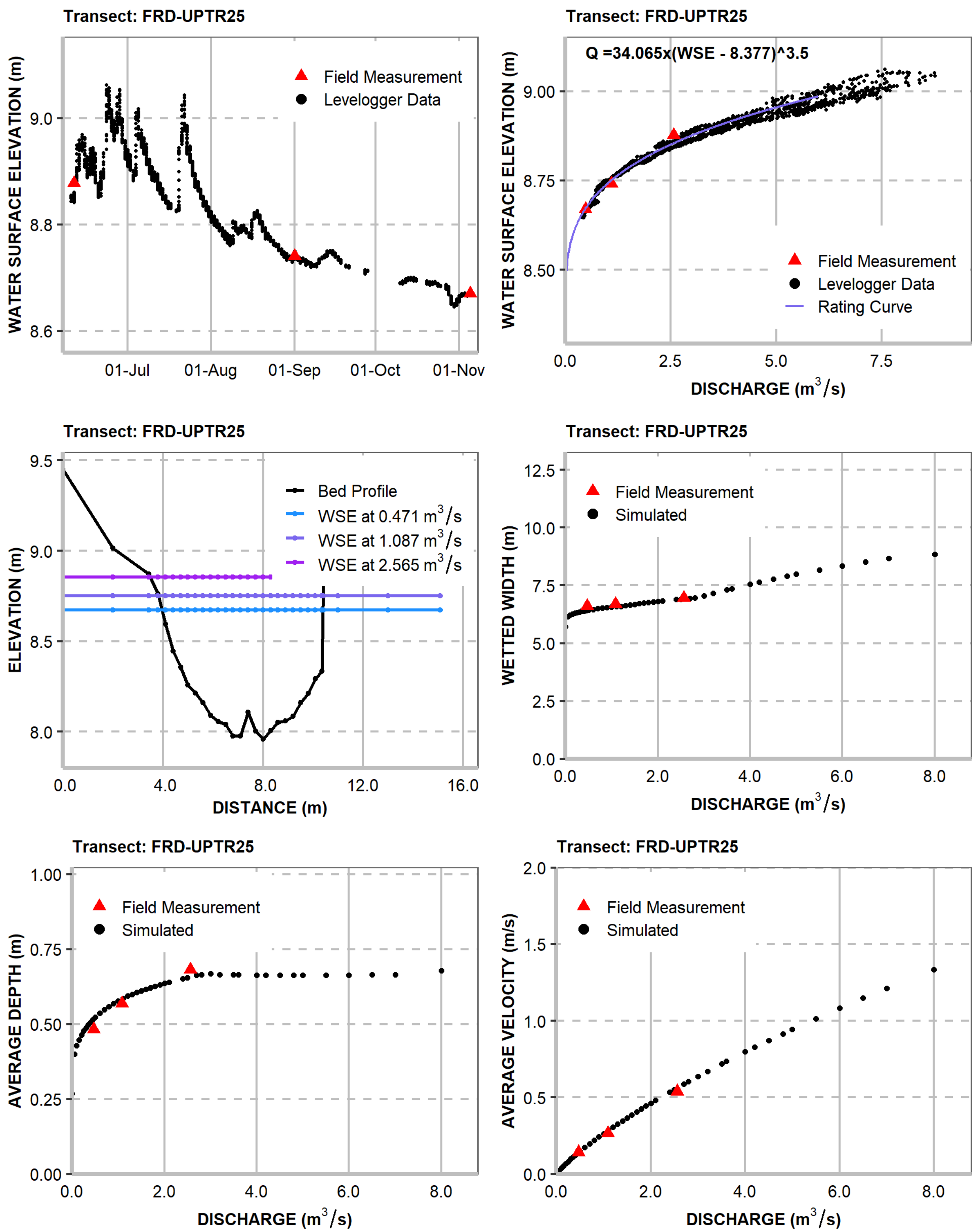

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Figure 29. River: Fording River, Transect: FRD-UPTR26.

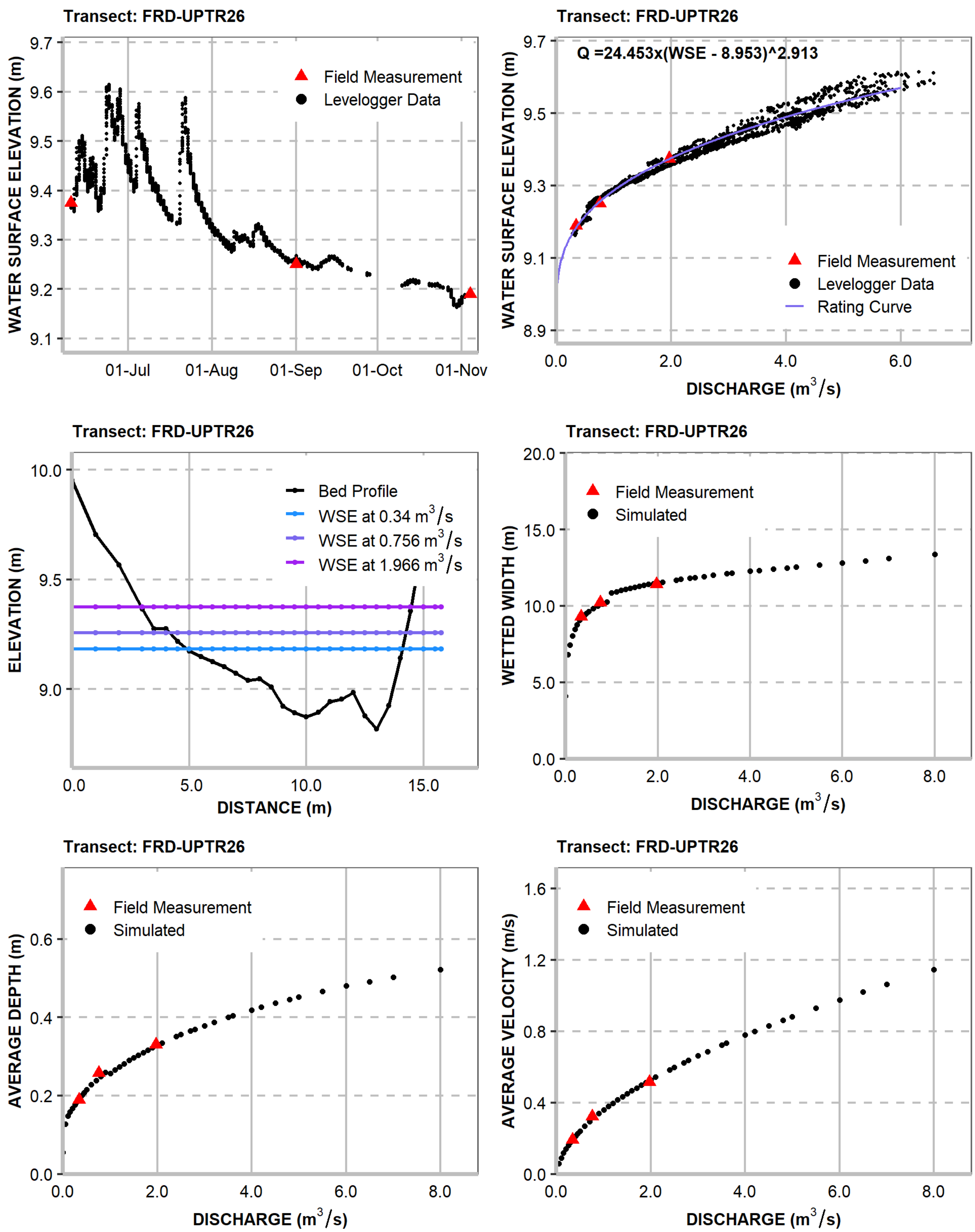

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Figure 30. River: Fording River, Transect: FRD-UPTR27A.

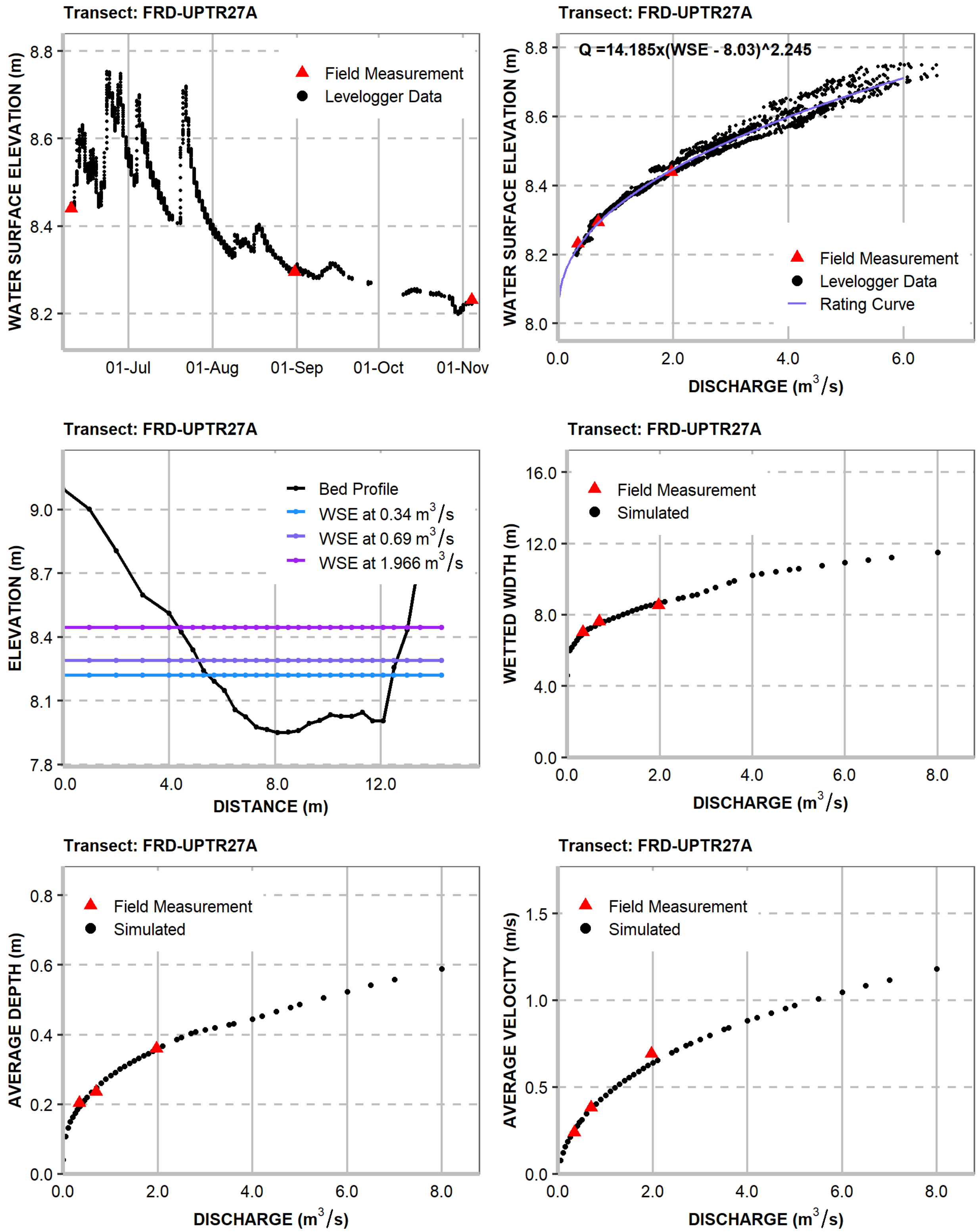


Figure 31. River: Fording River, Transect: FRD-UPTR27B.

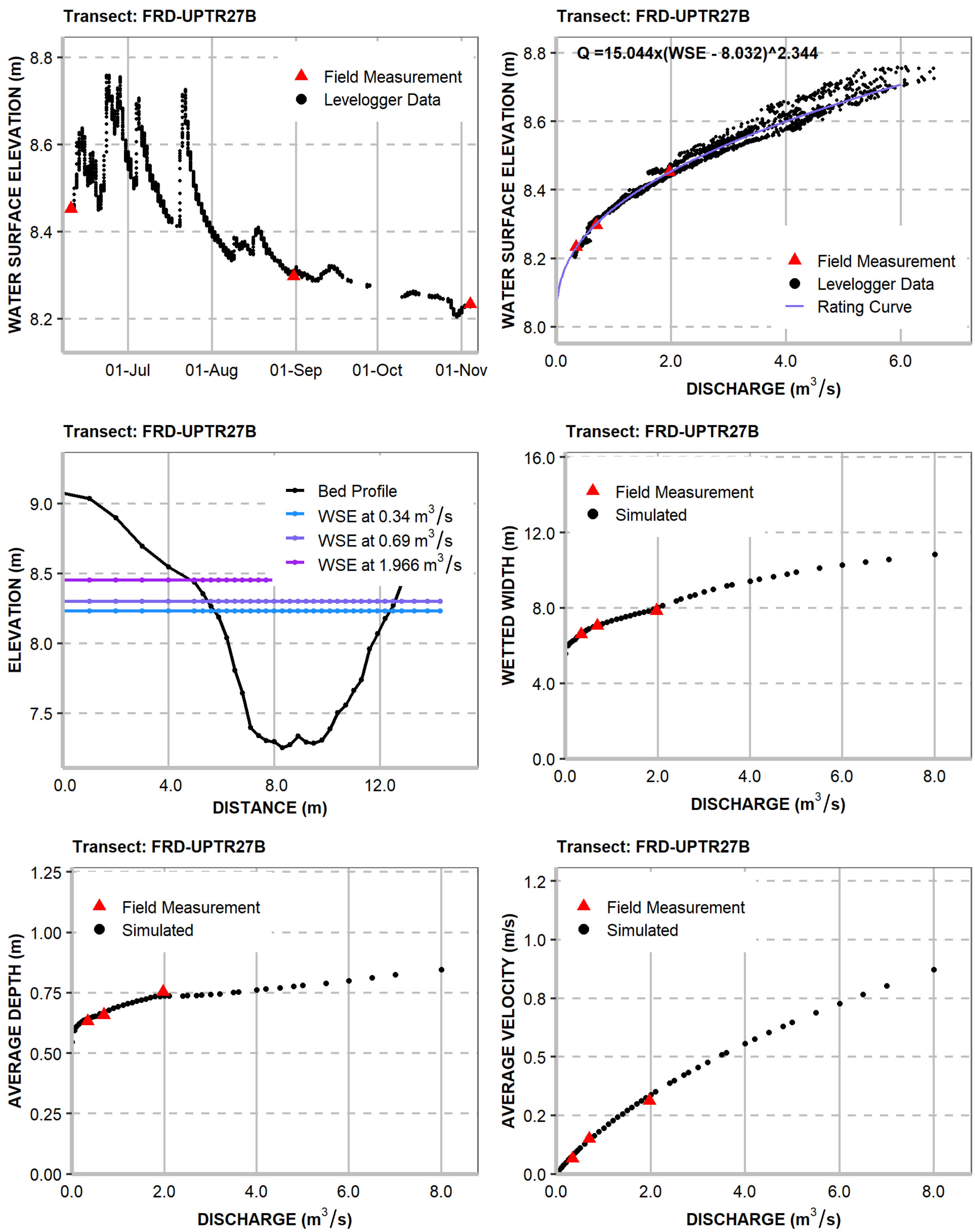


Figure 32. River: Fording River, Transect: FRD-UPTR28.

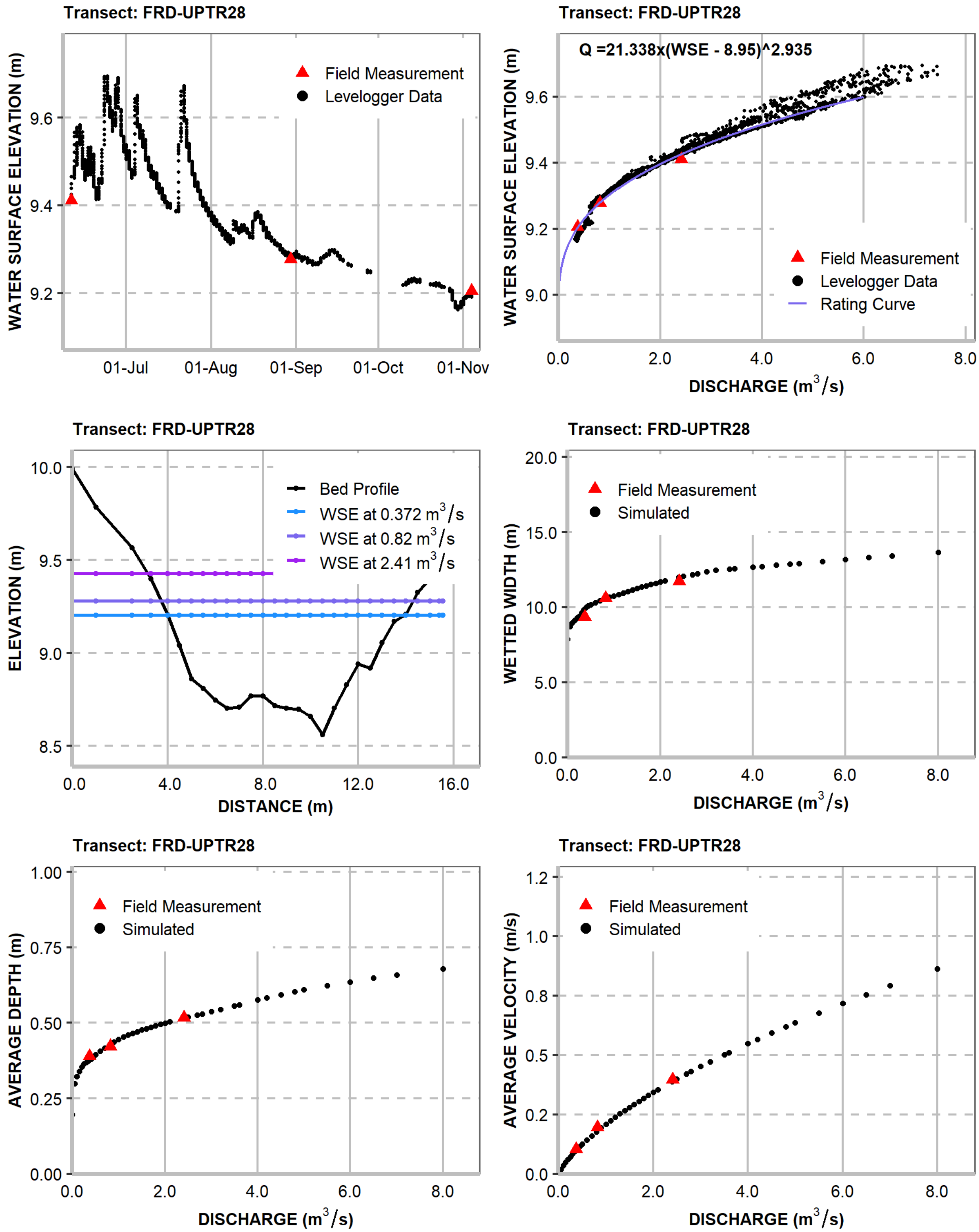


Figure 33. River: Fording River, Transect: FRD-UPTR29A.

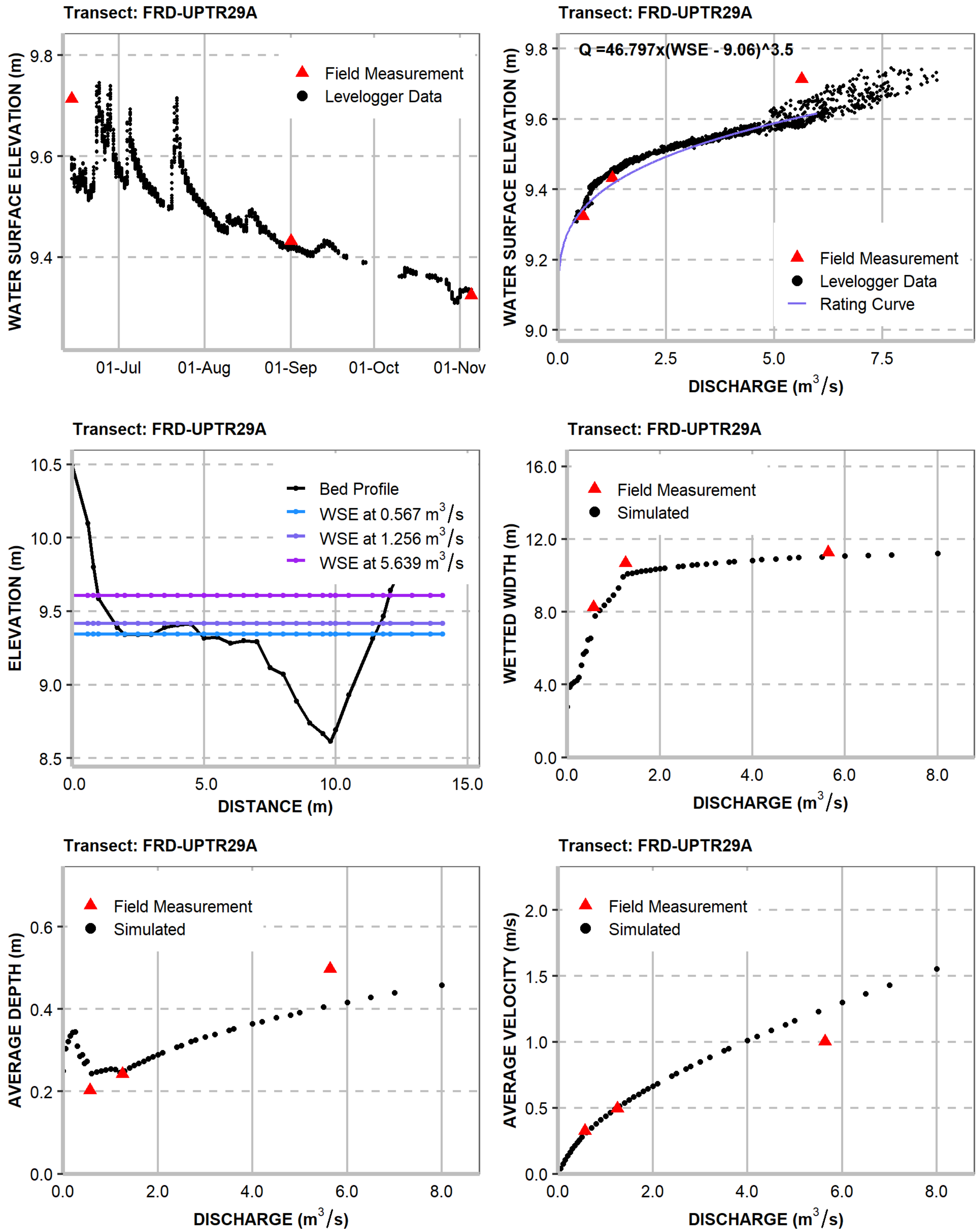


Figure 34. River: Fording River, Transect: FRD-UPTR29B.

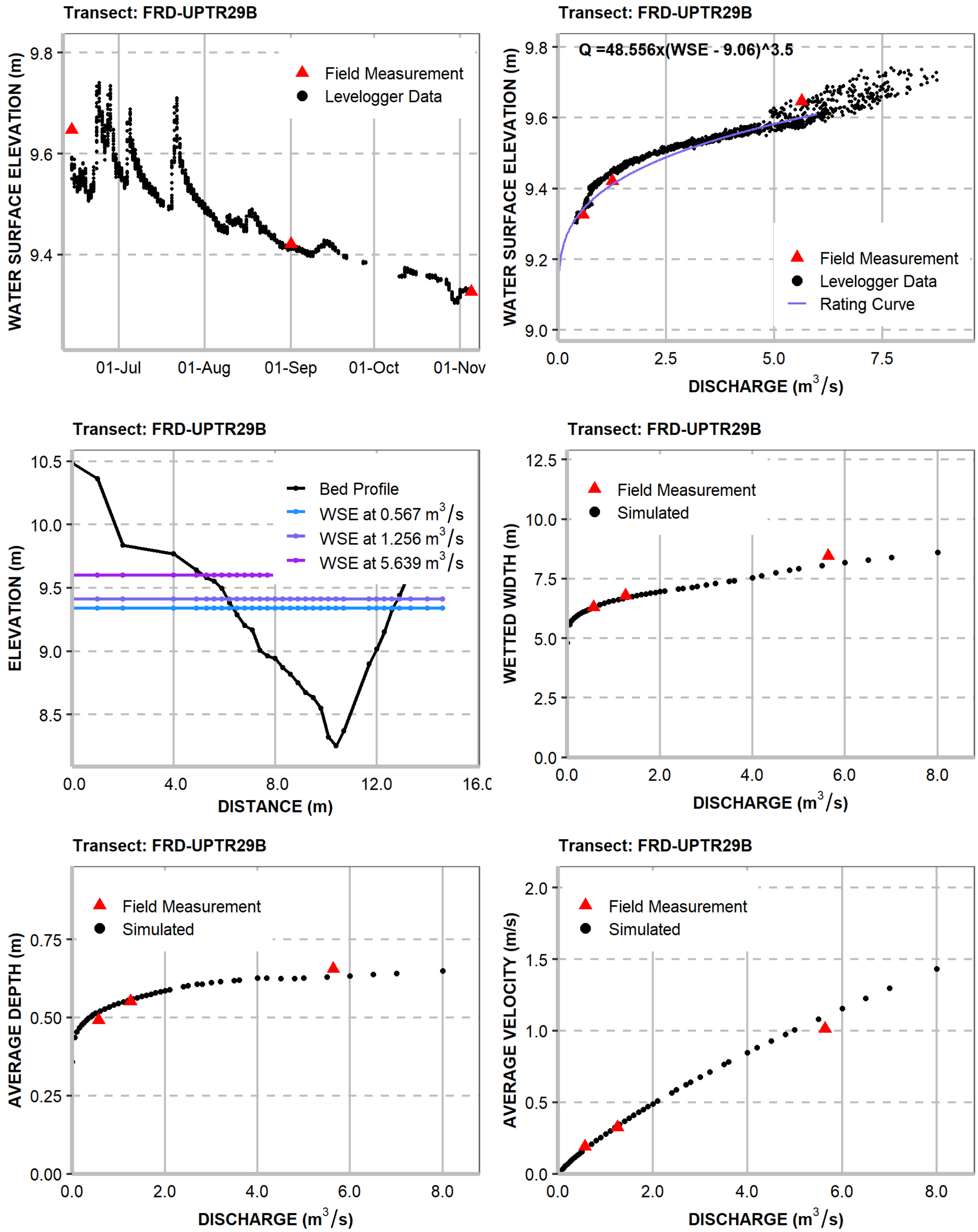


Figure 35. River: Fording River, Transect: FRD-UPTR30A.

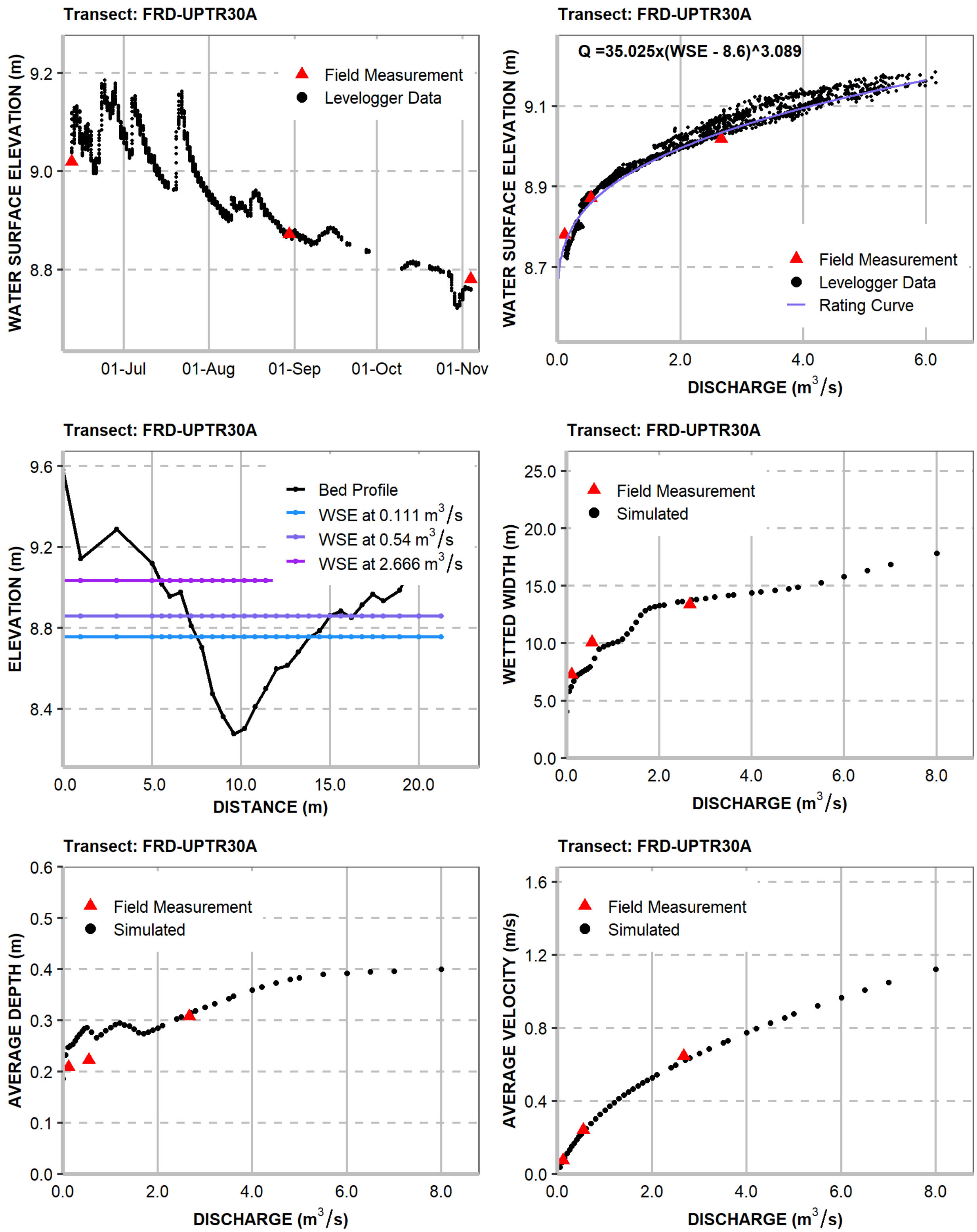


Figure 36. River: Fording River, Transect: FRD-UPTR30B.

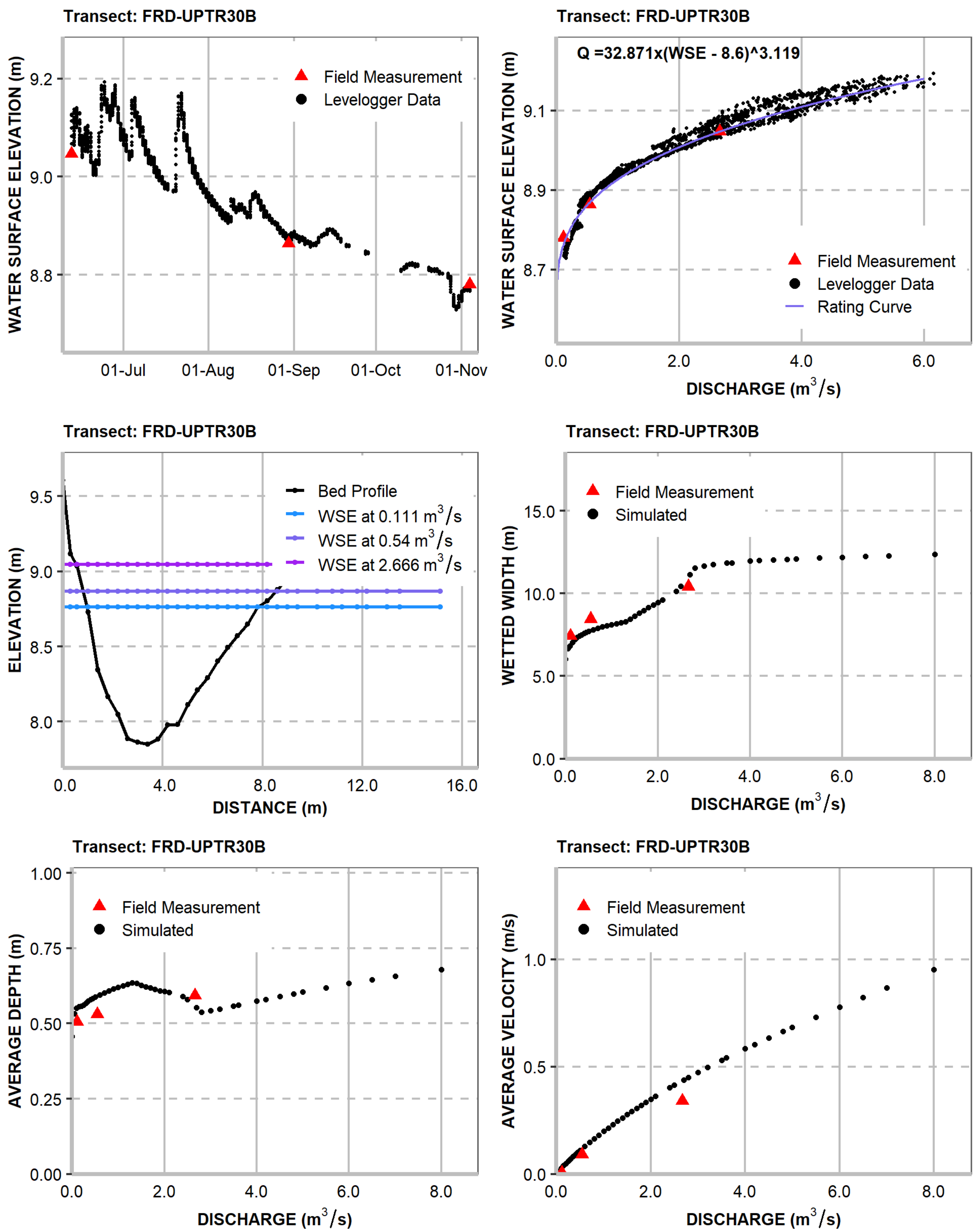


Figure 37. River: Fording River, Transect: FRD-UPTR31.

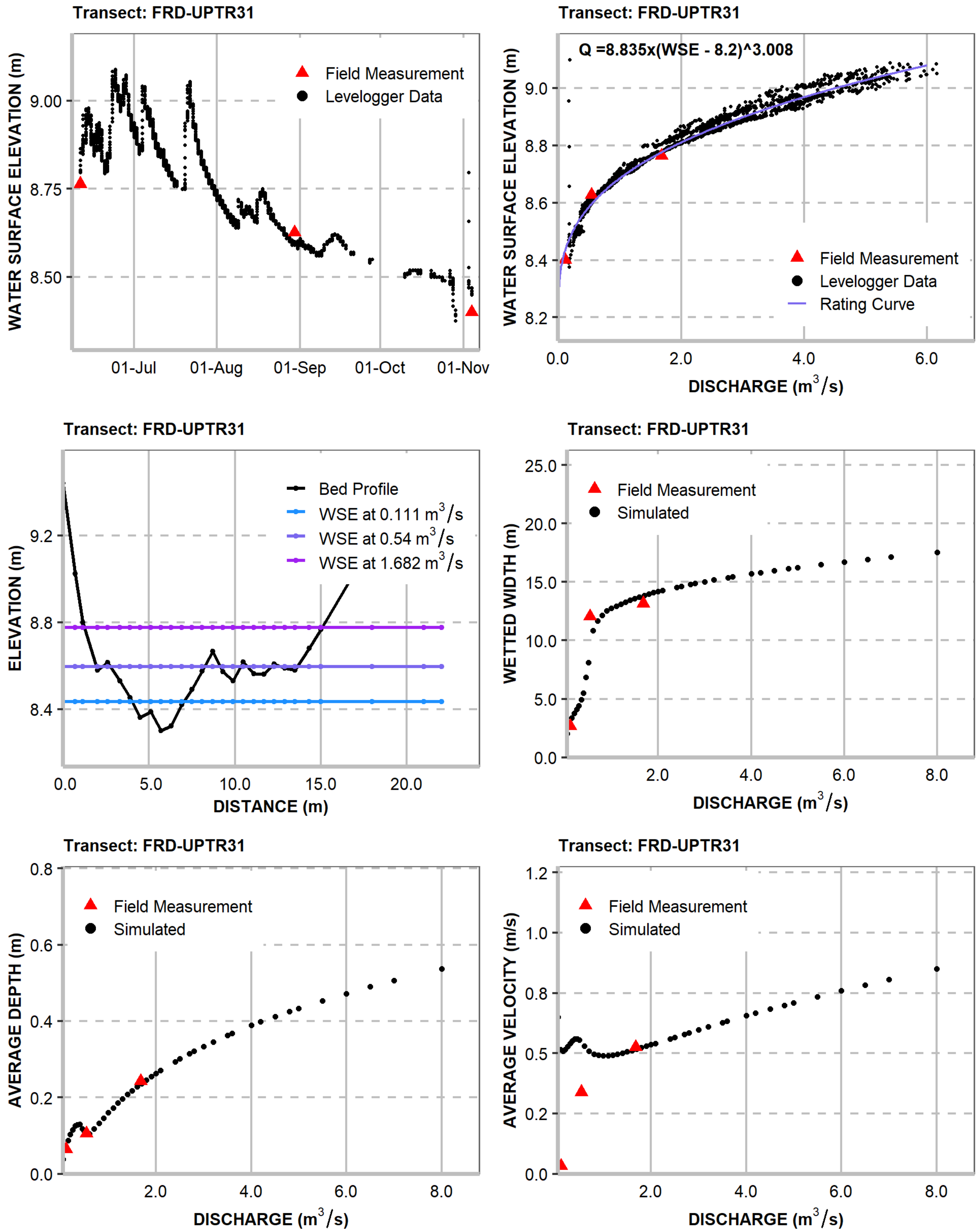


Figure 38. River: Fording River, Transect: FRD-UPTR32.

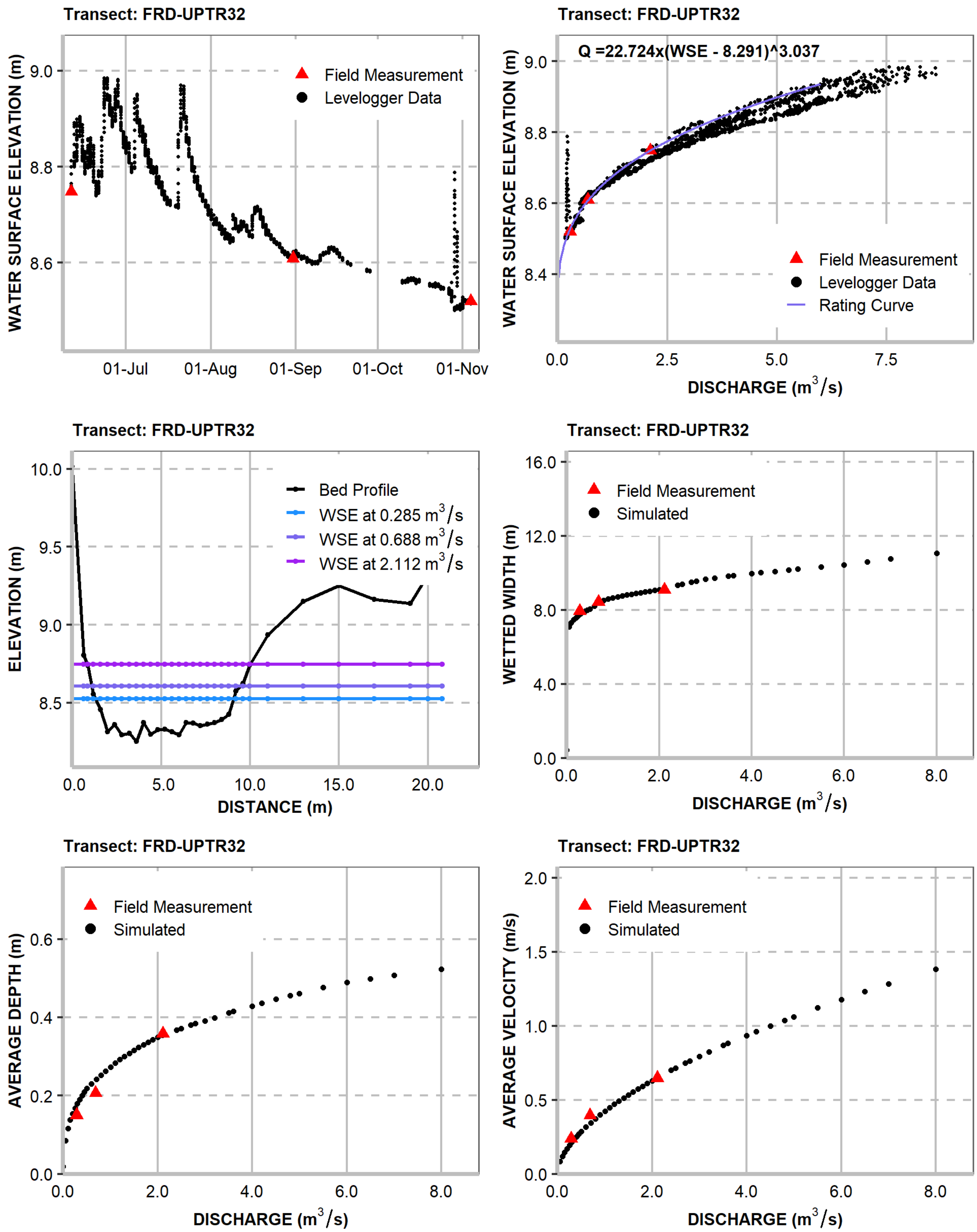


Figure 39. River: Fording River, Transect: FRD-UPTR33.

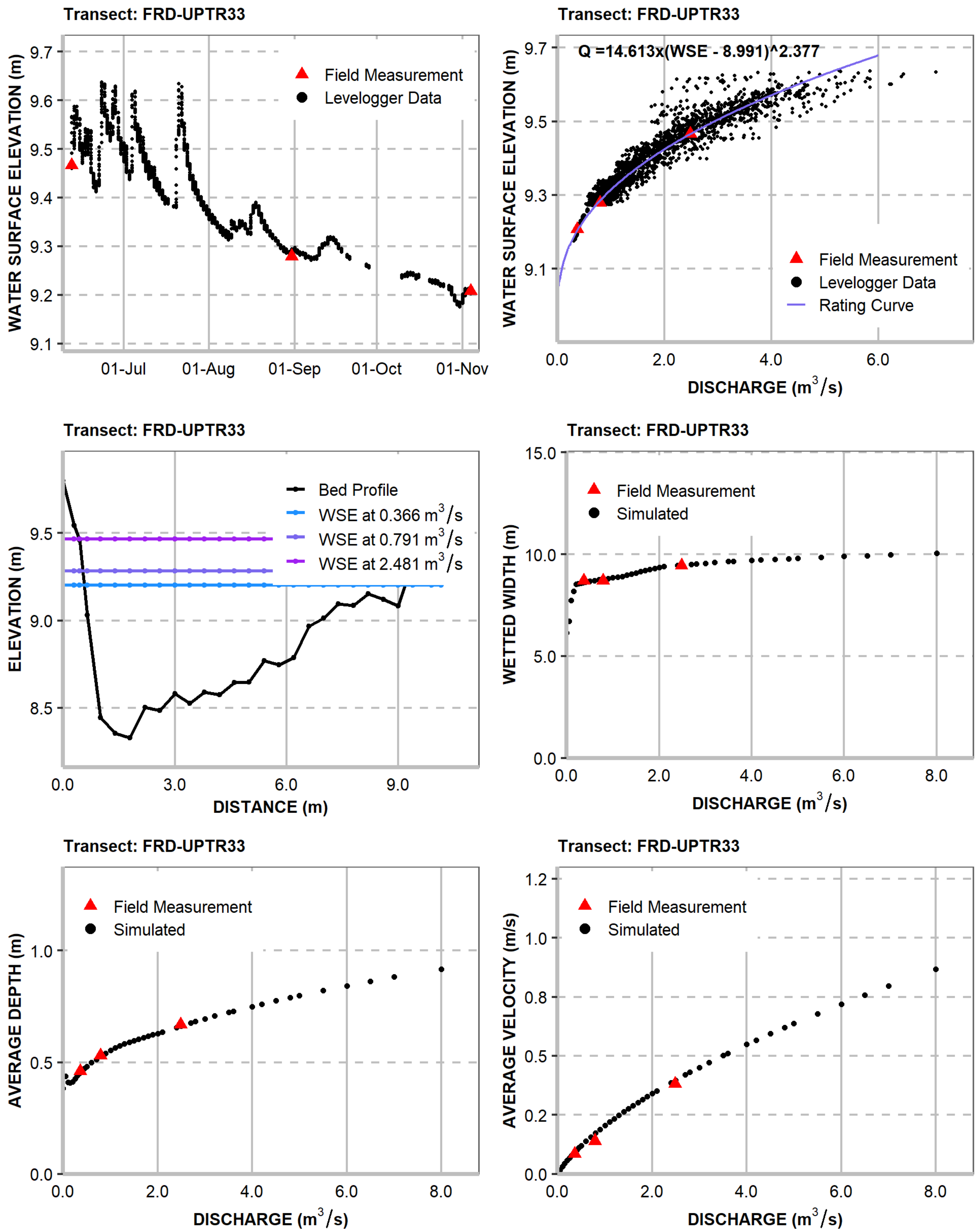


Figure 40. River: Fording River, Transect: FRD-UPTR34.

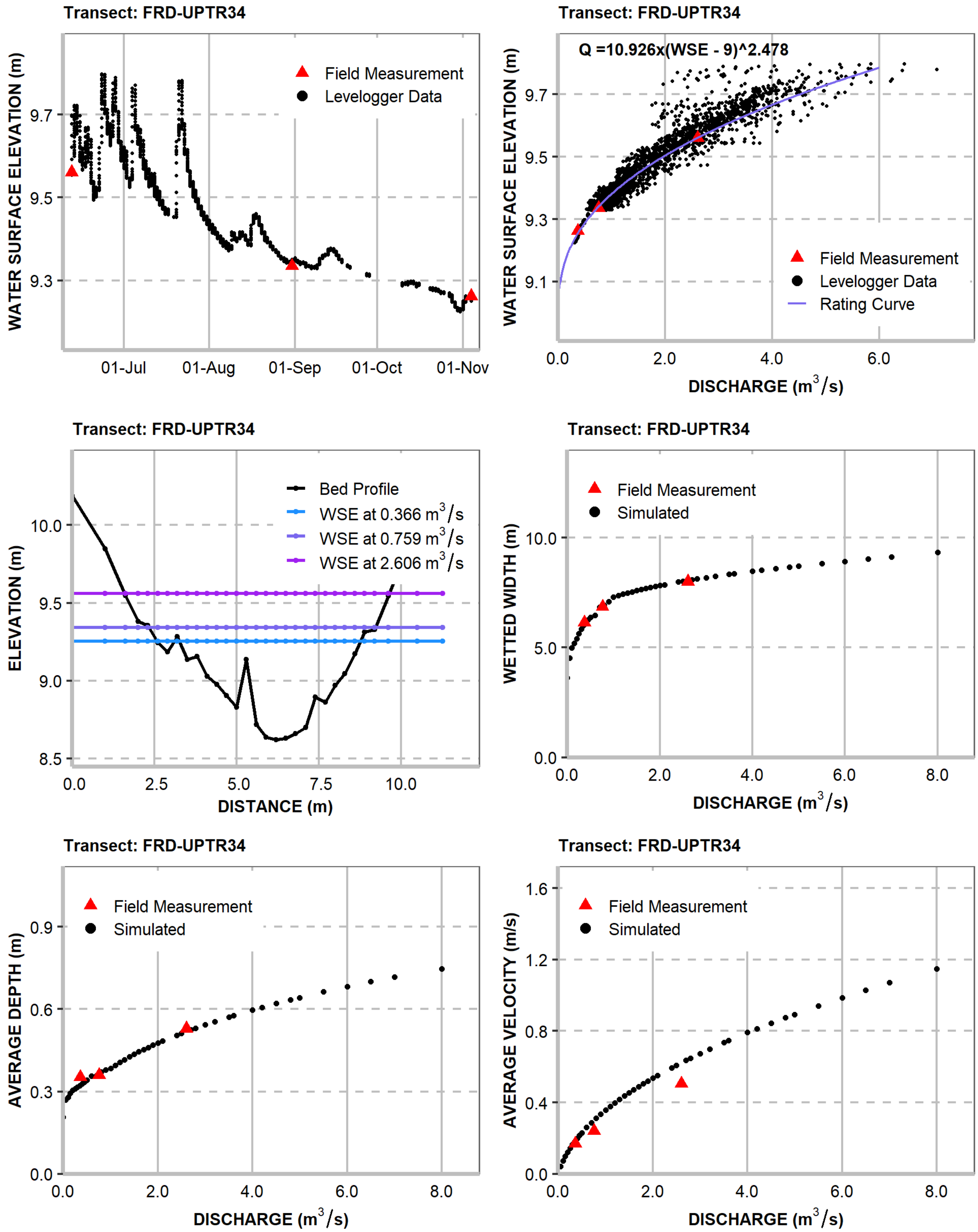


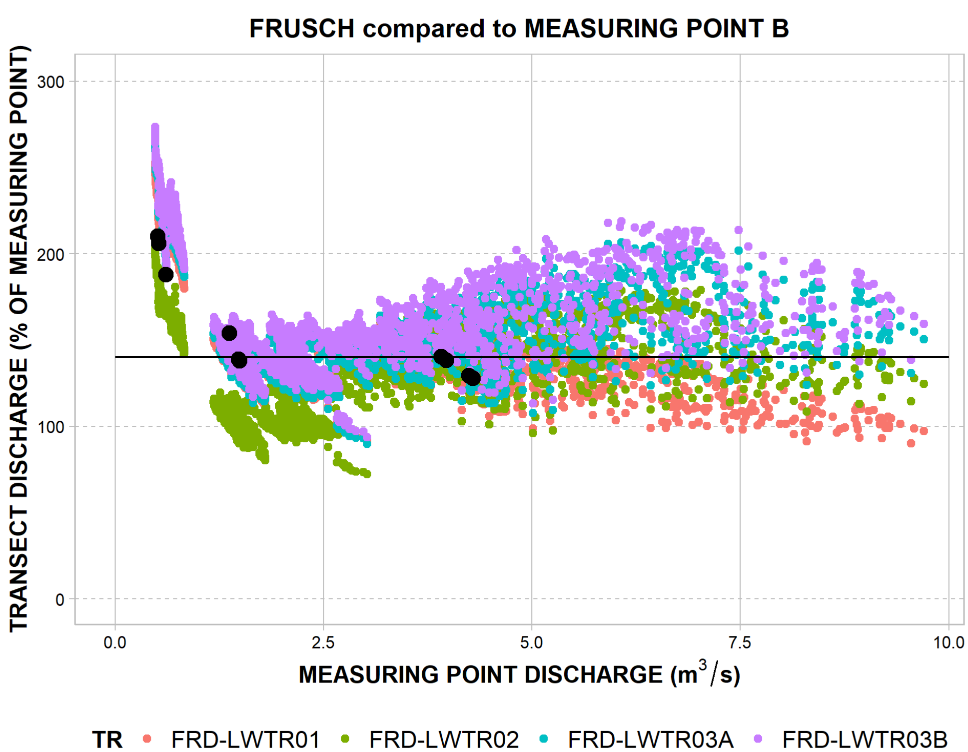
Table 1. Transect calibration notes.

Transect	Calibration Notes
FRD-LWTR01	
FRD-LWTR02	Undercut on river right
FRD-LWTR03A	
FRD-LWTR03B	
FRD-LWTR04	
FRD-LWTR05	
FRD-LWTR06	Left channel covered by ice during November trip
FRD-LWTR07A	
FRD-LWTR07B	
FRD-LWTR08	
FRD-LWTR09	
FRD-LWTR10	
FRD-LWTR11	Covered by ice during November trip
FRD-LWTR12	
FRD-LWTR13	Adjusted by +0.032 m for station 5.25m Covered by ice during November trip
FRD-LWTR14	
FRD-LWTR15	Adjusted by -0.050 to -0.095 for stations 3.6 to 6.0 m. Backwatering by downstream ice during November trip
FRD-LWTR16	Adjusted by -0.024 to -0.030 for stations 13.3 to 14.3 m.
FRD-UPTR17	
FRD-UPTR18	
FRD-UPTR19	
FRD-UPTR20	
FRD-UPTR21A	
FRD-UPTR21B	
FRD-UPTR22	
FRD-UPTR23	
FRD-UPTR24	
FRD-UPTR25	
FRD-UPTR26	
FRD-UPTR27A	
FRD-UPTR27B	
FRD-UPTR28	
FRD-UPTR29A	Adjusted by +0.114 to 0.169 m for distance ≤ 4.5 m
FRD-UPTR29B	

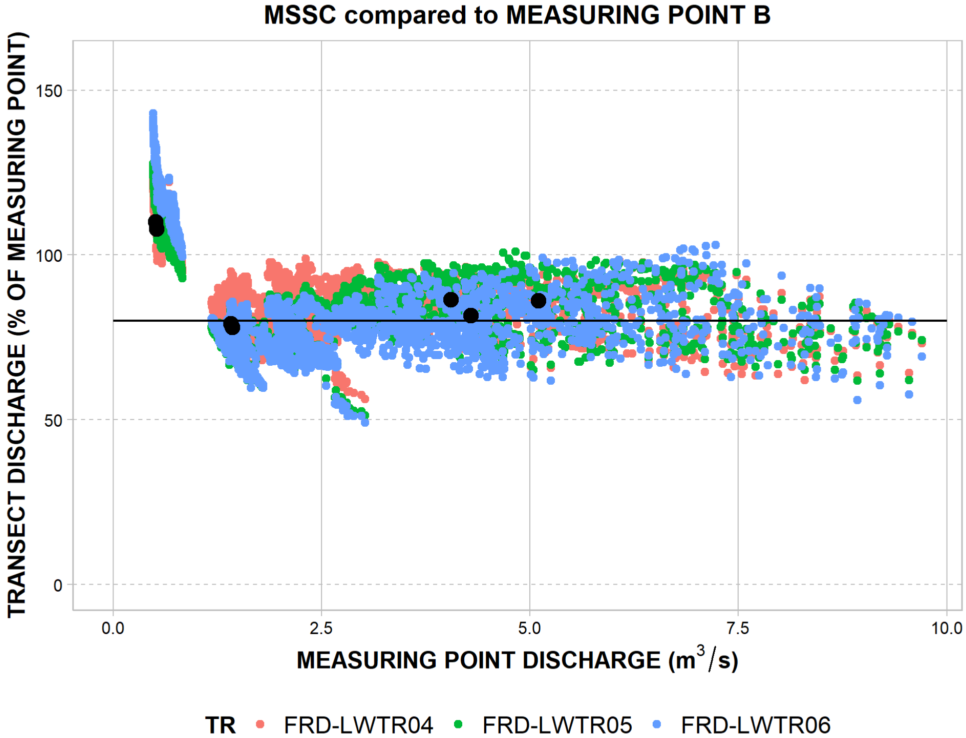
Transect	Calibration Notes
FRD-UPTR30A	
FRD-UPTR30B	
FRD-UPTR31	Adjusted by -0.141 m for distance ≥ 9.30 m
FRD-UPTR32	
FRD-UPTR33	
FRD-UPTR34	

Figure 41. **Measured (black dots) and time series estimated (coloured), and assumed (black lines) relationship between discharge at transects and Measuring Points for transects a) between lower side channel and Chauncey Creek (FRUSCH), b) Fording River mainstem adjacent to the lower side channel (MSSC), c) Fording River within the lower side channel (LWSC), d) between the S7 drying section and the lower side channel (DSDRY), e) the S7 drying section (DRY), f) FRD-LWTR14, g) FRD-LWTR15, h) FRD-LWTR16, i) FRD-LWTR17, j) near the FR_NTP hydrometric gauge (NTP), k) downstream of Clode Creek (DSCC), l) upstream of Clode Creek (USCC), m) near Turnbull arch (FR1), n) Fording River downstream of Henretta Creek confluence, and o) in Henretta Creek.**

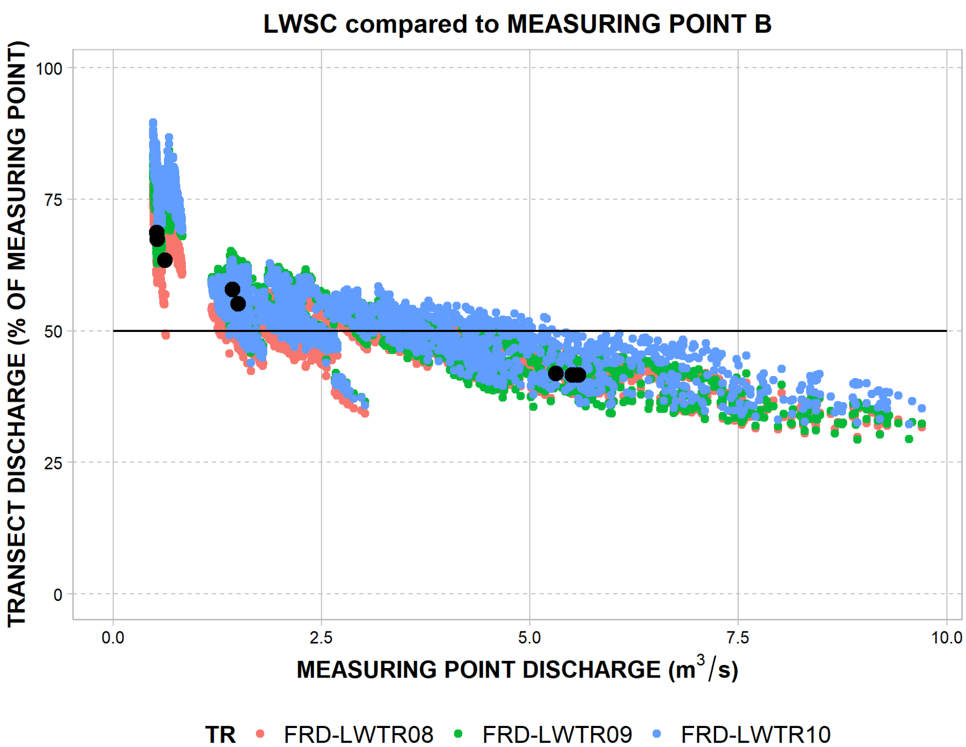
a) **Between lower side channel and Chauncey Creek (FRUSCH).**



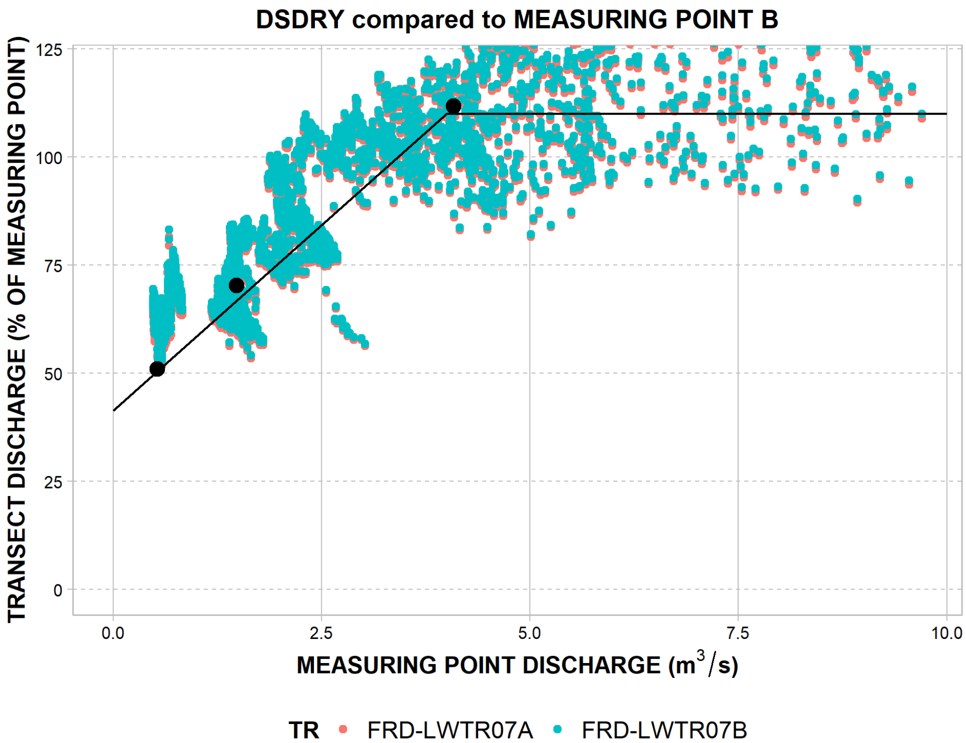
b) Fording River mainstem adjacent to the lower side channel (MSSC).



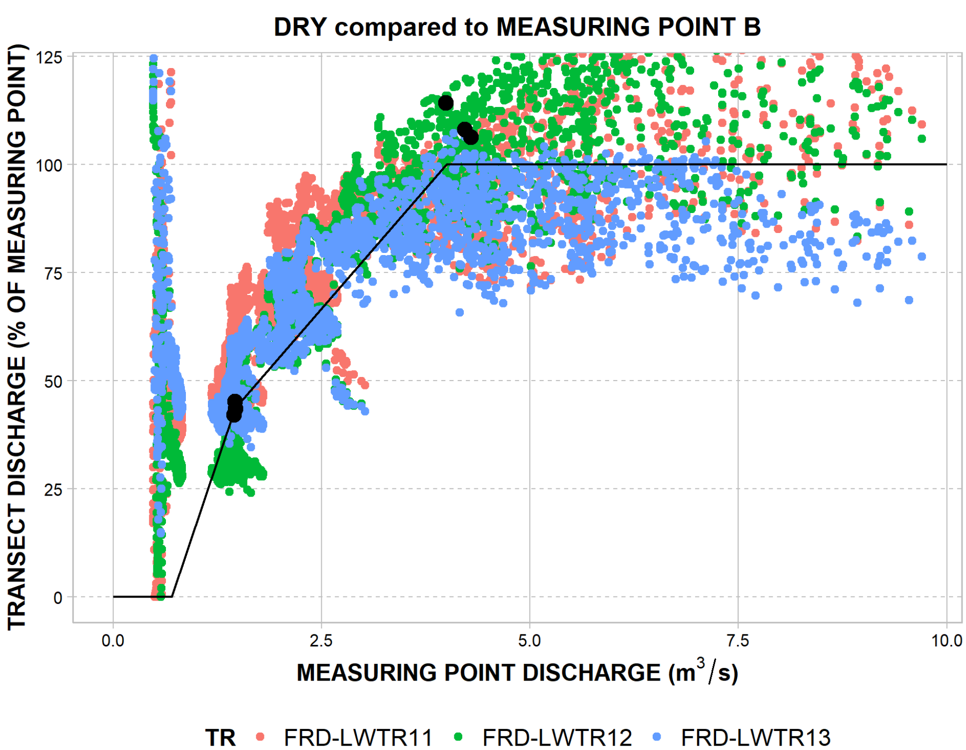
c) Fording River within the lower side channel (LWSC).



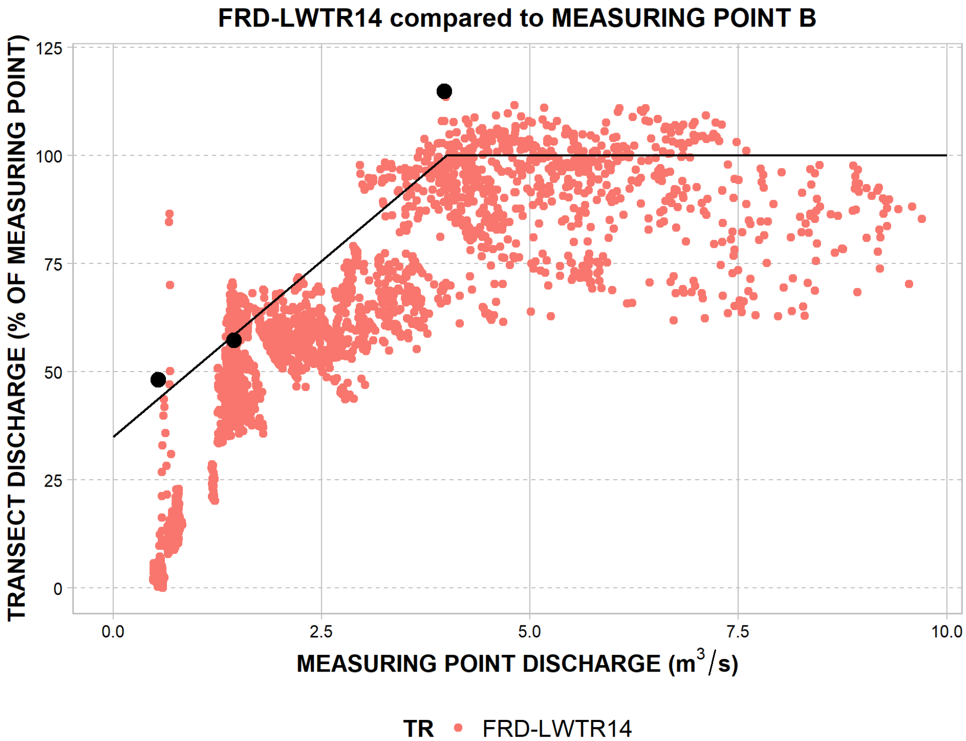
d) Between the S7 drying section and the lower side channel (DSDRY).



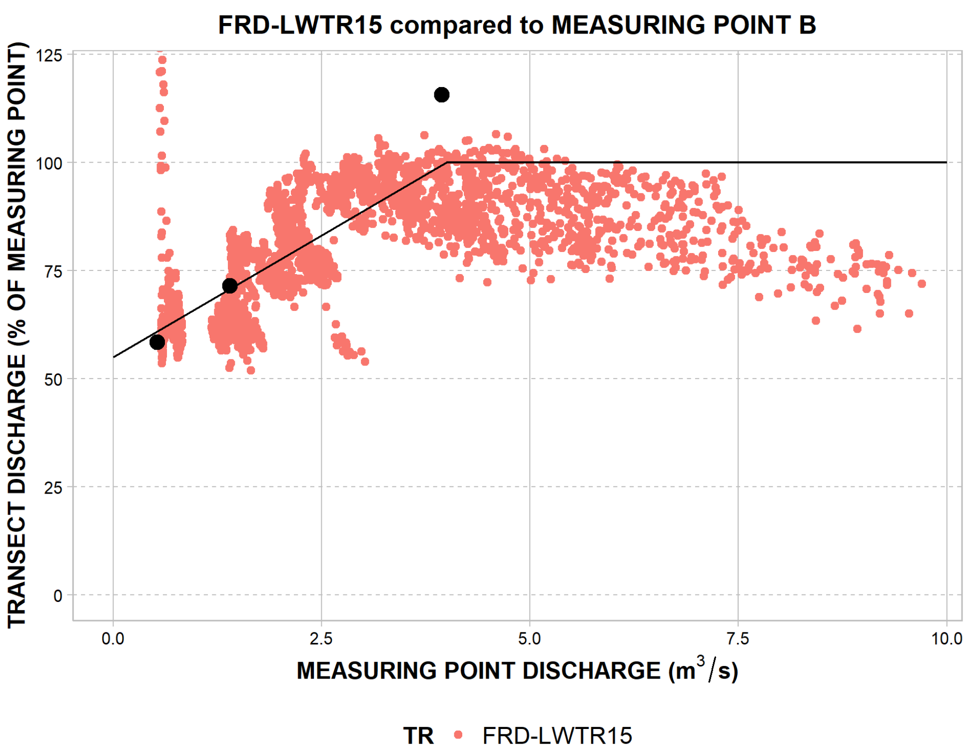
e) The S7 drying section (DRY).



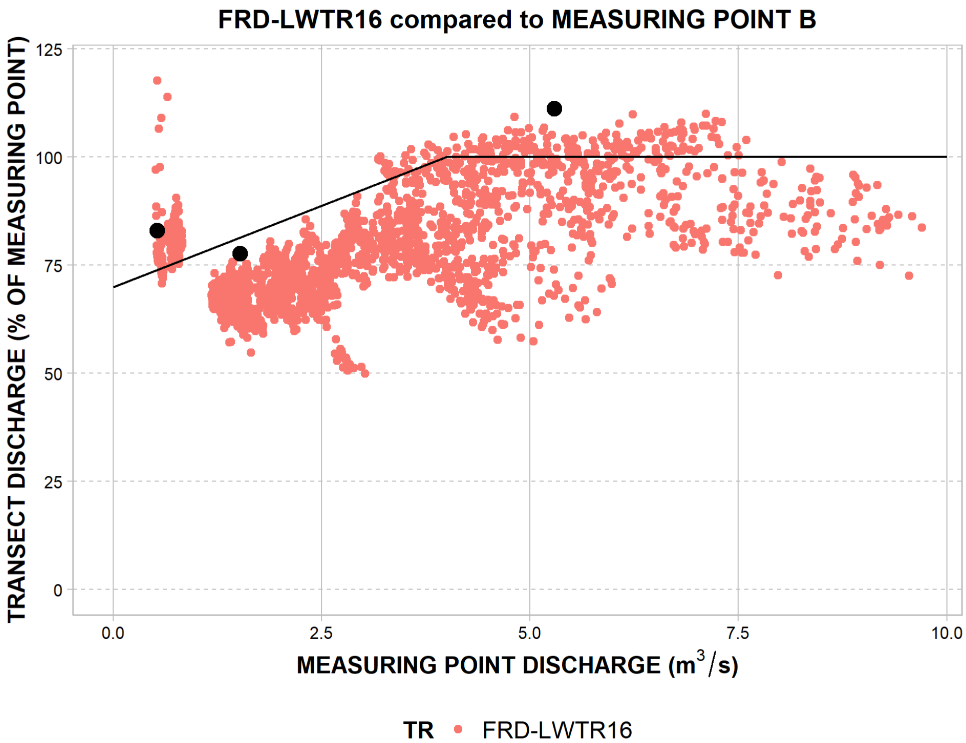
f) FRD-LWTR14.



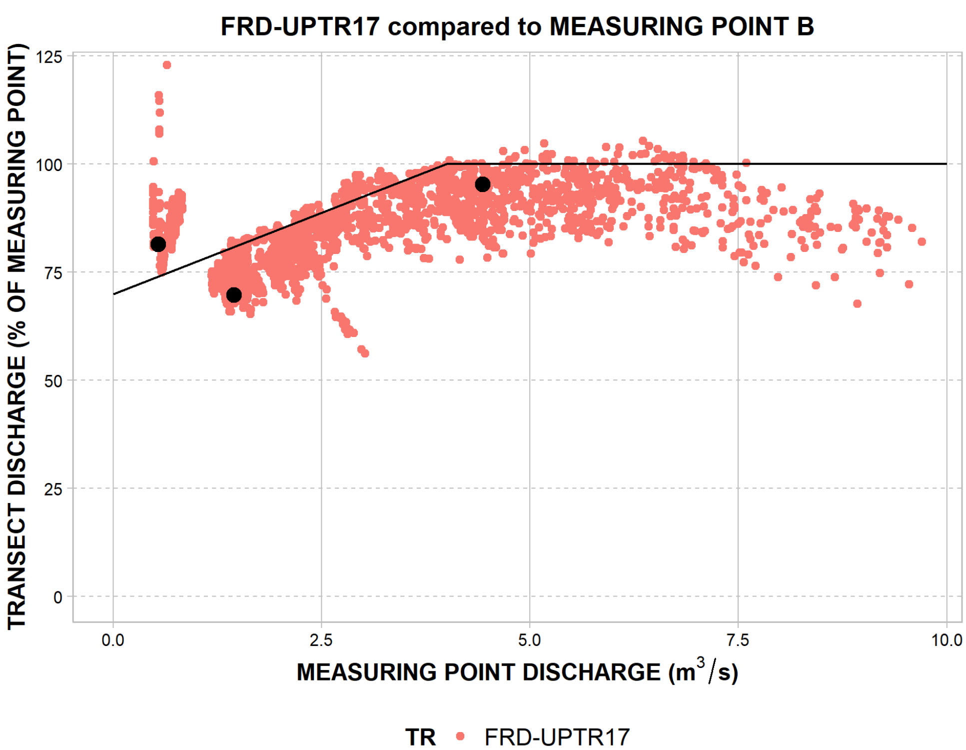
g) FRD-LWTR15.



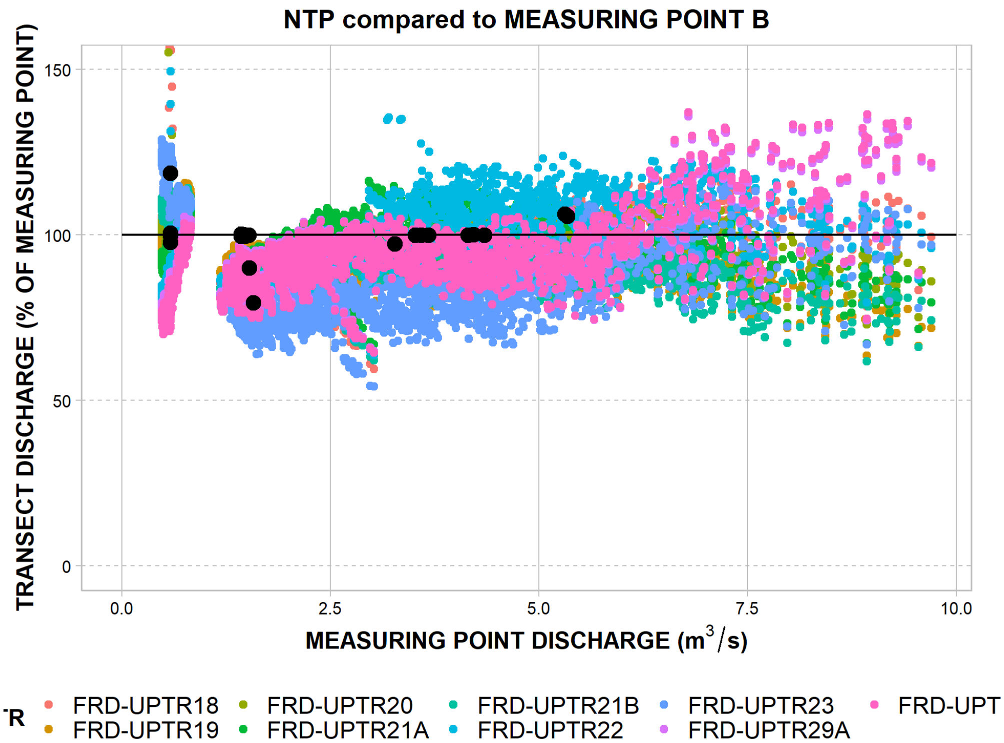
h) FRD-LWTR16.



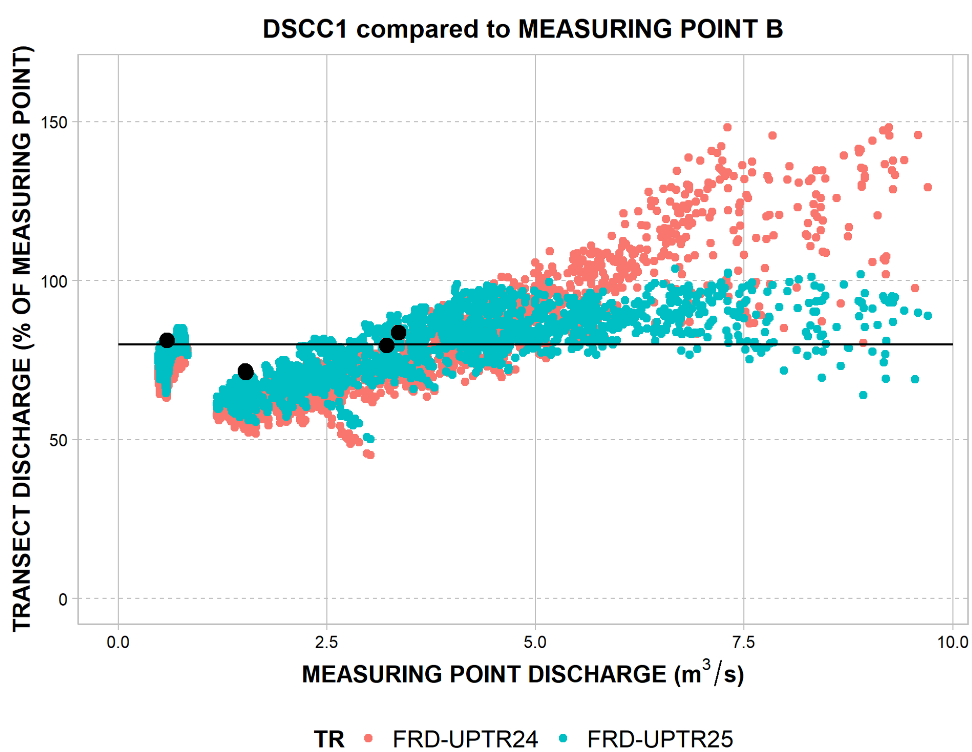
i) FRD-LWTR17.



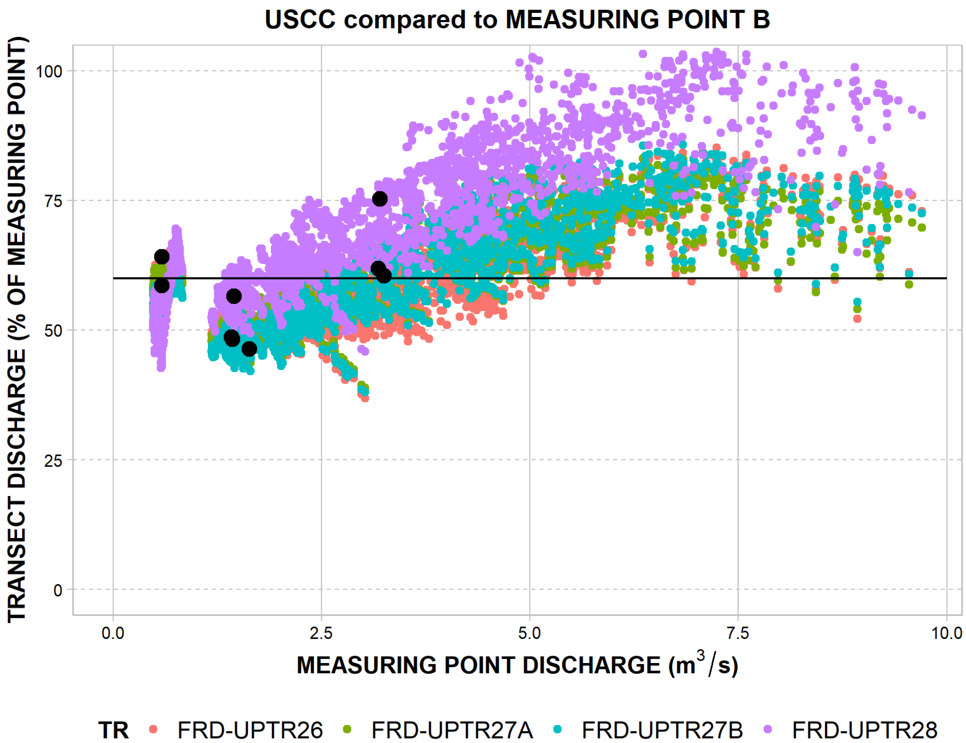
j) Near the FR_NTP hydrometric gauge (NTP).



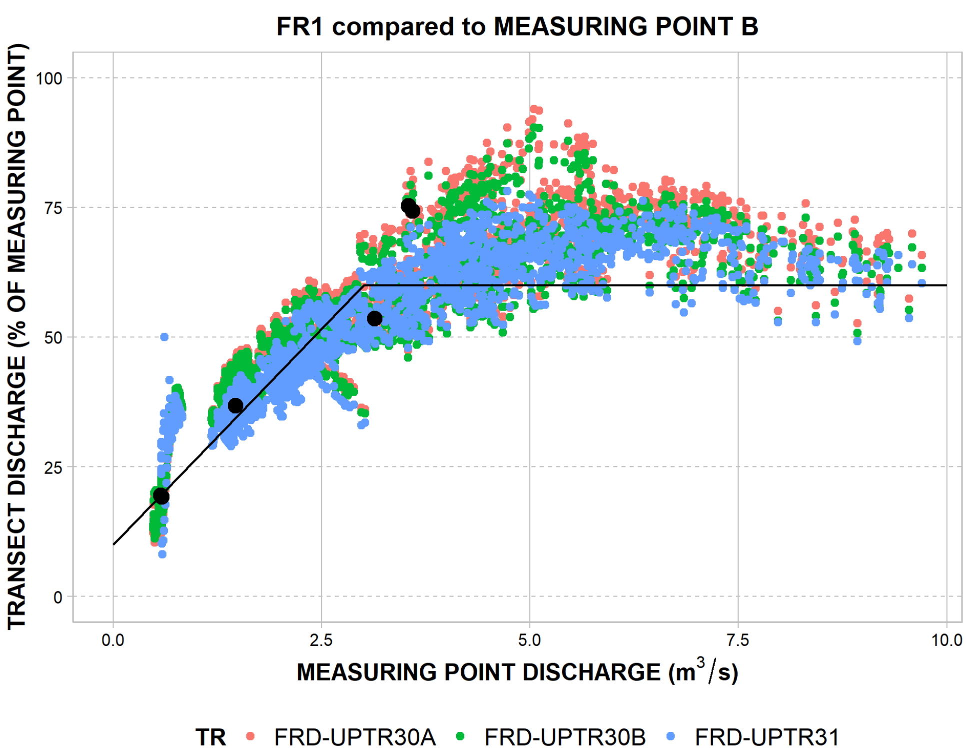
k) Downstream of Clode Creek (DSCC).



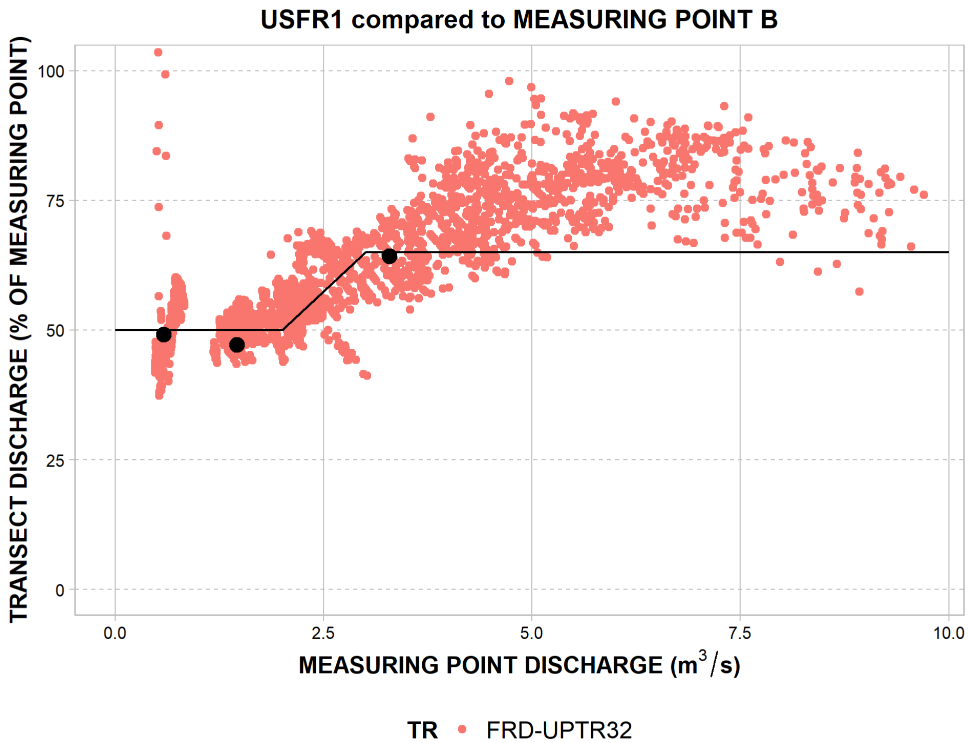
l) Upstream of Clode Creek (USCC).



m) Near Turnbull arch (FR1).



n) Fording River downstream of Henretta Creek confluence



o) In Henretta Creek.